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EXECUTIVE SUMMARY

The 2005 National Energy Efficiency Strategy (NEES) included targets for improvements in energy efficiency to be achieved by 2015 relative to a 2000 baseline. These targets were defined in terms of the reduction in final energy demand to be achieved, and were set at the economy-wide level (12%) and also for certain individual sectors (industry & mining – 15%, commercial & public – 15%, residential – 10%, transport – 9%). Since 2012, the Energy Efficiency Target Monitoring System (EETMS) has been under development to allow the monitoring of progress towards achieving these targets. EETMS comprises not only the processes and algorithms for analysing data, but also the underlying set of procedures, roles and responsibilities involved in data collection. However, it should be noted that this EETMS report does not include sector-level monitoring of the transport sector. This sector is gradually being incorporated into the EETMS due to its complexity and analysis of the sector is likely to be provided in the Annual Report 2016. This report presents the main results obtained from this system for the period up to 2012 – the latest date for which comprehensive data is currently available.

It is worth noting that the 2015 Annual Monitoring Report uses GDP (constant 2010 Rand) as opposed to the GDP (constant 2005 Rand) used in the 2014 report. Therefore, the historical analysis does differ between the reports.

Between 2000 and 2012, the energy intensity (energy consumed per unit of value-added) of the economically productive sectors reduced by over 28%, while that of the residential sector (measured in terms of energy consumption per household) fell by over 15%. Using the process of decomposition analysis reveals that efficiency changes accounted for a reduction of almost 24% in economy-wide energy consumption relative to a baseline projected from 2000. Against a general trend of improving efficiency, there have been small reversals in some years, the most notable of which were consecutive year-on-year falls in energy efficiency of 5.3 and 6.1% during 2007-09, likely to have been due to the global economic crisis.

Measured in terms of energy consumed per unit of value-added, the energy intensity of the industry & mining sector decreased by 34% between 2000 and 2012. A decomposition analysis using existing data on energy consumption and gross value-added was used to separate out the effects of structural change. The results indicate that the total energy savings attributable to efficiency improvements over that period amounted to 34% relative to a baseline projected from 2000. This is comfortably above the NEES target for the sector of a 15% improvement by 2015, barring a catastrophic fall in efficiency between 2011 and 2015.

Energy intensity is not necessarily a good proxy for energy efficiency within the industry & mining sector, so the Department of Energy has commenced collecting data on energy consumption and physical production levels, directly from firms in the key energy-intensive industry & mining branches. Data has so far been collected for the period 2010-14, although the data coverage for the period 2012-14 is still poor. The 2010-12 data was used to conduct a bottom-up analysis of energy efficiency trends, which indicates that efficiency fell by about 1.8% between 2010 and 2012. Because the detailed company-level data is available only from 2010 onwards, the opportunity is very limited for a direct comparison between the results of the top-down decomposition analysis and the

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bottom-up process. However, for the two years for which both analyses could be conducted (2010-12) the top-down analysis indicated year-on-year improvements of 8.8% and 7.3%, while the bottom-up analysis showed a 0.4% improvement from 2010 to 2011, but a decline of 2.2% in the following year. This difference in results can be accounted for by several factors, including changes in the economic value of products and, most significantly, the fact that the company-level data used for the bottom-up analysis is not representative of the whole sector.

Analysing energy efficiency trends in the commercial & public sector is hampered by a lack of detailed data, making it difficult to identify and separate out structural effects. Available data on total energy consumption tends not to be disaggregated, data on value-added is poorly disaggregated, and data on activity levels measured in physical units is practically non-existent. A decomposition analysis was conducted using data on electricity consumption, which was available in a disaggregated form but only from 2003 to 2013. This analysis suggests that electricity efficiency over this period remained almost unchanged, showing an improvement of just 0.3% (the NEES target for the sector is a 12% improvement by 2015 relative to a baseline projected from 2000). However, it is important to remember that the absence of detailed data meant that this analysis was not able to take into account the increased use of energy-intensive office equipment, which is likely to have been responsible for a large part of the observed increase in energy consumption.

Analysis of the residential sector had the aim of separating out the influences of increasing numbers of households and improving living standards in order to identify the effect of changes in energy efficiency. To do this, the population was stratified into four bands based on LSM (Living Standards Measure) system pioneered by the South African Audience Research Foundation. Household surveys were conducted in order to determine the average energy intensity of each LSM band, and a simple model was used to project this result back to previous years. Unsurprisingly, the results of the decomposition analysis indicated that a growth in the middle and high LSMs relative to the lower bands (i.e. a general improvement in living standards) was responsible for a large part of the observed increase in residential sector energy consumption. Efficiency improvements between 2000 and 2012 have resulted in a fall in consumption of 28% relative to a baseline projected from 2000, significantly above the NEES sector target of a 10% improvement by 2015.

The conducting of household energy surveys also provided the opportunity to collect data on those factors that influence the direction and rate at which energy efficiency in the residential sector changes. Analysis of these 'driving force' results highlights the importance of the middle LSM bands of 3-7 as determinants in the future growth in household energy demand. These are the households that are acquiring a wide range of domestic appliances for the first time, but the survey results also suggest that on average they are unlikely to consider the energy efficiency of appliances when making purchases. More encouragingly, the survey results also indicate that householders have a generally good level of awareness of how much energy they are using, and feel that their current energy expenditure is a significant burden.

Overall, South Africa is on track to meeting the energy efficiency targets set under NEES, with the important exception of the commercial & public sector. However, even in this sector the apparently unchanged efficiency may in fact reflect increases in consumption due to higher levels of energy service (e.g. energy intensive office equipment) that are masking actual improvements in efficiency. This highlights the urgent need for the regular collection of consistent and comprehensive data on

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energy usage patterns in the commercial & public sector if energy efficiency trends are to be tracked effectively in the future.

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ECONOMY-WIDE OVERVIEW

INTRODUCTION

The National Energy Efficiency Strategy (NEES) sets a target of a 12% reduction in energy consumption across the whole economy by 2015 relative to 2000. This implies a target of a 12% reduction in final energy consumption that is *attributable to improvements in efficiency* (rather than, for example, through cutting back on most energy-intensive economic activities). With this in mind, the Energy Efficiency Target Monitoring System has the purpose of analysing observed changes in energy consumption in order to identify the portion of the change that is attributable to efficiency changes. The process used is called ‘decomposition’, and is described in detail in Annex A.

DATA SOURCES AND ISSUES

The main data requirements for conducting a decomposition analysis at the economy-wide level are:

- annual gross value-added (GVA) of the main productive sectors
- annual total number of households
- annual total energy consumption disaggregated by the main sectors

Data on GVA was taken from the Bulletin of Statistics produced annually by Statistics South Africa (StatsSA). The total number of households in South Africa was obtained from StatsSA’s annual General Household Survey (GHS). This source provided data only as far back as 2002, so figures for 2000-01 were extrapolated from the available data, based on a best-fit cubic polynomial.

The sources of data on total energy consumption were the Energy Balance Tables produced annually by the Department of Energy. These tables are currently only available for years up to 2012, so the analysis described in this report covers the period 2000-12.

In some cases, gaps or inconsistencies in this data set required some values to be imputed, based on other sources of information. In particular, the data on coal consumption in the residential sector contained inconsistencies in some years. These inconsistencies were addressed by using Information on household expenditure on coal (from StatsSA’s Income and Expenditure Survey), combined with information on the number of households using coal (from the GHS). Where single-year inconsistencies were identified in the raw energy consumption data, they were addressed by simple linear interpolation between the adjacent years.

ENERGY CONSUMPTION BY ENERGY CARRIER

Between 2000 and 2012, a significant shift occurred in the relative roles played by different energy carriers in South Africa’s total final energy consumption. In 2000, coal and electricity accounted for similar shares of total final consumption, with the share of petroleum products somewhat higher. By

2012, the consumption of electricity and especially petroleum products had increased significantly, while that of coal had declined. These trends are shown in Table 1 and Figure 1 below.

It is worth emphasising here that these figures represent total final energy consumption, rather than primary energy demand. They do not therefore include energy that is consumed or transformed in the energy conversion processes (for example, power generation and the synthesis of liquid fuels from coal). Although the final consumption of coal has fallen over the time period covered in this analysis, the large increases in the final consumption of electricity and petroleum products have largely been met through coal-based energy conversion processes. Hence the reduction in total final consumption of coal does not imply an overall reduction in the South African economy's dependence on coal.

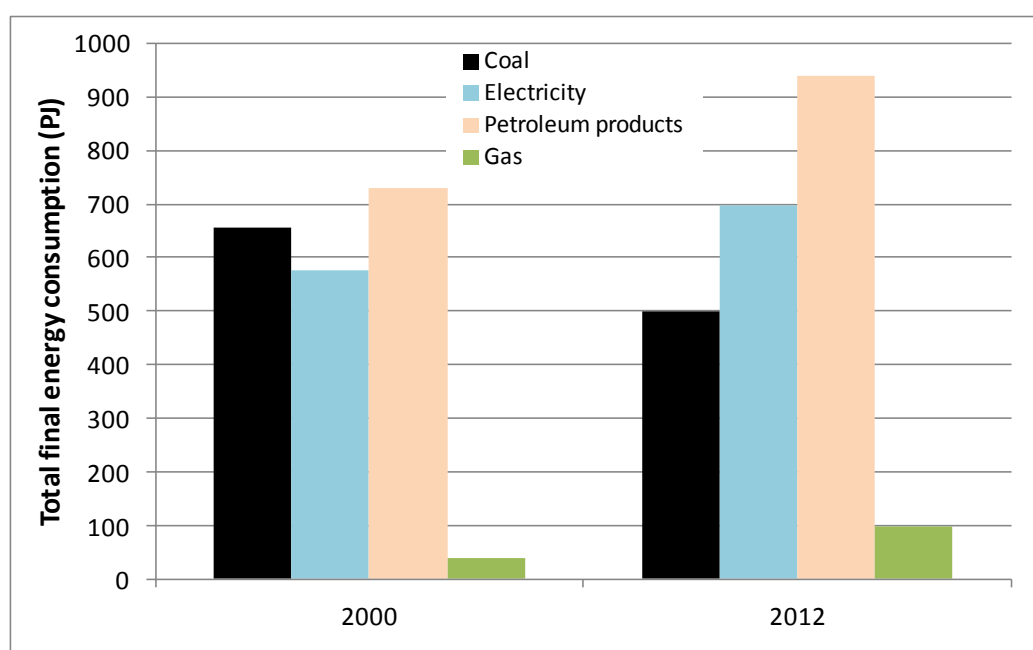


Figure 1 Fuel mix of final energy consumption for the South African economy – 2000 versus 2012

Table 1 Composition of total final energy consumption (PJ) by energy carrier, 2000 and 2012

	2000	2012	% change in consumption
Coal	655 (33%)	401 (22%)	-24%
Petroleum products	731 (36%)	938 (42%)	+28%
Gas	40 (2%)	99 (4%)	+148%
Electricity	577 (29%)	698 (31%)	+21%
TOTAL	2,003	2,236	+12%

Note that these figures include the portion of total final energy consumption that is unattributable to any sector (referred to in the Energy Balance Table as 'Non-specified'), whereas this component has been excluded from the decomposition analysis described below. Overall `total figures may therefore not agree.

ENERGY INTENSITY TRENDS

As of 2012 (the most recent year for which aggregate data is currently available), the total final energy consumption of the South African economy stood at about 2,108 PJ, an overall increase of 4.8% from its 2000 baseline of 2,011 PJ. Over the same period, the total GVA¹ of South Africa's productive sectors increased by about 44%, from about R1,798 billion up to R2,588 billion, while the number of households increased by about 42% from an estimated 10.3 million in 2000 up to 14.6 million in 2012. Considering the productive sectors alone, energy intensity decreased from 1.02 MJ/R in 2000 to 0.73 MJ/R in 2012, equivalent to an annual compounded reduction in energy intensity of about 2.7%.

Figure 2 below shows how energy intensity has changed in each of the main sectors. In order to make these trends easier to observe, this graph shows five-year rolling average to smooth out the wide fluctuations sometimes seen between consecutive years. In addition, the figures have been indexed to the base year of 2004. The graph indicates that the commercial & public sector saw a substantial increase in energy intensity to 2009, after which it has fallen back to close to its 2000 level. The energy intensity of the transport sector has changed relatively little over the 12-year analysis period, while that of the other three sectors has fallen by significant and similar amounts, with their average energy intensity over the five years to 2012 being approximately 20% lower than for the five years to 2004.

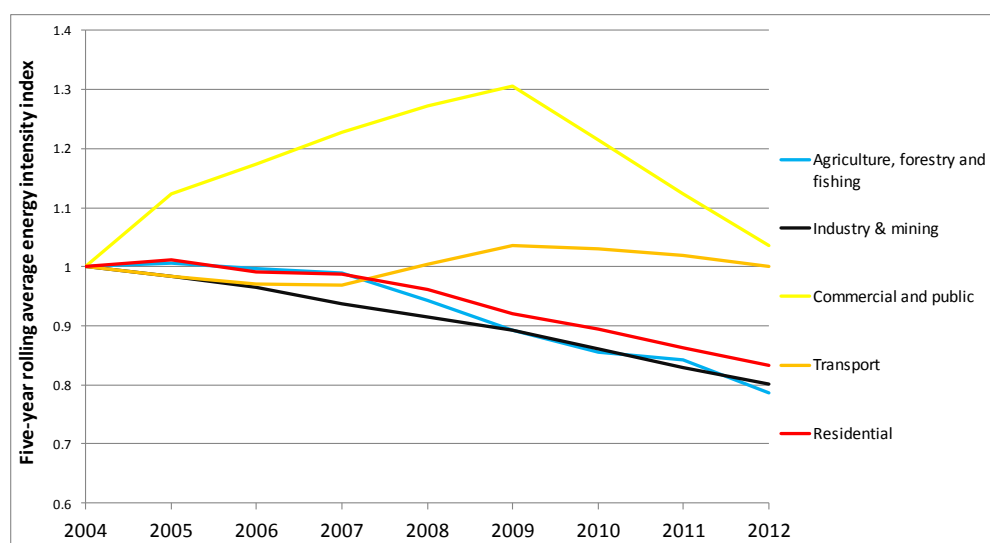


Figure 2 Trends in sector energy intensity. For clarity, five-year rolling average figures are shown in order to smooth out sharp fluctuations. Figures are expressed as an index relative to the value for 2004

DECOMPOSITION ANALYSIS

Methodological overview

The method of decomposition analysis breaks down observed changes in total energy consumption into component parts that are attributable to different effects. In its most common form, three

¹ At constant 2010 prices

component parts are identified, corresponding to the portion of the total change in energy consumption that is due to: (i) changes in the overall level of activity; (ii) structural changes i.e. changes in the relative size of the different sectors; (iii) changes in energy efficiency. An analysis may be conducted at the economy-wide level (as described here), but it may also be carried out at the sector-level, in which case the structural effects that the analysis identifies correspond to changes in the relative size of the different sub-sectors. A detailed description of the process of decomposition analysis is described in Annex A.

Conducting a decomposition analysis at the economy-wide level is a relatively simple process, using aggregated data on the energy consumption and GVA of the main sectors of the economy. However, such an analysis can only reveal the effects of structural changes *between* the main sectors – it cannot ‘see’ the effects of structural changes *within* the main sectors, since the analysis does not extend to that depth. In order to provide a more complete picture of economy-wide trends in energy efficiency, the structural effects identified in a series of sector-level analyses (described in the remaining chapters of this report) have been aggregated together and incorporated into the analysis described here.

Decomposition analysis results

A decomposition analysis was performed on changes in the total final energy consumption of the South African economy between 2000 and 2012, with the results shown in Table 2 below. As discussed above, the structural effects identified in this analysis include a summation of all of the intra-sectoral structural effects revealed by the sector-level analyses described in the later chapters of this report. The analysis indicates that total final energy consumption increased by 66,122 TJ between 2000 and 2012, with this overall change being composed of:

- an increase in total final energy consumption of 819,155 TJ due to increased overall activity levels in the economy;
- a decrease in total final energy consumption of 115,463 TJ due to structural changes in the economy
- a decrease in total final energy consumption of 637,570 TJ due to improvements in energy efficiency

These results are displayed graphically in Figure 3 below.

Of the 115,463 TJ total reduction in energy consumption due to structural changes, this was composed of a somewhat larger reduction attributable to structural changes *between* the main sectors, offset by a significant increase in consumption due to structural changes *within* the residential sector (and to a lesser extent within the industry & mining sector). These intra-sectoral structural changes are examined in more detail in the individual sector-specific chapters. Note however that intra-sectoral structural change in the commercial & public sector could not be calculated for years before 2003, as sufficiently disaggregated data was not available. Given that the structural changes within the commercial & public sector tend to be very small, their omission from those years where they could not be calculated is not expected to introduce a significant error into the economy-wide analysis.

Table 2 indicates that, relative to the 2000 baseline, there had been a cumulative improvement in energy efficiency by 2012 of 23.7%, but some significant variations in the year-on-year changes in

efficiency. Between 2004-05 and again between 2009-10, energy efficiency improved greatly, but these improvements were in part offset by the falls in energy efficiency between 2003-04 and particularly between 2007-09.

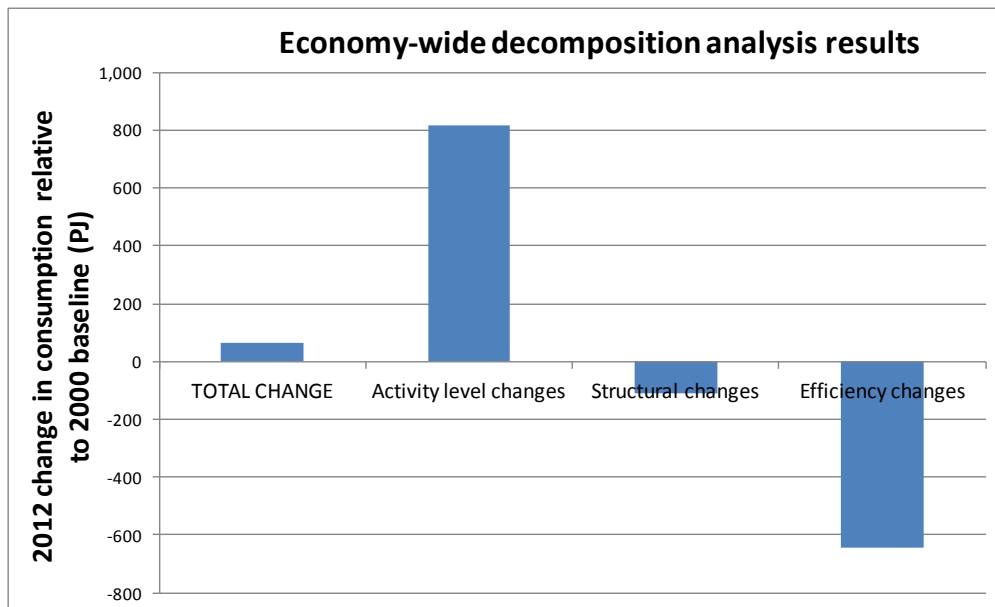


Figure 3 Decomposition analysis of cumulative change in total final energy consumption, 2000-12.

Table 2 Results of decomposition analysis of changes in total final energy consumption in South Africa between 2000-2012

YEAR-ON-YEAR CHANGES												
	2000-01	2001-02	2002-03	2003-04	2004-05	2005-06	2006-07	2007-08	2008-09	2009-10	2010-11	2010-12
CHANGE IN FINAL ENERGY CONSUMPTION (TJ)	63,312	10,636	68,216	213,728	-48,122	-2,138	54,230	185,268	16,618	-376,556	-46,659	-72,411
ACTIVITY LEVEL EFFECT	42,824	52,563	63,021	89,711	106,684	109,554	119,187	80,461	-20,836	68,883	61,427	45,676
STRUCTURAL EFFECTS	9,042	35,703	-2,171	10,296	-12,841	-15,451	11,384	-23,739	-108,365	4,371	-5,645	-18,048
<i>Inter-sectoral</i>	-1,404	11,581	7,621	651	-22,833	-36,878	-6,125	-32,589	-55,716	-2,172	-20,649	-19,993
<i>Intra-sectoral (industry & mining sector)</i>	10,566	22,065	-10,558	7,663	5,836	12,380	2,590	4,515	-48,790	6,039	7,913	-640
<i>Intra-sectoral (residential sector)</i>	-120	2,058	767	2,107	4,169	9,294	15,042	4,582	-3,989	312	7,341	2,671
<i>Intra-sectoral (commercial & public sector)</i>				-126	-14	-246	-124	-246	131	192	-250	-85
EFFICIENCY EFFECT	11,446	-77,629	7,365	113,721	-141,965	-96,241	-76,342	128,545	145,819	-449,809	-102,441	-100,039
% CHANGE IN ENERGY CONSUMPTION DUE TO EFFICIENCY CHANGES	0.6%	-3.6%	0.3%	5.1%	-5.8%	-4.0%	-3.1%	5.3%	6.1%	-17.1%	-4.6%	-4.6%

CUMULATIVE CHANGES (2000 base year)												
	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
CHANGE IN FINAL ENERGY CONSUMPTION (TJ)	63,312	73,948	142,164	355,892	307,770	305,632	359,861	545,129	561,747	185,192	138,532	66,122
ACTIVITY LEVEL EFFECT	42,824	95,387	158,408	248,119	354,803	464,357	583,544	664,006	643,170	712,052	773,479	819,155
STRUCTURAL EFFECTS	9,042	44,745	42,575	52,870	40,029	24,578	35,962	12,223	-96,142	-91,770	-97,416	-115,463
<i>Inter-sectoral</i>	-1,404	10,177	17,798	18,449	-4,383	-41,262	-47,387	-79,976	-135,692	-137,865	-158,514	-178,508
<i>Intra-sectoral (industry & mining sector)</i>	10,566	32,630	22,072	29,735	35,571	47,951	50,541	55,056	6,266	12,305	20,218	19,578
<i>Intra-sectoral (residential sector)</i>	-120	1,938	2,705	4,812	8,981	18,275	33,318	37,899	33,910	34,222	41,564	44,235
<i>Intra-sectoral (commercial & public sector)</i>	0	0	0	-126	-140	-386	-510	-756	-625	-433	-683	-768
EFFICIENCY EFFECT	11,446	-66,184	-58,818	54,903	-87,062	-183,303	-259,645	-131,099	14,719	-435,090	-537,531	-637,570
% CHANGE IN ENERGY CONSUMPTION DUE TO EFFICIENCY CHANGES	0.6%	-3.1%	-2.7%	2.4%	-3.7%	-7.4%	-10.0%	-4.9%	0.6%	-16.7%	-20.2%	-23.7%

The NEES economy-wide energy efficiency target of a 12% improvement by 2015 relative to a 2000 baseline equates (assuming a linear trend) to an annual improvement of 0.8 percentage-points. The actual improvement revealed by the decomposition analysis is shown relative to this target trend in Figure 4 below. On average, efficiency improvements have more than kept pace with the NEES, although the economy fell behind the rate of improvement needed as a result of the sharp falls in efficiency in 2004 and 2008-09.

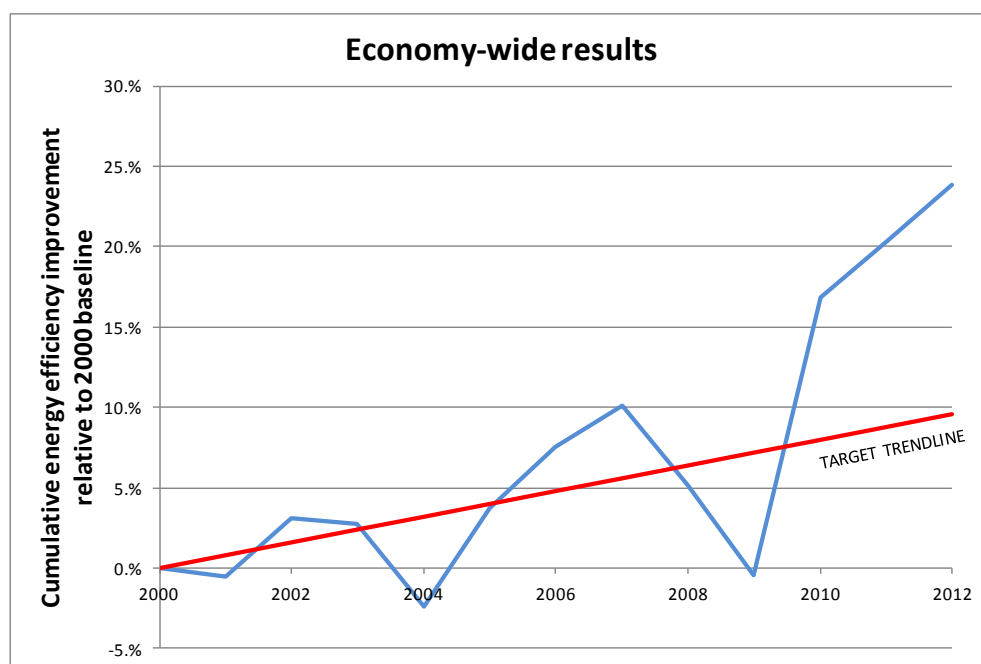


Figure 4 Cumulative improvement in energy efficiency relative to the projected 2000 baseline

Figure 5 below illustrates the impact that improvements in energy efficiency have had on the total final energy consumption of the South African economy. The green trace indicates the actual observed evolution of total final energy consumption between 2000 and 2012, while the red trace indicates what energy consumption would have been had there been no improvement in efficiency. The red shaded areas represent periods when energy efficiency was worse than in 2000, while the green shaded areas indicate periods when the overall cumulative change in efficiency relative to 2000 was positive. This graph clearly illustrates how, without any efficiency changes, total final energy consumption would have risen steadily over the whole period analysed, with the exception of 2008-09. The effect of efficiency changes means that the increase in total final consumption has been relatively modest.

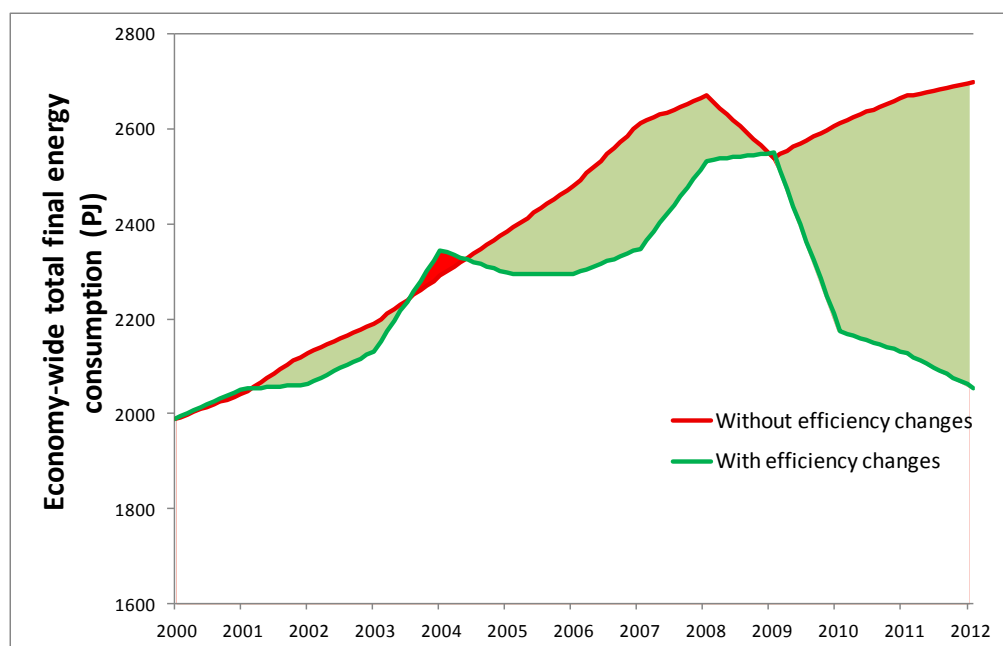


Figure 5 Impact of energy efficiency changes on total final energy consumption

Discussion of results

It is very likely that the decline in energy efficiency seen between 2007-09 results from a combination of the global economic crisis and the power shortages that occurred during that period. Energy efficiency tends to fall during times of economic decline, because there are significant components of energy consumption in both the industry & mining sector and the commercial & public sector that are relatively fixed, and hence do not decrease when output is cut. The major role played by mining and metals manufacturing in South Africa's energy consumption strengthened the impact of the global economic downturn on energy efficiency, as these activities are particularly prone to reduced energy efficiency when operating at reduced capacity.

The cumulative effect of structural changes on total final energy consumption between 2000-12 has been relatively small. Inter-sectoral structural changes alone have exerted a significant downward influence on energy consumption, resulting from the growth of the relatively less energy-intensive tertiary sector relative to manufacturing and mining. However, this effect has been partially offset by the increase in consumption resulting from rapidly improving living standards in the residential sector (which are interpreted in this analysis as structural changes).

The economy-wide analysis described here incorporates all sectors, including those for which no NEES target has been set (i.e. agriculture and transport). However, as described in the methodological overview above, the analysis is only able to 'see' trends that occur *within* the main sectors if the available data makes such an analysis possible. In the case of the transport sector, the necessary data is not currently available, so the results presented here do not take into account structural changes that are taking place within the transport sector. Instead, the effects of any such changes are subsumed into the efficiency component of the economy-wide analysis. If the net effect of structural changes within the transport sector is to increase energy consumption (for example, though a modal shift towards private cars), this would have the effect of making the economy-wide efficiency improvement appear smaller than it actually is.

CONCLUSIONS

The best estimate that can be made based on currently available data is that energy efficiency across the whole South African economy has improved by about 24% between 2000 and 2012. Although the effect of the economic crisis has been an apparent fall in efficiency between 2007-09, the trend of increasing efficiency returned from 2010 onwards. Although the necessary data is not yet available to continue the analysis to the present, these results suggest that the country is on track to achieve the economy-wide NEES target. However, it must be emphasised that the absence of a detailed analysis of the transport sector means that a potentially important component of overall efficiency change is missing from the results presented here.

INDUSTRY & MINING SECTOR

INTRODUCTION

The National Energy Efficiency Strategy (NEES) sets a sector target of a 15% improvement in energy efficiency for the industry & mining sector by 2015, relative to a 2000 baseline. NEES does not specify how changes in energy efficiency are to be measured in order to determine whether the target is being met. A lack of detailed disaggregated data for the period from 2000 to the present means that an accurate assessment of energy efficiency trends since 2000 is not possible. Historical analysis must therefore estimate past trends based on historic data at a highly aggregated level.

However, to address this the Department of Energy has, amongst other measures, developed a comprehensive strategy to promote energy efficiency improvements in the industrial sector. The Department is working towards the introduction of mandatory energy management plans for energy-intensive users and establishing the mechanism for the routine collection of energy consumption and production data at the level of individual firms and facilities. As this data set is gradually built up, it will allow a more precise estimate to be made of changes in energy efficiency, but this will necessarily be limited to the time period from when the collection of this data began.

Therefore at this stage, two types of analysis have been undertaken based on the availability of data: one using aggregate level historical data covering the period from 2000-2012, and the other using detailed data from individual firms and facilities, but covering only the period 2010-12.

DATA SOURCES

The data sources used for the analyses described in this section are as follows:

- Energy Balance Tables 2000-2012 (Department of Energy)
- Gross Domestic Product Annual Estimates 2000-2012 (Statistics South Africa Statistical Release P0441)
- Bulletin of Statistics 2000-2012 (Statistics South Africa)
- Data on energy consumption and physical output for 2010-2012 provided voluntarily to the Department of Energy by a sample of enterprises in the mining sub-sector and the most energy-intensive manufacturing sub-sectors.

The Energy Balance Tables and the Gross Domestic Product Annual Estimates use slightly different sub-sector definitions, which means that some sub-sectors in each data set must be combined in order to allow the calculation of energy intensities. Table 3 below shows the sub-sector definitions along with the combinations used.

Table 3 Mapping between sub-sector definitions used in Energy Balance Tables and Gross Domestic Product Annual Estimates

Sub-sectors used in the Energy Balance Tables		Sub-sectors used in the Gross Domestic Product Annual Estimates
Iron and steel	}	Metals, metal products, machinery and equipment
Non-ferrous metals		
Machinery		
Chemical and petrochemical*	↔	Petroleum products, chemicals, rubber and plastic*
Non-metallic minerals	↔	Other non-metal mineral products
Mining and quarrying	↔	Mining and quarrying
Paper pulp and print	}	Wood and paper, publishing and printing
Wood and wood products		
Food and tobacco	↔	Food, beverages and tobacco
Transport equipment	↔	Transport equipment
Textile and leather	↔	Textiles, clothing and leather goods
Construction	↔	Construction
Non-specified industry	{	Electrical machinery and apparatus Radio, TV, instruments, watches and clocks Furniture and other manufacturing

* See note in text below

Note that the sub-sector 'Chemical and petrochemical' in the energy balance table does not include petroleum refining or the synthetic fuels industry, as these are treated as energy conversion processes rather than elements of final consumption. In the data on GDP however, these activities are included in the sub-sector 'Petroleum products, chemicals, rubber and plastic'. In order to achieve a closer match between the activities covered in each of the two sub-sector definitions, the GDP for this sub-sector has been adjusted to remove the portion accounted for by the fuel production and conversion activities. This was estimated by assuming that the share of sub-sector GDP accounted for by fuel production and conversion was the same as the fraction of sub-sector value of sales, for which detailed data is available from Statistics South Africa's Bulletin of Statistics.

The procedures and protocols for collecting data directly from firms on energy consumption and physical production are still in their early stages of development. The provision of data has therefore been voluntary, and coverage is still being extended. The intention is that data will eventually be obtained from all the largest firms active in the most energy intensive sub-sectors (mining, metals manufacturing, non-metallic minerals, chemicals, pulp & paper). One of the two analyses described in this report is based on data provided by over 20 firms / facilities, which together account for approximately 40% of the total energy consumption of the industry & mining sector.

SECTOR OVERVIEW

Trends in energy consumption

As of 2012 (the most recent year for which aggregate data is currently available), the total final energy consumption² of the industry & mining sector stood at 847 PJ, an overall decrease of 20.5% from its 2000 baseline of 1,065 PJ. The fuel mix consumed by the industry & mining sector has changed significantly between 2000 and 2012. As shown in Figure 6 below, coal and electricity remain the dominant energy carriers, but the share of coal has fallen from 57% in 2000 to 34% in 2012. Over the same period, the share of electricity in industry & mining total energy consumption has increased from 35% to 49%. The share of petroleum products has remained almost constant at about 5-6%, while the share of gas has increased significantly from 4% to 12%.

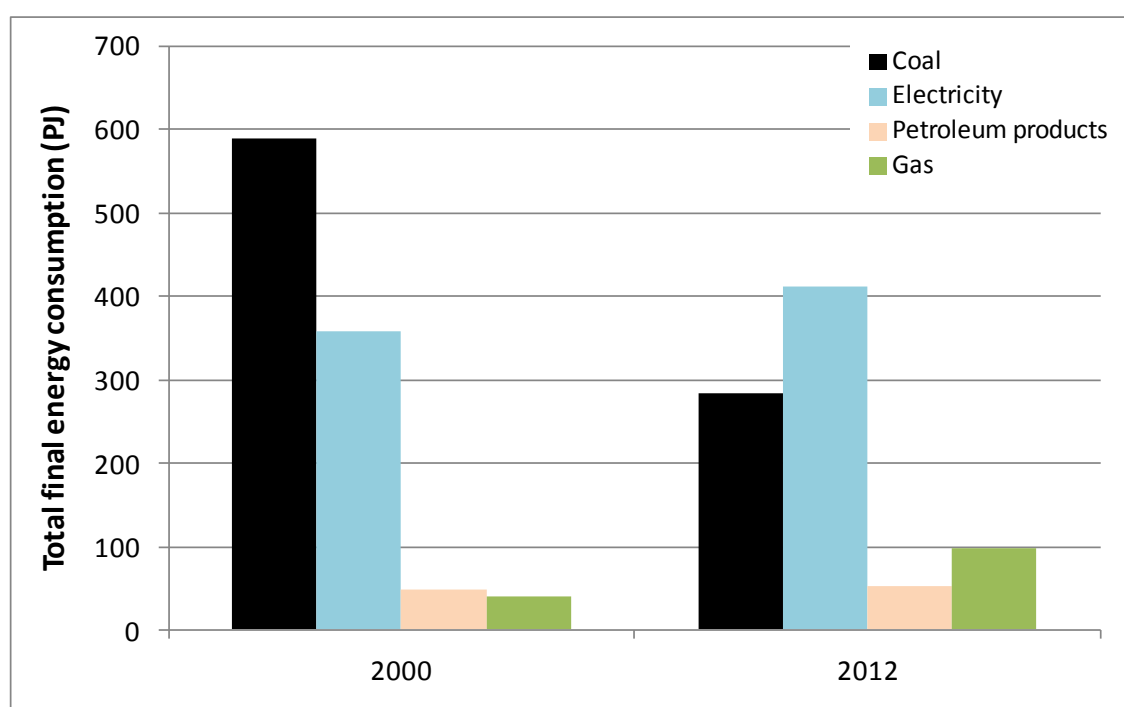


Figure 6 Total final energy consumption of industry & mining sector disaggregated by energy carrier, 2000 and 2012

Trends in gross value-added³ (GVA)

Over the period of analysis 2000-12, the total gross value-added⁴ (GVA) of South Africa's industry & mining sector increased by about 29%, from about R556 billion up to R673 billion. Generally speaking, the shares of GVA arising from the various sub-sectors remained relatively stable over this period. The most significant shifts were mining, whose share of GVA fell from 42.9% to 33.0%, and construction, whose share increased from 7.7% to 14.5%. Given that mining is a more energy intense

² Note that the synthesis of liquid fuel from coal and gas is an energy conversion process, so the inputs to the fuel synthesis industry are not considered to be part of final energy consumption

³ At constant 2010 prices

⁴ The gross value-added for a particular category of economic activities corresponds to its contribution to GDP

activity than construction, this shift alone can be expected to have contributed towards an increase in total energy consumption. Figure 7 below shows the trends in the shares of GVA among the main sub-sectors.

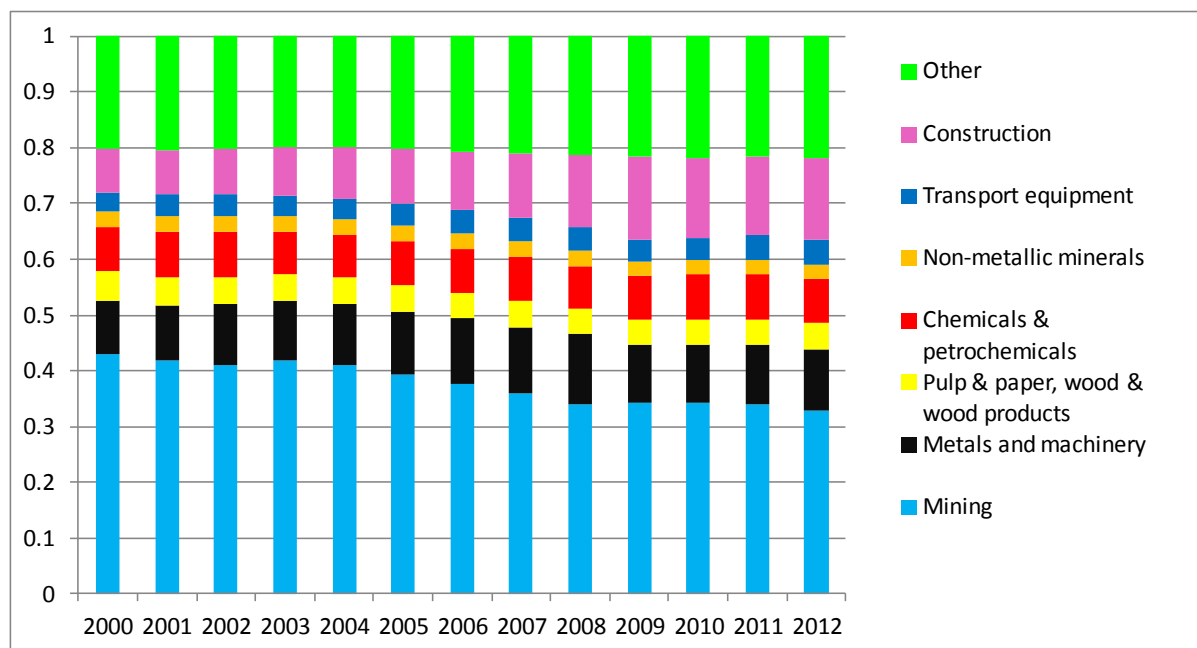


Figure 7 Share of total GVA by sub-sector (2000-2012)

Energy intensity trends

The energy intensity (the ratio of energy consumption to GVA) of the industry & mining sector decreased by 34%, from 1.92 MJ/R in 2000 to 1.26 MJ/R in 2012. This represents a compounded annual reduction of 3.4% in energy intensity. Trends in energy intensity at the level of the individual sub-sectors are illustrated in Figure 8 below. In order to make these trends easier to observe, this graph shows five-year rolling averages which smooth out the wide fluctuations in energy intensity that are often seen between consecutive years. Note that, because a five-year rolling average has been used, the base year for the trends displayed in this graph is 2004, with energy intensity being expressed as an index relative to the this base year.

The main trends that can be seen are: (i) an increase of nearly 40% in the energy intensity of the non-metallic minerals sub-sector; (ii) a large and rapid fall followed by an even more marked increase in the energy intensity of the transport equipment sub-sector that has left it about 30% higher than in 2000; (iii) a fall of almost 50% in energy intensity of the chemicals & petrochemicals sub-sector; (iv) significant decreases of 30-40% in the energy intensity of metals & machinery and construction. The energy intensity of mining when calculated as a five-year rolling average has remained fairly constant.

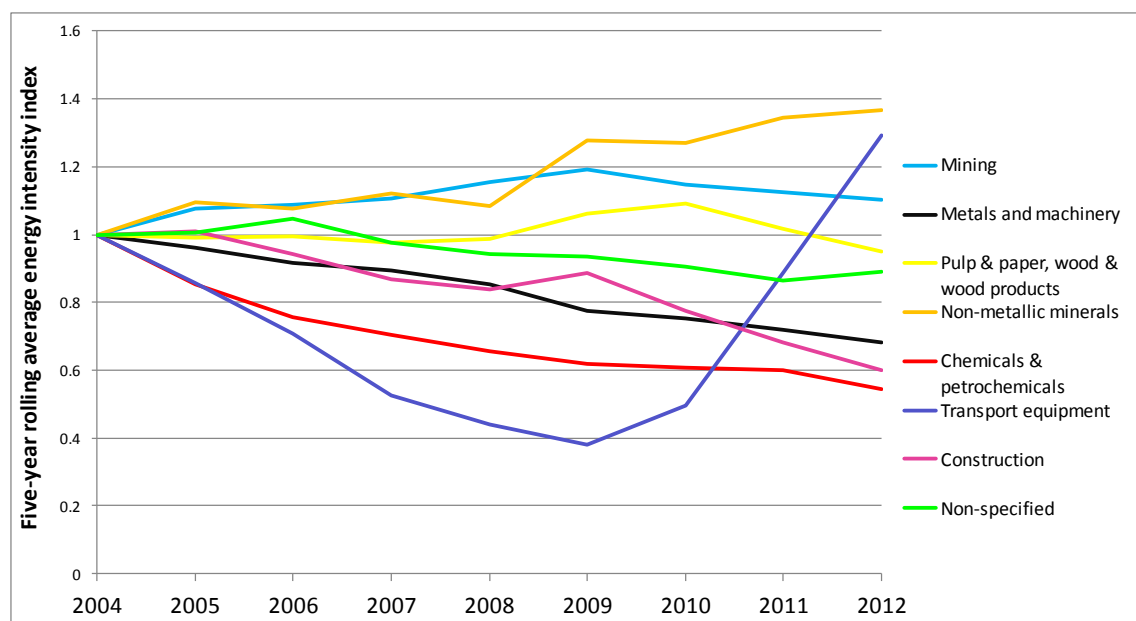


Figure 8 Trends in sub-sector energy intensity. For greater clarity, five-year rolling average figures are shown in order to smooth out sharp fluctuations. Figures are expressed as an index relative to the value for 2004.

DECOMPOSITION ANALYSIS

Methodological overview

Measuring changes in energy efficiency at the sector level is a complex process with no single universally applicable approach. It can be assumed that the NEES target of a 15% improvement in energy efficiency implies a 15% reduction in the amount of energy required to produce the same output, but in the case of the industry & mining sector, output may be quantified in either physical units (tonnes of output, for example) or in economic units (e.g. value-added measured in Rand).

For the period from 2000-2010, data was available only at the aggregate level – energy consumption data in the form of Energy Balance Tables from the Department of Energy, and output data in the form of GDP estimates from Statistics South Africa. Output is thus necessarily quantified in economic units, and energy intensity (energy consumption per unit of economic output) must serve as a proxy for energy efficiency. There are several reasons why energy intensity at an aggregate level is an imperfect proxy for energy efficiency. The most important of these is that it includes the effect of structural change⁵, but this factor can be quantified and separated out using a process known as ‘decomposition’. *Annex A: Decomposition methodology* provides a more detailed description of decomposition analysis.

The other significant reason that energy intensity is an imperfect proxy for energy efficiency is that output measured in terms of value-added is affected by changes in the unit value of the physical outputs produced, and by the costs of inputs. For example, if all else remains unchanged, a 10% increase in the world price of gold will result in a 10% fall in the energy intensity of gold mining – a fall that does not reflect any change in energy efficiency.

⁵ Changes in the relative size of sub-sectors that have different individual energy intensities will have an effect on aggregate energy intensity, even though the energy intensities of the individual sub-sector may not have changed.

As part of the process of monitoring energy efficiency trends in the industry & mining sector, the Department of Energy has started to use energy consumption and physical production data collected at the firm or facility level from the most energy intensive industry branches. This data allows trends in specific energy consumption to be tracked, but issues of commercial confidentiality preclude the collection of data on value-added at this level of disaggregation. Without information on value-added, it is impossible to calculate the effects of structural changes between the various entities that have provided data, so a full decomposition analysis is not possible. However, it is possible to track the effects of efficiency changes (with specific energy consumption serving as a proxy for efficiency) because the formulas to derive the efficiency component in a decomposition analysis do not require data on sub-sectoral shares of output (see *Annex A: Decomposition methodology* for more details).

As a proxy for energy efficiency, specific energy consumption is somewhat better than energy intensity, as it is not affected by changes in the price of inputs and outputs⁶. Because of this, the analysis based on physical production data provides a better indication of efficiency trends than that based on GVA. But since data on physical production is available only for the period beginning in 2010, an analysis based on energy intensity must be used for the historical analysis. It is important to remember that neither specific energy consumption nor energy intensity is a perfect proxy for energy efficiency. For this reason, both of the quantitative analyses of trends described below should be interpreted in the context of the accompanying narrative description, which addresses the main non-efficiency related factors that may have affected energy consumption.

Sectoral decomposition analysis based on historical data

Using the data sources described above, a standard top-down decomposition analysis was conducted following the process described in *Annex A: Decomposition methodology*. These results are shown in Table 4 below while Figure 9 shows the cumulative improvement in energy efficiency relative to 2000, expressed in terms of the fractional change in total energy consumption that can be attributed to efficiency changes.

The analysis results show that, between 2000 and 2012, energy efficiency improved significantly albeit very unevenly. Over the twelve-year period, if other factors had remained constant, improvements in efficiency would have led to a 443 PJ fall in energy consumption, which is 34.3% of the projected baseline figure. This is equivalent to a compounded annual fall of about 3.4% in energy consumption attributable to efficiency improvements. This is well in excess of the rate of improvement in energy efficiency needed to achieve the sectoral target as set out in the Energy Efficiency Strategy, indicated by the red line in Figure 9.

⁶ It is nevertheless an imperfect proxy, meaning that in some cases an observed variation in specific energy consumption may not be entirely due to changes in energy efficiency. For example, in the mining sub-sector the energy consumed per unit of physical output may be strongly affected by the accessibility of the ore. Even if energy efficiency remains unchanged, exploiting an inaccessible ore body requires more energy per tonne of product relative to more easily accessible ore.

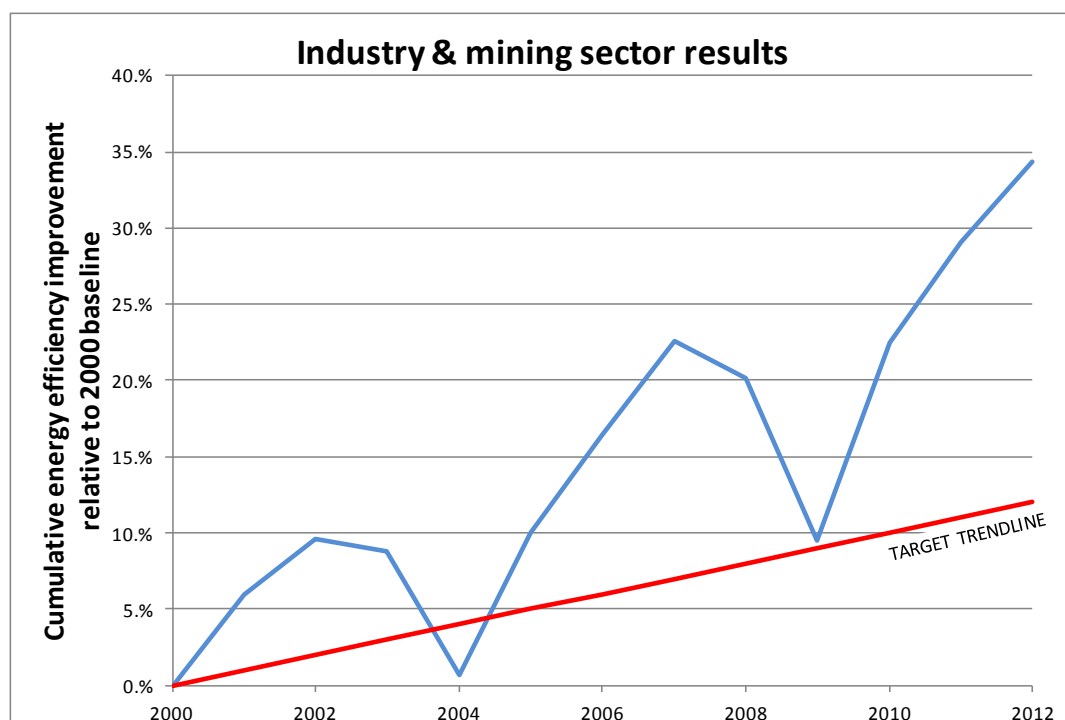


Figure 9 Cumulative change in energy consumption attributable to energy efficiency changes, expressed as a percentage of the total sectoral energy consumption in the projected 2000 baseline

Figure 10 provides a graphical representation of the full decomposition results for 2012 relative to a 2000 baseline. Total energy consumption in the industry & mining sector in 2012 had decreased by 218 PJ relative to 2000. This change is composed of the sum of:

- a 205 PJ increase due to greater levels of activity;
- a 20 PJ increase due to structural changes;
- a 443 PJ decrease due to efficiency improvements.

The effect of efficiency changes alone is illustrated in Figure 11, where the green curve (“With efficiency changes”) is the actual observed change in the total final energy consumption of the sector from 2000-2012, while the red curve (“Without efficiency changes”) is the trend in total final energy consumption that would have been observed if the efficiency components revealed by the decomposition analysis had been absent. The green shaded areas indicate periods when efficiency had improved relative to the baseline; at no stage during the analysis period did efficiency fall below the baseline level.

Table 4 Results of decomposition analysis of changes in industry & mining sector energy consumption, 2000-2012

YEAR-ON-YEAR CHANGES												
	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
CHANGE IN FINAL ENERGY CONSUMPTION (TJ)	-43,308	2,029	12,052	137,940	-64,940	-36,051	-44,806	36,645	41,741	-114,140	-75,096	-70,273
ACTIVITY LEVEL EFFECT	10,883	24,228	12,917	39,241	44,952	37,485	43,279	-74	-61,821	50,866	5,684	-2,886
STRUCTURAL EFFECT	10,566	22,065	-10,558	7,663	5,836	12,380	2,590	4,515	-48,790	6,039	7,913	-640
EFFICIENCY EFFECT	-64,757	-44,264	9,693	91,036	-115,728	-85,916	-90,675	32,205	152,351	-171,045	-88,693	-66,747
% CHANGE IN ENERGY CONSUMPTION DUE TO EFFICIENCY CHANGES	-6.0%	-4.1%	0.9%	8.4%	-9.5%	-7.4%	-8.1%	3.1%	16.0%	-14.7%	-8.8%	-7.3%

CUMULATIVE CHANGES (2000 base year)												
	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
CHANGE IN FINAL ENERGY CONSUMPTION (TJ)	-43,308	-41,279	-29,227	108,713	43,773	7,721	-37,085	-439	41,301	-72,839	-147,935	-218,208
ACTIVITY LEVEL EFFECT	10,883	35,111	48,029	87,269	132,221	169,706	212,985	212,911	151,091	201,957	207,641	204,755
STRUCTURAL EFFECT	10,566	32,630	22,072	29,735	35,571	47,951	50,541	55,056	6,266	12,305	20,218	19,578
EFFICIENCY EFFECT	-64,757	-109,020	-99,327	-8,292	-124,020	-209,936	-300,611	-268,407	-116,055	-287,100	-375,794	-442,541
% CHANGE IN ENERGY CONSUMPTION DUE TO EFFICIENCY CHANGES	-6.0%	-9.6%	-8.8%	-0.7%	-10.1%	-16.4%	-22.6%	-20.1%	-9.5%	-22.4%	-29.1%	-34.3%

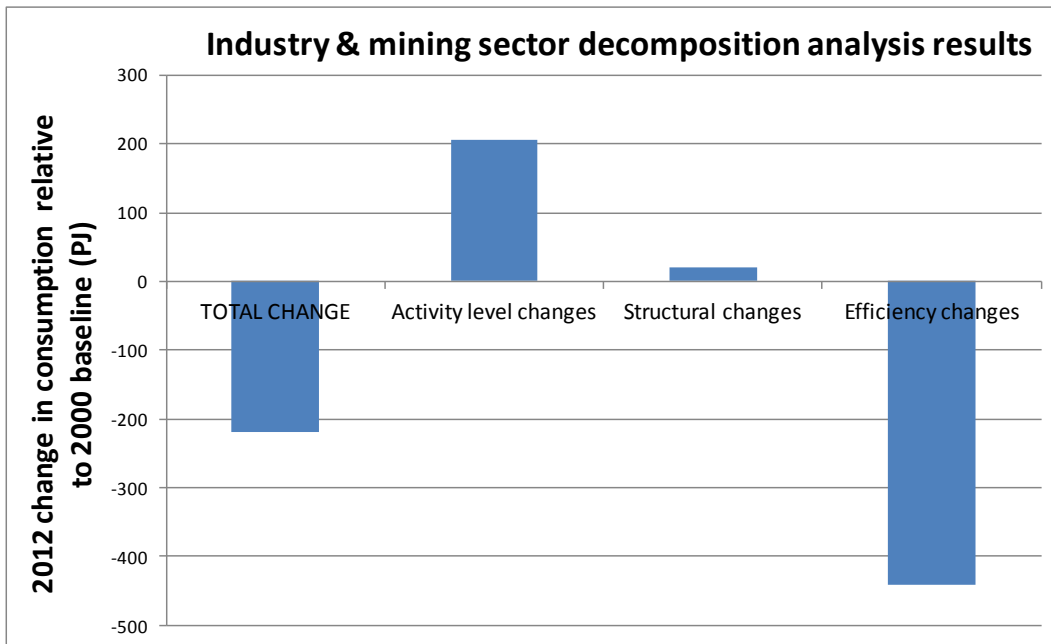


Figure 10 Cumulative change in energy consumption between 2000-2012 decomposed into three main components

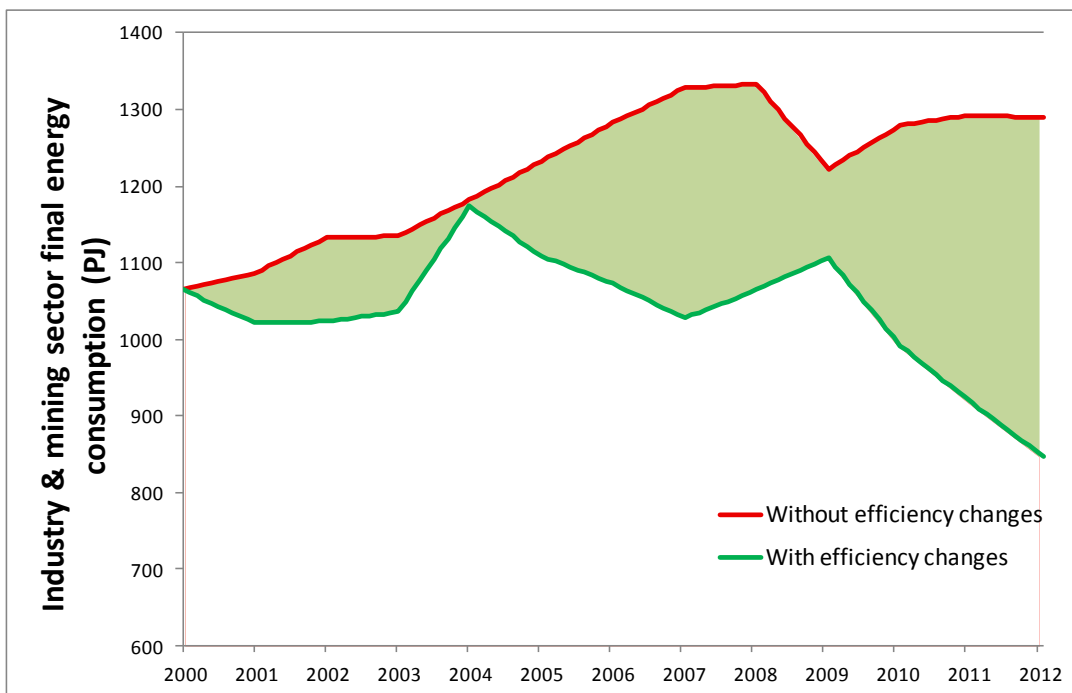


Figure 11 Comparison of actual observed trends in energy consumption of the industry & mining sector (green trace) versus trends that would have occurred with no efficiency change (red trace).

It is worth reiterating here that the efficiency changes identified in this analysis are actually changes in energy intensity after the effects of structural change have been quantified and allowed for. The available data allows only for the effects of structural change *between* the main industrial sub-

sectors to be identified. Any structural changes *within* the sub-sectors⁷ are invisible to this level of analysis and hence cannot be quantified. Hence the extent to which energy intensity serves as a good proxy for energy efficiency at this level of analysis is limited.

Analysis of energy intensive branches 2010-12

Data was obtained for the years 2010-14 on energy consumption and physical production from firms in the most energy intensive sub-sectors: mining; iron & steel; non-ferrous metals; non-metallic minerals; pulp & paper; chemicals. The firms and facilities that submitted data account for approximately 40% of the total energy consumption of the whole industry & mining sector, and over two-thirds of the energy consumption of those energy intensive sub-sectors from which data was sought. Although data was provided for the whole period 2010-14 by a number of industrial and mining firms, coverage for the period 2012-14 was incomplete. For this reason, the analysis described here was conducted only for the period 2010-12, for which a complete and consistent set of data was available.

In many cases, more than one quantifier for physical output is available for a particular industry branch. For example, the output from the iron & steel industry may be quantified in terms of tonnes of crude steel (as used by the World Steel Association), or in terms of final products (the units preferred by the US Government). Similarly, the level of activity in the cement industry may be quantified in terms of clinker production or by the production of finished cement products. Although there are no universally accepted standards for quantifying physical outputs, the units used here have been chosen to match the most frequently used international conventions. These are summarised in Table 5 below.

For some industry branches, complexities also exist in quantifying energy consumption. This is particularly the case where energy intensive process inputs are produced on-site in some facilities but are imported from a third party in other facilities⁸. Particularly in the iron & steel industry, the possibility also exists for energy carriers to be exported off site. For example, some iron & steel firms also manufacture and sell coke ('market coke'), but use the coke oven gas resulting from coke production as an energy input into the iron & steel making processes. This particular situation was accounted for in the analysis conducted here by adding together all fuels consumed, including coal for market coke, then subtracting the energy content of the market coke produced and sold. This provides a value for the net energy consumption for iron & steel making.

Table 5 Quantifiers of physical output used for the main industry branches analysed

Industry branch	Quantifier of physical output
Mining of precious metals	kg of refined metal
Mining of other metals	tonnes of ore
Manufacture of ferro-alloys	tonnes of product

⁷ For example, a growth in deep mining (which is intrinsically more energy intensive) relative to surface mining will result in an increase in the aggregate energy intensity of the mining sub-sector, independently of any changes in energy efficiency.

⁸ A more detailed discussion of this issue can be found in "Assessing measures of energy efficiency performance and their application in industry"; IEA Information Paper 2008.

Manufacture of aluminium	tonnes of primary aluminium
Manufacture of iron & steel	tonnes of crude steel
Manufacture of non-metallic minerals	tonnes of clinker plus lime
Manufacture of pulp & paper	tonnes of pulp

More generally, since the aim of this analysis is to identify trends through time, rather than comparing the specific energy consumption figure *between* sub-sectors, ensuring longitudinal consistency (i.e. from one year to the next) is more important than achieving cross-sectional consistency (i.e. between different facilities).

Specific energy consumption for the years 2010-12 was calculated for each of the firms and facilities that provided data. Using a variation of the standard decomposition approach, the calculated values for specific energy consumption were combined to derive estimates of the fraction of the total change in reported energy consumption that is attributable to changes in efficiency. Because the activity levels of each sub-sector are quantified in physical units, there is no meaningful way to define the each sub-sector's share of total activity. It is therefore not possible to calculate the structural effect in this analysis – instead, the analysis decomposes the change in total energy consumption into a component attributable to efficiency changes and a component attributable to a combination of activity level changes and structural changes⁹.

The total energy consumption of the entities that provided data was 369 TJ in 2010, falling to 341 TJ in 2012. The results of the decomposition analysis indicate that there was an improvement in energy efficiency of 0.38% for the year from 2010-11, but this was followed by a fall in efficiency of 2.22% between 2011-12. Over the whole two year period, the total cumulative change has been a fall in efficiency of 1.82%. In other words, if the effects of structural change and changes in activity level are factored out, changes in energy efficiency alone would have resulted in an increase total energy consumption among those entities that reported data of 1.82% relative to where it would be if efficiency had not changed.

The results of this analysis are summarised in Table 4 and Figure 12 below. These results indicate that the change in total final energy consumption between 2010 and 2012 among those entities included in this analysis was a reduction of 28.11 PJ. Over this period, changes in activity level and structural effects combined were responsible for a decrease in total final energy consumption of 34.7 PJ. This decrease was offset by a *fall* in efficiency that was responsible for an *increase* in total final energy consumption of 6.59 PJ. The overall efficiency reduction was made up of a small improvement in efficiency between 2010-11 (accounting for a decrease in total final consumption of 1.42 PJ) followed by a larger fall in efficiency between 2011-12 (which contributed a net increase of 8.01 PJ to total final consumption).

⁹ Although arithmetically equivalent to a standard decomposition analysis, the approach used in this analysis is somewhat akin to the bottom-up approach used in calculating the Odex indicators under the EU ODYSSEE-MURE project.

Figure 12 Summary of results of analysis based on detailed energy consumption and output data provided by firms and facilities

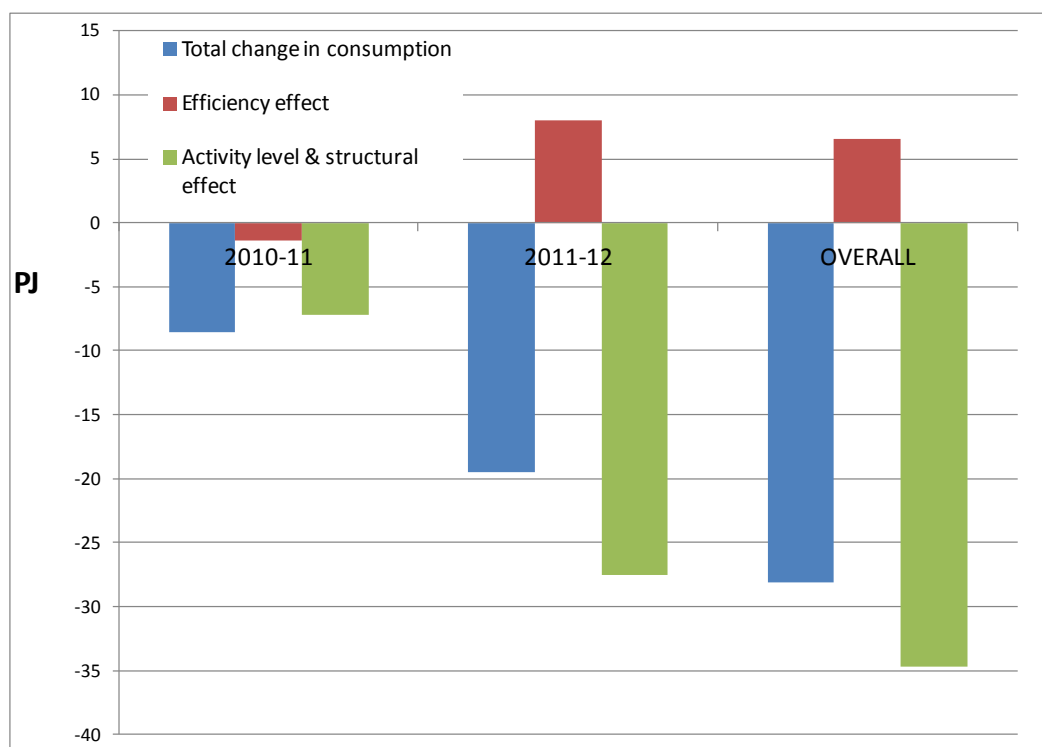


Table 6 Summary results of analysis based on detailed energy consumption and output data provided by firms and facilities

	2010-11	2011-12	OVERALL
Total change in energy consumption (PJ)	-8.60	-19.51	-28.11
Portion attributable to efficiency changes	-1.42	8.01	6.59
Portion attributable to activity level & structural effects	-7.17	-27.52	-34.70

DISCUSSION AND INTERPRETATION OF RESULTS

For the purposes of this discussion, the analysis based on aggregate-level energy consumption data from the Department of Energy and GVA data from Statistics South Africa will be referred to here as the ‘top-down’ analysis, while the analysis based on energy consumption and physical production data obtained directly from firms and facilities will be referred to as the ‘bottom-up’ analysis.

The most striking features observable in the results obtained from the top-down analysis for the period from 2000-12 (see Figure 9) are the large falls in efficiency that occurred in 2003-04 and again from 2007-09. A closer examination of the underlying data suggests that the first of these falls in efficiency was largely attributable to a sharp increase in the electricity consumption for the ‘Non-specified industry’ category in 2004, which appears to be an artefact arising from inconsistencies in the raw data. The raw data also indicates a significant increase in coal consumption in the iron & steel industry in 2004, which was not accompanied by a corresponding increase in production. This may have been connected with two planned major blast furnace outages that Mittal Steel undertook during 2004.

The global financial crisis of 2008, which led to the South African economy entering recession in 2009, is likely to be a major driver behind the fall in efficiency observed from 2007-09. This would have been exacerbated by the power shortages and rolling blackouts that occurred during the early part of this period. Both the global economic crisis and the rolling blackouts would have resulted in many industries operating at greatly reduced capacity utilisation, with adverse effects on energy efficiency (the effects of capacity utilisation on energy efficiency are discussed below). An equally dramatic improvement in efficiency for the period 2009-12 has left the industry & mining sector more energy efficient in 2012 than it had been in 2007. Although this analysis cannot provide conclusive evidence of causality, it is likely that this improvement in energy efficiency was at least in part driven by increases in electricity prices over that period.

The cumulative energy efficiency improvements since 2000 have left the sector above the target level for all years except 2003-4. The top-down analysis therefore suggests that the industry & mining sector is comfortably on track to meet the NEES target of a 15% improvement in energy efficiency by 2015 relative to the projected 2015 baseline.

The bottom-up analysis indicates a much smaller year-on-year improvement in efficiency for the single year from 2010 to 2011 than that indicated by the top-down analysis. The year-on-year change from 2011 to 2012 is a *fall* in efficiency of about 2.2% according to the bottom-up analysis, contrasting with a 7.3% improvement in efficiency for the same period according to the top-down analysis. The reasons for the differences in the results obtained from the two types of analysis are discussed in detail in the following section.

Differences in results between two types of analysis

A direct comparison of the two types of analysis described in the previous section is possible only for the two-year period from 2010 to 2012. For years prior to 2010, detailed data on energy consumption and physical production from individual firms and facilities was not available, while aggregate level energy consumption data is not yet available for the years following 2012. Table 7 compares the results obtained from the two types of analysis.

Table 7 Comparison of the results obtained from the top-down versus the bottom-up analysis of energy efficiency changes for the period 2010-2012

	Year-on-year improvement in efficiency	
	2010-11	2011-12
Top-down analysis	8.8%	7.3%
Bottom-up analysis	0.4%	-2.2%

For the year from 2010-11, the top-down analysis shows an 8.8% improvement in energy efficiency, while the bottom-up analysis shows a substantially smaller improvement in efficiency of 0.4%. For the year from 2011-12, the top-down analysis shows an improvement of 7.3%, while the bottom-up analysis indicates that efficiency declined by 2.2%.

All else being equal, specific energy consumption measured at the firm or facility level will be a closer proxy than aggregate level energy intensity for tracking energy efficiency changes. In itself, this would suggest that the bottom-up analysis is likely to provide a better indication of efficiency trends than that obtained from the top-down analysis that uses aggregate-level energy intensity

data. However, there are several reasons why the results obtained may be expected to differ between the two analyses, and it cannot simply be said that one analysis is 'better' than the other. These reasons are discussed in more detail in the following sections.

Sampled firms not representative of the sector

The results from the bottom-up analysis represent the best estimate for the change in efficiency *among the industry & mining sector branches from which data was obtained*, but this result cannot necessarily be extrapolated to the sector as a whole, because these branches are unlikely to be representative of the whole industry & mining sector.

In particular, the chemicals sector and the category 'Other'¹⁰ are both omitted from the bottom-up analysis. These two industry groups are responsible for a large fraction of the overall improvement in energy efficiency of the industry & mining sector that was shown in the top-down analysis (see 'Sub-sector trends' under). Their omission from the bottom-up analysis will have the effect of greatly underestimating the overall sector-wide improvement in efficiency, and is therefore likely to account for most of the difference seen between the two types of analysis.

This highlights the difficulty of analysing energy efficiency trends based on incomplete data sets. In order to derive a true picture of how energy efficiency is changing in the industry & mining sector, it is essential to continue to broaden the collection of data from industrial firms and facilities. For a complete understanding, it will also be necessary to include data on the driving forces behind changes in energy efficiency, and narrative information from representatives of the key energy intensive industry branches.

Changes in the economic value of outputs

Another potential source of differences in results between the top-down and bottom-up analyses is linked to changes in the economic value of the outputs produced. All else being equal, a price increase that leads to an increase in the value of an output will result in a reduction in energy intensity, even if specific energy consumption remains unchanged. Hence the top-down approach will show an improvement in energy efficiency while no change in efficiency will be indicated under a bottom-up analysis. Conversely, if the market price of an output decreases, a top-down analysis will produce a smaller estimate of efficiency improvement relative to that calculated using a bottom-up approach.

During 2011, the prices of most of the major commodities produced in South Africa increased significantly¹¹. Hence the value of the outputs from both the metals & machinery and the mining sub-sectors increased, putting a downward pressure on the energy intensity of those sub-sectors. This leads to the top-down analysis showing an improvement in energy efficiency that is greater than that shown by the bottom-up analysis (which looks only at changes in specific energy consumption, and is hence not affected by changes in the value of outputs).

However, with the exception of gold, the prices of the main commodities fell back during 2012. Hence it would be expected that the year-on-year improvement in efficiency estimated by the top-

¹⁰ This category includes the 'Food, drink & tobacco' and 'Textiles & leather' sub-sectors as well as 'Non-specified industry'.

¹¹ This includes the prices of coal, gold, platinum, manganese and aluminium (see for example the World Bank 'Pink Sheets' on global commodity prices)

down analysis would be lower than that shown by the bottom-up analysis. In fact, the top-down analysis continued to show a substantial improvement in efficiency, while the bottom-up analysis indicated that efficiency fell. This suggests that changes in commodity prices are not sufficient to fully account for the differences between the results from the two analyses.

Another sub-sector where the relative value of products has increased is the cement industry, where a shift towards blended products means that the clinker content of cementitious products has been steadily declining for several years. Because clinker production is by far the most energy intensive stage in the manufacture of cement, this trend leads to a fall in the energy consumed per unit of *value* of final product. Hence a top-down analysis would be expected to show an improvement in efficiency much greater than that indicated by a bottom-up analysis, which is based on the energy consumption per tonne of clinker. This may partially explain the difference between the two analyses for the period 2010-11, during which the energy intensity of the non-metallic minerals sub-sector fell by 12%, while the specific energy consumption of clinker manufacturing fell by about 9%. But again, it cannot account for the difference observed between 2011-12, during which the improvement in specific energy consumption (3.7%) was greater than the fall in energy intensity (1.6%).

Example from the Pulp and Paper Industry

“What is worth noting with respect to the pulp and paper industry are the structural changes that have occurred during the period under review, where pulp production of certain pulp mills was increased and at other mills, pulp mill operations were curtailed. There has also been a general shift in the types of pulps being produced (less Kraft and more chemical cellulose or dissolving pulp). This would have had a significant impact on energy efficiencies and intensities over the 2004-2012 time periods.”

Comment provided by PAMSA

Hidden structural effects

Another reason why the results from the two analyses might be expected to differ is that the top-down analysis is ‘blind’ to structural changes that take place *within* the main industry branches analysed. Depending on the nature of these hidden structural effects, the change in efficiency estimated by the top-down analysis may be either greater or smaller than that estimated using the bottom-up approach. There is some evidence to suggest that hidden structural effects may be responsible for at least part of the difference seen here between the two analyses for the year 2010-12.

For example, structural changes taking place within the pulp & paper industry may be expected to show industry-wide improvements in energy intensity that are much greater than any plant-level improvements in specific energy consumption (see box). Since this industry is over-represented in the sample of firms that provided detailed data on energy use, it has a disproportionate impact on the overall results from the bottom-up analysis.

Also, when measured in terms of gross output¹², the non-ferrous metals industry appears to have grown slightly relative to the iron & steel industry, and since non-ferrous metals manufacturing is less energy intensive than iron & steel, the net effect of this structural shift would have been a reduction in overall energy consumption. This would have manifested itself as slightly greater *apparent* increase in efficiency at the level of aggregation at which the top-down analysis was

¹² Data on gross output is available from Statistics South Africa at a much greater level of disaggregation than data on GVA

conducted, since an analysis at that level cannot ‘see’ the structural changes taking place between the industry branches.

Sub-sector trends

Figure 13 below shows the extent to which each sub-sector contributed¹³ towards the cumulative sector-level improvement in energy efficiency between 2000 and 2012, as revealed by the top-down analysis. Two sub-sectors account for almost all of the observed improvement in energy efficiency: metals & machinery and chemicals & petrochemicals, with the category ‘Other’ also making a significant positive contribution. The mining and non-metallic minerals sub-sectors have shown small declines in energy efficiency under the top-down analysis, hence they are shown below the x-axis in Figure 13 as having made a negative contribution to the cumulative change in energy efficiency. The contributions of all other sub-sectors are relatively very small.

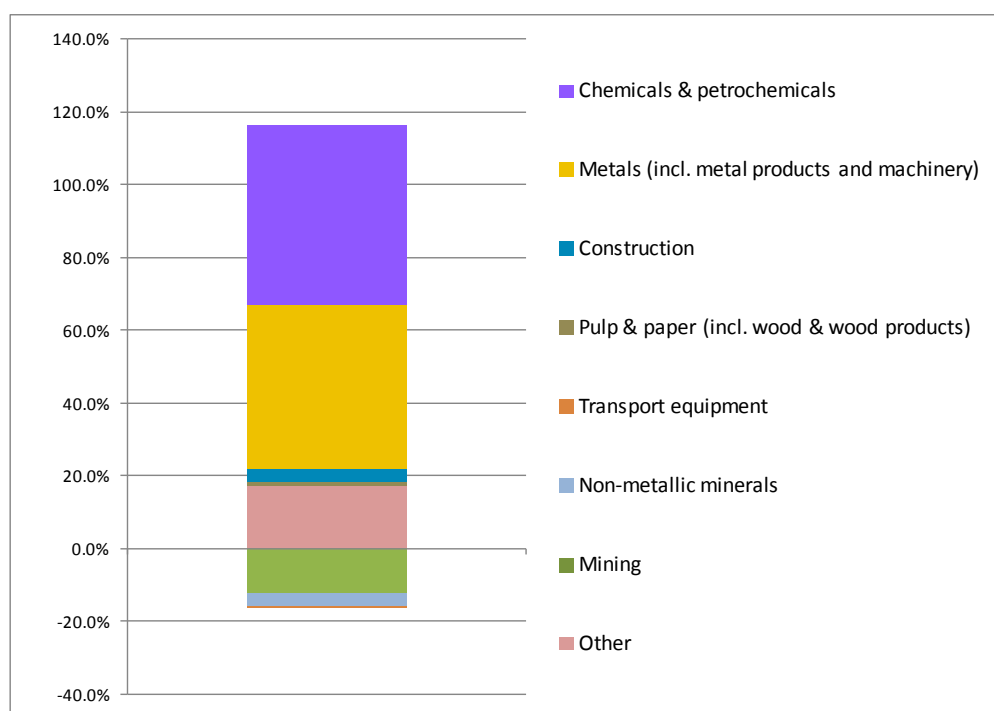


Figure 13 Contribution of each sub-sector to the overall sector-level change in energy efficiency between 2000-2012 as estimated from the top-down analysis. The y-axis represents the fraction of the total calculated change in efficiency that can be attributed to each sub-sector.

The bottom-up analysis conducted for the period 2010-12 indicates that the strongest influence on the observed changes arose from the metal manufacturing industries, which showed a large increase in specific energy consumption over the second year of the two-year period (see Figure 14). Given the strong dominance of iron & steel in this sub-sector, it appears likely that this increase was a result of the closure of three of Arcelor Mittal’s electric arc furnaces during 2012, as well as the closure for repair of a blast furnace. The mining industries also showed a significant increase in specific energy consumption, while both pulp & paper and non-metallic minerals reduced their overall specific energy consumption over the two-year period.

¹³ This contribution takes into account the fractional change in energy intensity of the sub-sector, weighted according to that sub-sector’s share of total sectoral energy consumption

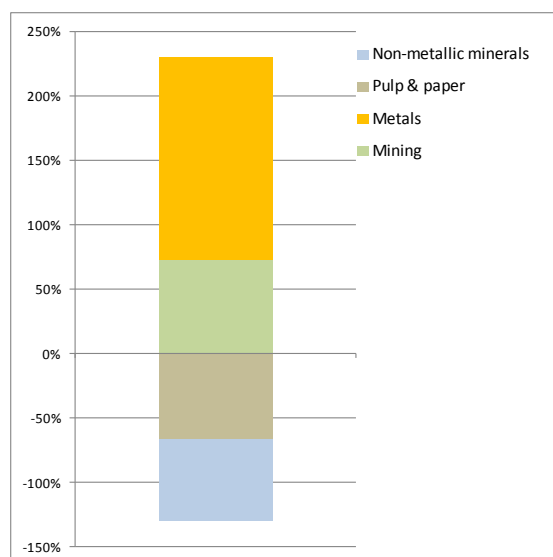


Figure 14 Contribution of each sub-sector to the overall sector-level change in energy efficiency between 2010-2012 as estimated from the bottom-up analysis. The y-axis represents the fraction of the total calculated change in efficiency that can be attributed to each sub-sector.

The impact of capacity utilisation

In almost any economic activity, a certain fraction of total energy consumption is fixed (i.e. it does not vary with the level of output produced), and the industry & mining sector is no exception. In the long term, it would be unusual for a facility to operate at a capacity utilisation outside of a range of approximately 80-90%, but short-term fluctuations are likely in response to a wide range of circumstances including economic conditions, planned maintenance or unplanned shutdowns.

All else being equal, when a facility is operating at reduced capacity the specific energy consumption would be expected to increase, because the fixed portion of energy consumption is being shared across fewer units of output. For the same reason, operation at higher than normal levels of capacity utilisation may lead to a decrease in specific energy consumption, although the relationship is less certain – for example, the additional capacity brought into operation to meet spikes in demand may be older and less energy-efficient than that which is used normally.

Data on capacity utilisation is available from Statistics South Africa, but only for the manufacturing sub-sectors and, for the years prior to 2005, only at an aggregated level. Energy intensity (in MJ/R) was plotted against this capacity utilisation data for those sub-sectors where data is available, in order to identify any relationship. The results indicated no statistically significant correlation at the 95% level, so no conclusions can be drawn from this analysis.

CONCLUSIONS

Based only on a decomposition analysis from 2000-12 of aggregate-level data on GVA and final energy consumption, South Africa's industry & mining sector appears to be on course to meet the NEES target of a 15% improvement in energy efficiency by 2015 relative to a projected baseline. However, this analysis is insufficiently detailed to detect structural changes that are taking place within the main industry sub-sectors. Such structural changes may be revealed by a more detailed

analysis based on changes in specific energy consumption, calculated from data obtained directly from individual firms and facilities.

An analysis of this kind was conducted for the period 2010-12, but was constrained by incomplete coverage of the energy intensive industrial branches. The analysis based on firm and facility-level data indicates that there was a significant fall in efficiency between 2010-12, but the group of firms and facilities on which this bottom-up analysis was based is not representative of the sector as a whole. The results from this analysis are therefore not considered sufficiently robust to provide an indication of sector-wide trends.

Moving forward, the collection of detailed data from firms and facilities in the energy intensive sub-sectors will be extended, with the aim of reaching close to 100% coverage. This greater level of coverage combined with a steadily increasing time series of detailed data will complement the aggregate level data and provide a clearer picture of the energy efficiency trends occurring. It is also hoped that working in increasingly close partnership with industry players will enable a continuous refinement of the indicators used for quantifying energy consumption and physical output, and a clearer understanding of the factors affecting the energy efficiency trends.

COMMERCIAL & PUBLIC SECTOR

INTRODUCTION

The National Energy Efficiency Strategy (NEES) does not separate the commercial and public sectors, so they are addressed jointly here. NEES sets a target for the commercial & public sector of a 15% improvement in energy efficiency by 2015 relative to a 2000 baseline. Measuring changes in energy efficiency at the sector level is a complex process with no single universally applicable approach. It can be assumed that the target of a 15% improvement in energy efficiency implies a 15% reduction in the amount of energy required for a given level of activity.

In the case of the commercial & public sector, activity levels may be quantified in a number of different ways. In common with the industry & mining sector, gross value-added (GVA) is frequently used to quantify activity levels in economic units. Quantifying activity in physical units is more challenging, as the range of activities undertaken across the whole sector is very diverse. Commonly used proxies for activity level are the total number of employees and the total floor area in use, both of which are appropriate for sub-sectors that consist mostly of office-based activities. But for some sub-sectors, more specific indicators may be used, such as total number of guest-nights for the hospitality industry and total number of students in the education sub-sector.

OVERVIEW OF TRENDS IN CONSUMPTION AND ENERGY INTENSITY

A lack of reliable energy consumption data for the commercial & public sector, partly attributable to poor quality data from original data sources, makes it very difficult to state with any certainty the main trends in energy consumption, energy intensity and the fuel mix. Data from the Energy Balance Tables indicated that the total energy consumption of this sector is the lowest, but the fastest growing, of all the sectors for which an energy efficiency target has been set. This data indicates that, between 2000 and 2012, the energy consumption of the commercial & public sector increased by 117%, equivalent to a compounded annual growth rate of 6.7%. However, this same data also shows a fall in total energy consumption for the sector of 42% over the single year period 2009-10. Discontinuities such as these arise because of changes in the assumptions and approximations which, out of necessity, are used to estimate total energy consumption from the available data. Unfortunately, the presence of discontinuities in the data presents particular challenges when that data is used for monitoring trends.

This anomaly in the data for total energy consumption is reflected in the energy intensity of the commercial & public sector, measured in terms of energy consumption per unit of Gross Value-Added (GVA¹⁴). The total increase over the whole period from 2000-2012 is a 37% (from 0.081 MJ/R in 2000 up to 0.111 MJ/R by 2012), equivalent to a compounded annual increase of only about 2.7%.

14 Measured at constant 2010 Rand

However, this trend includes the anomalous 44% fall in energy intensity between 2009-10, when calculated using the *Energy Balance Table* data on total energy consumption.

The anomalous step-change in total energy consumption that is shown for this sector in the *Energy Balance Tables* is almost entirely accounted for by an equivalent step-change in coal consumption. This suggests that a more reliable result might be obtained by using data only on electricity consumption, particularly since the commercial & public sector is more strongly dependent on electricity than any of the other sectors. However, the electricity consumption of the commercial & public sector is shown in the *Energy Balance Tables* as being constant between 2006-11, which again renders this data unusable for calculating energy intensity trends.

Activity levels in this sector are often quantified in terms of number of employees, an indicator that has advantages for use in the EETMS as it can be applied equally well at the aggregated and the disaggregated levels. Unfortunately, using this indicator of activity levels¹⁵ illustrates another data anomaly. The total number of full-time employees in the commercial & public sector according to Statistics South Africa's *Annual Bulletin of Statistics* is shown as increasing by 65% between 2002-03, a step-change that suggests there was a change in the way that this figure is estimated.

Perhaps the most reliable source of data on energy consumption in the commercial & public sector is the electricity sales data, disaggregated by SIC code, provided by Eskom. Although this data does not include electricity generated by independent power producers, this has little impact as Eskom accounts for over 90% of the total electricity sold in South Africa. This data set therefore represents a reasonably complete picture of total electricity consumption, although it should be noted that the total sectoral electricity consumption according to this data is between 5 and 6 times lower than the corresponding figure in the *Energy Balance Tables*.

According to Eskom electricity sales data (which is currently available between 2003-13), the electricity intensity of the commercial & public sector decreased slightly from 3.92 MWh/million R in 2003 to 3.74 MWh/million R in 2013, representing a compounded annual reduction of just 0.47%.

DECOMPOSITION ANALYSIS BASED ON HISTORICAL DATA

Because of a lack of reliable data on total energy consumption, the decomposition analysis described here is based on *electricity consumption data only*. Furthermore, since electricity consumption data is currently available only for the period 2003-13, the decomposition analysis described below covers only this period from 2003 onwards.

The Eskom electricity sales data provides a very high degree of disaggregation, down to the 4-digit SIC level. The data on GVA obtained from Statistics South Africa's *Annual Bulletin of Statistics* is disaggregated into ten sub-sectors and, since the decomposition analysis required that both data sets are aggregated to the same level, this constrains the level of detail possible. The sub-sectors on which the decomposition analysis is based, along with the corresponding SIC codes, are as follows:

¹⁵ A value of 0.5 full-time equivalent is ascribed to all part-time employees.

Sub-sector description	SIC codes included
Wholesale trade	61xxx
Retail trade; repairs of household goods	62xxx
Motor trade; repair of motor vehicles	63xxx
Hotels and restaurants	64xxx
Communication	74xxx, 75xxx
Finance and insurance	81xxx, 82xxx, 83xxx
Real estate	84xxx
Business services	85xxx, 86xxx, 87xxx, 88xxx
General government services	91xxx, 92xxx, 93xxx, 94xxx
Personal services	95xxx, 96xxx, 99xxx

Using the data sources described above, a standard decomposition analysis was conducted covering the period 2003-13. These results are shown in Table 8 below, while Figure 15 shows the cumulative improvement in electricity efficiency relative to a projected baseline from 2003, expressed in terms of the fractional change in total electricity consumption that can be attributed to efficiency changes.

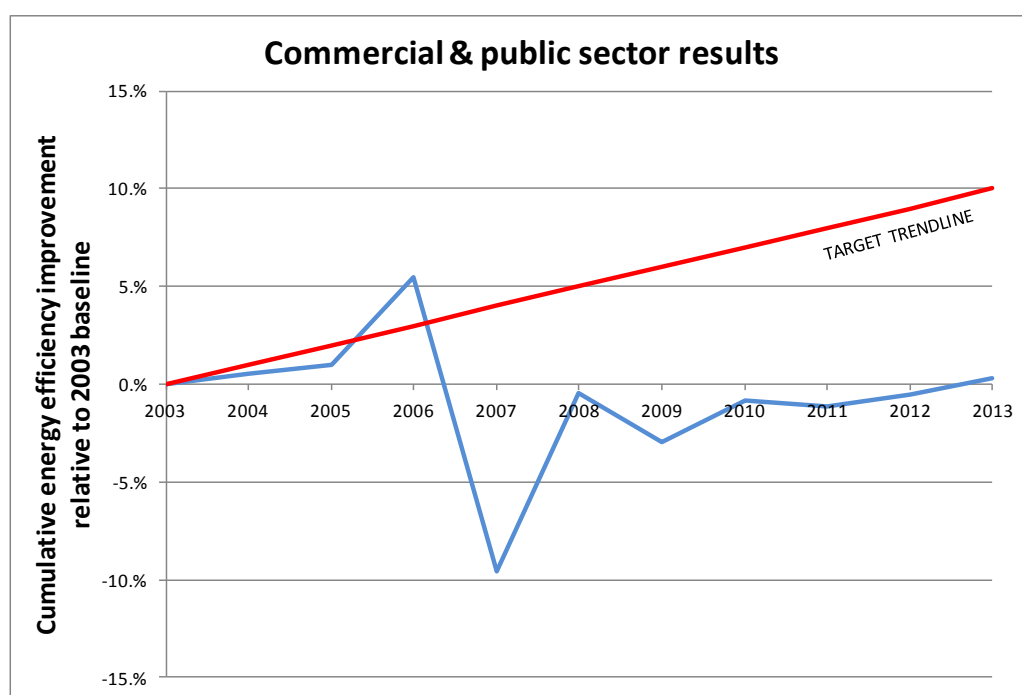


Figure 15 Cumulative change in electricity consumption attributable to energy efficiency changes, expressed as a percentage of the total sectoral electricity consumption in the projected 2000 baseline

Table 8 Results of decomposition analysis of changes in commercial & public sector electricity consumption, 2003-2013

YEAR-ON-YEAR CHANGES										
	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
CHANGE IN FINAL ELECTRICITY CONSUMPTION (GWh)	138.57	228.46	10.96	1064.22	-303.37	236.44	76.31	178.27	134.34	75.21
ACTIVITY LEVEL EFFECT	197.44	256.24	306.44	312.47	249.68	60.45	141.07	228.80	191.34	159.72
STRUCTURAL EFFECT	-35.02	-3.77	-68.43	-34.36	-68.45	36.35	53.36	-69.32	-23.72	-30.70
EFFICIENCY EFFECT	-23.85	-24.01	-227.06	786.10	-484.61	139.65	-118.12	18.79	-33.28	-53.80
% CHANGE IN ELECTRICITY CONSUMPTION DUE TO EFFICIENCY CHANGES	-0.52%	-0.50%	-4.55%	15.58%	-8.06%	2.48%	-1.98%	0.31%	-0.54%	-0.86%

CUMULATIVE CHANGES (2003 base year)										
	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
CHANGE IN FINAL ELECTRICITY CONSUMPTION (GWh)	138.57	367.03	377.99	1442.21	1138.831	1375.28	1451.58	1629.85	1764.19	1839.40
ACTIVITY LEVEL EFFECT	197.44	453.69	760.13	1072.60	1322.28	1382.73	1523.80	1752.59	1943.93	2103.65
STRUCTURAL EFFECT	-35.02	-38.79	-107.22	-141.57	-210.03	-173.68	-120.32	-189.64	-213.36	-244.06
EFFICIENCY EFFECT	-23.85	-47.86	-274.92	511.18	26.58	166.23	48.11	66.90	33.62	-20.18
% CHANGE IN ELECTRICITY CONSUMPTION DUE TO EFFICIENCY CHANGES	-0.52%	-1.00%	-5.45%	9.61%	0.48%	2.97%	0.83%	1.12%	0.55%	-0.32%

The analysis results show that, between 2003 and 2013, energy efficiency remained almost unchanged overall, with sharp fluctuations in 2006 and 2007 (which may be attributable to artefacts in the data). Over the ten-year period, if other factors had remained constant, reductions in efficiency would have led to a 20 GWh decrease in electricity consumption, which is 0.32% of the projected baseline figure. Figure 15 illustrates this increase in efficiency relative to the increasing trend required to achieve the sectoral target as set out in the Energy Efficiency Strategy (indicated by the red line).

Figure 16 provides a graphical representation of the full decomposition results for 2013 relative to the 2003 baseline. Total electricity consumption in the commercial & public sector in 2013 had increased by 1,839 GWh relative to 2003. This change is composed of the sum of:

- a 2,104 GWh increase due to greater levels of activity;
- a 244 GWh decrease due to structural changes;
- a 20 GWh decrease due to efficiency reductions.

The effect of efficiency changes alone is illustrated in Figure 17, where the green curve (“With efficiency changes”) is the actual observed change in the total electricity consumption of the sector from 2003-2013, while the red curve (“Without efficiency changes”) is the trend in total electricity consumption that would have been observed if the efficiency components revealed by the decomposition analysis had been absent. The green shaded areas indicate periods when efficiency had improved relative to the baseline, while red shaded areas are periods when efficiency was worse than the baseline.

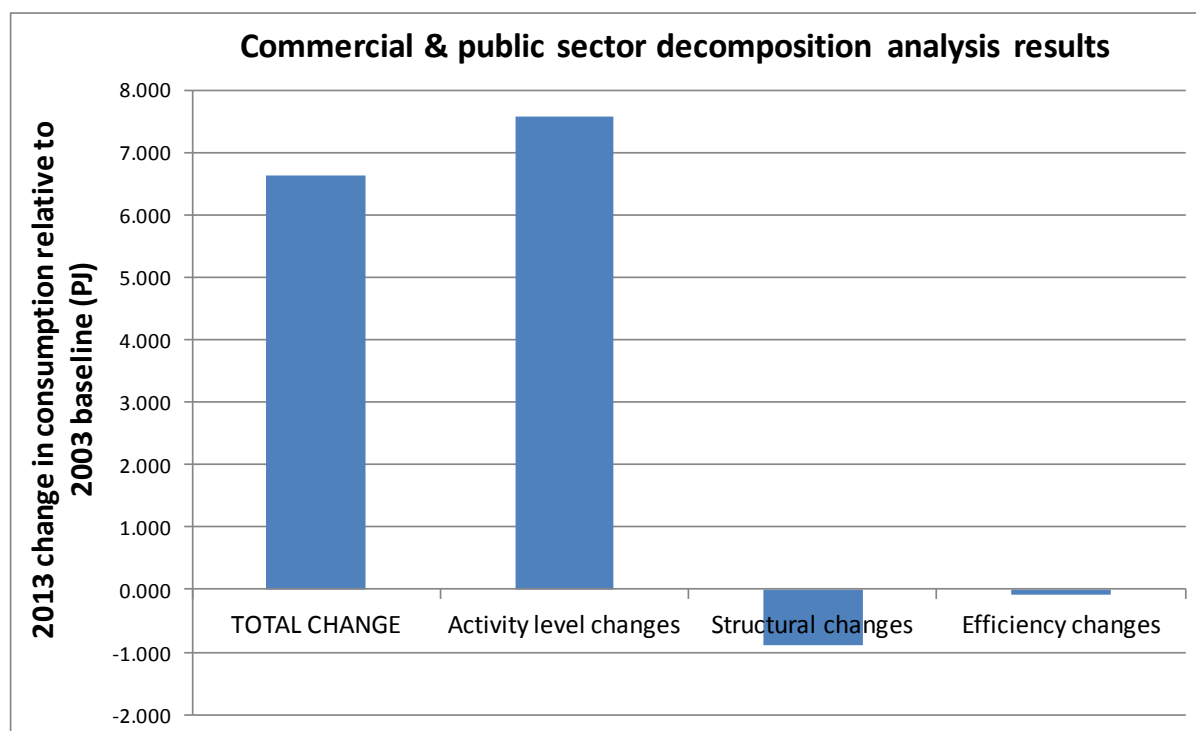


Figure 16 Cumulative change in electricity consumption between 2003-2013 decomposed into three main components

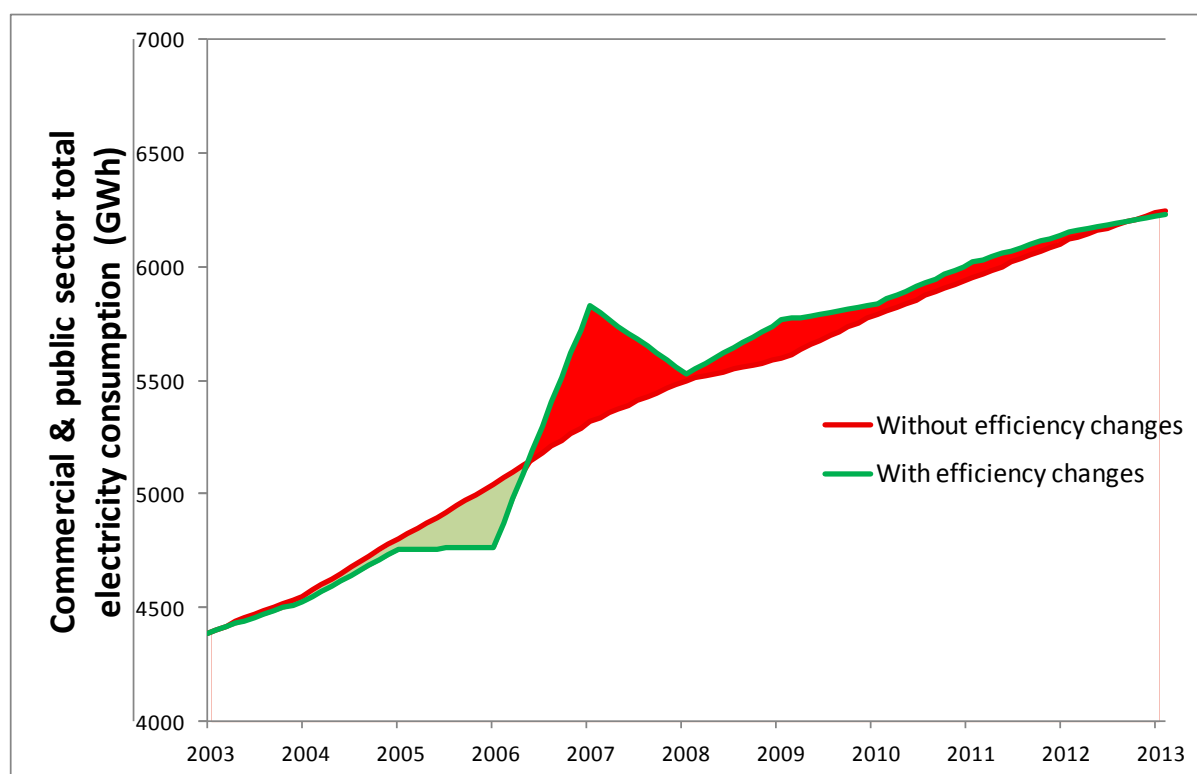


Figure 17 Comparison of actual observed trends in energy consumption of the commercial & public sector (green trace) versus trends that would have occurred with no efficiency change (red trace).

The results of this analysis indicate that, with the exception of 2006-08, the electricity efficiency in South Africa's commercial & public sector has changed relatively little over the period of analysis. In 2006 and again in 2008, there were apparent improvements in electricity efficiency, which were more than offset by a steep decline in 2007. Cumulative changes over the whole period mean that electricity consumption in 2013 was only 0.32% lower than it would have been if efficiency had not changed.

It is worth reiterating here that the changes in consumption that are to efficiency in a decomposition analysis actually encompass all those changes that cannot be attributed to activity level or structural changes. More than in any other sector, office-based activities play a very significant role in the commercial & public sector, and for at least the last two decades the office environment has seen increasing levels of what is often referred to a 'auxiliary equipment'. This consists of energy consuming IT equipment (desktop and laptop computers, servers, printers, photocopiers, networking hardware etc.) as well as air conditioners. Increased use of this auxiliary equipment will lead to significant increases in energy intensity that are not connected with falls in efficiency, regardless of which indicator is used to quantify activity levels.

It is therefore likely that the apparently almost unchanged electricity efficiency from 2003-13 is actually the result of an increase in actual efficiency offset by greater consumption due to increased use of auxiliary equipment. Unfortunately, it is likely to prove practically impossible to conduct a

retrospective analysis of this trend, as consistent and reliable historical data on penetration levels of this equipment does not exist.

ANALYSIS OF BUILDING-LEVEL DATA

A very simple bottom-up analysis of energy intensity trends in commercial buildings was undertaken using building-level data provided by Investment Property Databank South Africa (IPD)¹⁶. Data on electricity consumption and gross lettable floor area was available for the years 2012 and 2013 for a sample of commercial buildings in the retail, office and light industrial sub-sectors across four provinces. Data for 344 buildings with a total gross lettable area (GLA) of 5.75 million m² was available for 2012, while for 2013 the number of buildings for which data was available had expanded to 461, with a total GLA of 7.88 million m².

The data provided is summarised in Table 9 under. The overall specific energy consumption of the sample increased slightly from 256.2 kWh/m² in 2012 to 259.7 kWh/m² in 2013. However, the composition of the sample also changed, with the 461 buildings in 2013 including a relatively larger fraction of office buildings and a smaller fraction of retail and industrial buildings. Given that these building types each has a different characteristic specific energy consumption, changes in the composition of the building sample may be expected to affect the overall specific energy consumption.

Table 9 Building-level data provided by IPD

Segment:	GLA (m ²)		Specific energy consumption (annual kWh/m ²)	
	2012	2013	2012	2013
Retail	3,098,557	4,001,648	366.3	372.1
Office	784,535	1,624,634	220.4	225.8
Industrial	1,774,128	2,142,616	95	85.6
Other	97,431	110,613	112.7	n/a
TOTAL	5,754,651	7,879,511	256.2	259.7

Such structural effects can be revealed through a simple decomposition analysis, the results of which are shown in Table 10 under¹⁷. Total annual electricity consumption for the sample of buildings increased by 563 GWh between 2012 and 2013, almost all of which was accounted for by the fact that the sample included a significantly larger GLA (activity level effect). Changes in the composition of the sample (structural change) accounted for 3.2 GWh of the total increase, while an overall decline in efficiency accounted for the remaining 8.4 GWh increase in total energy consumption. This represents a year-on-year increase in specific energy consumption of about 0.4%.

¹⁶ This data represents a pilot phase of IPD's Green Property Indicators initiative. As the initiative is rolled out, the number of properties covered is expected to increase hugely.

¹⁷ Because the specific energy composition of buildings in the 'Other' category was not available for 2013, this category was omitted from the analysis. This category accounted for 15 buildings in 2012 and 7 buildings in 2013.

Table 10 Results of decomposition analysis of changes in electricity consumption between 2012 and 2013

Change In total electricity consumption	562.81 GWh
Activity level component	551.20 GWh
Structural component	3.21 GWh
Efficiency component	8.40 GWh

CONCLUSIONS

More than any other sector, the commercial & public sector presents challenges in tracking energy efficiency trends because of the dearth of data on activity levels and the unreliability of data on the consumption of energy carriers other than electricity. Ideally, activity in this sector would be characterised by indicators relating to building floor area and the level of use of energy-intensive office equipment (computers, servers, printers, photocopiers) and other building services (HVAC and water heating). In the absence of such data, the conducted here used GVA as a proxy for activity level, and was based on electricity consumption only. The results obtained should therefore be treated with great caution.

Over the 2003-13 period, the NEES target implies a 10% cumulative improvement in energy efficiency for this sector. The decomposition analysis indicates that electricity efficiency remained largely unchanged over this period. Although no definitive data is available, the level of building services and the penetration rates of energy-intensive office equipment are likely to have increased over this period. If this is the case, then the apparently unchanged electricity efficiency may in fact be the result of a combination of improvements in efficiency and increased levels of energy service. However, given the data available it must be concluded that this sector is not on track to reach its NEES target.

The priority for the commercial & public sector should be to improve the quality and quantity of data on all aspects of energy consumption and activity levels, to allow energy efficiency trends to be tracked moving forward. The prospects are promising for improvements in the availability of data on the building stock in the near future. The Department of Public Works are in the process of preparing an asset register that will provide essential information on their buildings¹⁸, while current initiatives to implement smart metering in public buildings will result in a steady improvement in the availability of data on energy use patterns. In the commercial sector, IPD are expected to roll out their Green Property Indicators initiative in the next few years, which will provide data on energy and water consumption for a significant fraction of the whole stock of commercial properties in South Africa.

A combination of these emerging data sources with the use of targeted surveys to collect data on the penetration rates of auxiliary equipment in offices will allow a more accurate picture of true efficiency trends to be developed in the future.

¹⁸ However, this asset register is not expected to include leased buildings.

RESIDENTIAL SECTOR

INTRODUCTION

The National Energy Efficiency Strategy (NEES) sets a target for the residential sector of a 10% improvement in energy efficiency by 2015 relative to a baseline projected from 2000. Measuring changes in energy efficiency at the sector level is a complex process with no single universally applicable approach. As with other sectors, it can be assumed that the target of a 10% improvement in energy efficiency implies a 10% reduction in the amount of energy required for a given level of activity, and as in other sectors defining activity levels in the residential sector is challenging.

For the purposes of this analysis, the basic unit of account for the residential sector is taken to be the household. The relevant level of activity for the residential sector is therefore the total number of households in the country, but simply tracking changes in energy intensity (i.e. the annual total energy consumption per household) would not provide an accurate picture of changes in energy efficiency. In fact, energy intensity in the residential sector is determined by a wide range of factors, not all of which are necessarily connected with efficiency. These include:

- Household size: all else being equal, a household with more members will consume more energy than one with fewer members. A household with more members is likely to be physically bigger and hence have greater space heating requirements, and it is also likely to own a larger refrigerator and use appliances such as washing machines more frequently. However, the relationship between household size and energy consumption per household is very unlikely to be proportional¹⁹ – for example, cooking a meal for four people is unlikely to require twice as much energy as cooking a meal for two.
- Behavioural and lifestyle factors: the employment / education status of household members will affect whether the dwelling is occupied during the day, which is likely to affect its energy consumption. Other lifestyle-related factors include the consumption of hot water for bathing, and the number and complexity of cooked meals typically prepared. The propensity of household members to switch off unused appliances and lighting is also a significant factor.
- Changes in living standards: many households in South Africa are undergoing a rapid improvement in living standards, which is associated with the acquisition for the first time of a wide range of energy-using household appliances.
- Technological factors: the energy performance of the dwelling (thermal efficiency, use of natural lighting) and the technical efficiency of the appliances it contains are the factors most often implied when discussing energy efficiency.

In common with the other sectors of the economy, the main analysis conducted on the residential sector uses a process known as decomposition to separate out the main factors affecting energy consumption. Accounting for the effect of changes in the total number of households is relatively

¹⁹ If it was proportional, the solution would simply be to use the individual person as the basic unit of account, rather than the household (i.e. define energy intensity as annual energy consumption per person)

straightforward, but separating out the effects of the four sets of factors described above is more difficult. In fact, given the current constraints on data availability, the only other factor that it is feasible to analyse is changes in living standard, which is conveniently quantifiable using the 'Living Standards Measure' (LSM) stratification pioneered by SAARF²⁰. All the other factors (technological, behavioural, lifestyle and household size) are implicitly interpreted in the analysis described here as being facets of changing energy efficiency.

DATA SOURCES AND ISSUES

The sources of data on total energy consumption for the residential sector are the Energy Balance Tables produced annually by the Department of Energy. There are known to be some issues with regard to the figures for household coal consumption in these tables, so revised versions of the aggregated energy balance tables were used in this analysis, in which coal consumption was estimated using a simple model²¹. Energy Balances data is itself only available at present for years up to 2012 and, since the analysis requires data on sector-level total energy consumption, it has only been possible to conduct an analysis for the period 2000-12.

Data on the total number of households is available from a number of different sources, but there are frequently discrepancies between these. The most complete and reliable source of data appears to be that provided by the General Household Survey (GHS) conducted annually by Statistics South Africa (StatsSA). Data from this source is available only as far back as 2002, so figures for 2000-01 were extrapolated from the available data, based on a best-fit cubic polynomial.

For the years from 2004 onwards, data on the distribution of households by LSM was obtained from Eighty20, a consulting company that manages and disseminates much of the value-added data resulting from surveys conducted by SAARF. However, the total number of households implied by this data set differs from the figures provided by StatsSA's GHS. This discrepancy was addressed by using only the *fractions* of households by LSM from the Eighty20 data, and applying these fractions to the GHS data to obtain the total numbers of households in each LSM. Data for the years before 2004 was imputed, based on: (i) data on the number of individuals by LSM obtained from SAARF; (ii) estimates of average household size during that period, derived by extrapolating back from known figures for 2004 onwards.

Estimates of energy intensity by LSM were based on the results obtained from household energy survey conducted in April 2015 (see 'Household energy survey' below). The survey results provide snapshots of energy intensity by LSM for the present day only, so figures for energy intensity versus LSM for the years extending back to 2000 were imputed using a process described in the section Methodological overview under.

²⁰ South African Audience Research Foundation

²¹ This used data from the GHS on the fraction of households that use coal for cooking and space heating, along with data from StatsSA's Income and Expenditure Surveys on expenditure on solid fuels.

HOUSEHOLD ENERGY SURVEYS

A total of three household energy surveys have been conducted during the period that the EETMS has been under development. The first of these was conducted during January to March 2013 under the pilot phase of EETMS development, in which 1,720 responses were obtained across eight municipalities²². A similar survey was conducted in May 2014, but because of resource constraints, the sample size and geographical scope of the 2014 survey was more restricted than for the 2013 survey, with responses from a total of 968 households across four different municipalities²³. The most recent and largest survey was conducted during April 2015, covering 20 municipalities²⁴ with 3,386 respondents.

The same survey questionnaire was used for all three surveys, with enumerators using hand-held electronic devices to record responses, which were automatically uploaded to a central database. The questionnaire included the following categories of question:

- A set of questions for determining which LSM band the respondent household falls into. These questions are adopted from those published by SAARF for the same purpose. Note however that the questions relating to appliance ownership were modified to determine not only ownership but also the estimated age of the appliance in question
- Questions to determine which energy sources are used for the major household applications of cooking, water heating, space heating and lighting. Respondents were asked to indicate not only their main energy source but also, where applicable, any secondary sources used.
- Quantitative estimates of consumption of different energy carriers. Respondents answered either in terms of expenditure or in physical units – in the former case, the estimates were converted into physical consumption estimates during the post-survey data processing using data on energy prices. In some cases, data on actual consumption of electricity for the respondent household was available from the respective municipality.
- A group of questions designed to determine the driving forces behind changes in energy efficiency. These included questions on ownership and awareness of energy saving technologies, and on the extent of energy saving behaviour. Note that relevant data on ownership and age of household appliances was generated from responses to the LSM questions described above.

The full survey questionnaire is provided in Annex B.

SECTOR-WIDE TRENDS

Over the period covered by the analysis described here, the total number of households in South Africa increased from 10.3 million in 2000 to 14.6 million in 2012. This represents an increase of almost 42%, equivalent to a compounded annual increase of about 3%. Over the same period, the

²² Buffalo City, City of Johannesburg, Emalahleni, King Sabata Dalindyebo, Mbombela, Polokwane, Rustenburg and Umhlathuze.

²³ Beaufort West, Ephraim Mogale, Mantsopa and Randfontein.

²⁴ Alfred Nzo District, Beaufort West, Capricorn District, Ekurhuleni, Henry Gwala District, Kannaland, Khara Hais, King Sabata Dalindyebo, Lephalele, Mafikeng, Mantsopa, Matjhabeng, Mogale City, Moqhaka, Mossel Bay, Nelson Mandela Bay, Newcastle, Randfontein, Swartland and Thulamela.

total energy consumption of the residential sector is estimated to have increased by about 20%, from 173 PJ in 2000 up to 207 PJ in 2012²⁵. The energy intensity of the residential sector over this period therefore fell from 16.8 GJ per household in 2000 to 14.2 GJ per household in 2012.

The same twelve year period has seen a major change in the living standards of South African households. In 2000, almost 11% of households fell into the LSM 1 stratum, which is characterised by an almost complete absence of household amenities and appliances. By 2012, this fraction had fallen to only about 2%, with the fraction of households in LSMs 2 & 3 also falling steeply. Meanwhile, the middle and upper range of LSMs grew significantly, with LSMs 6 and 7 together accounting for almost one-third of all households in 2012.

For the purposes of this analysis, individual LSM strata have been grouped into four bands: low (LSMs 1 – 3); lower-middle (LSMs 4 & 5); upper-middle (LSMs 6 & 7); and high (LSMs 8 – 10). The reason for this grouping is to avoid a situation in the household energy survey where the number of respondents in a single LSM is excessively small. Figure 18 below provides a graphical representation of changes in the distribution of households by LSM band between 2000 and 2012. This illustrates the huge fall in the fraction of households in the lowest three LSMs and the rapid growth in the ‘upper-middle’ band.

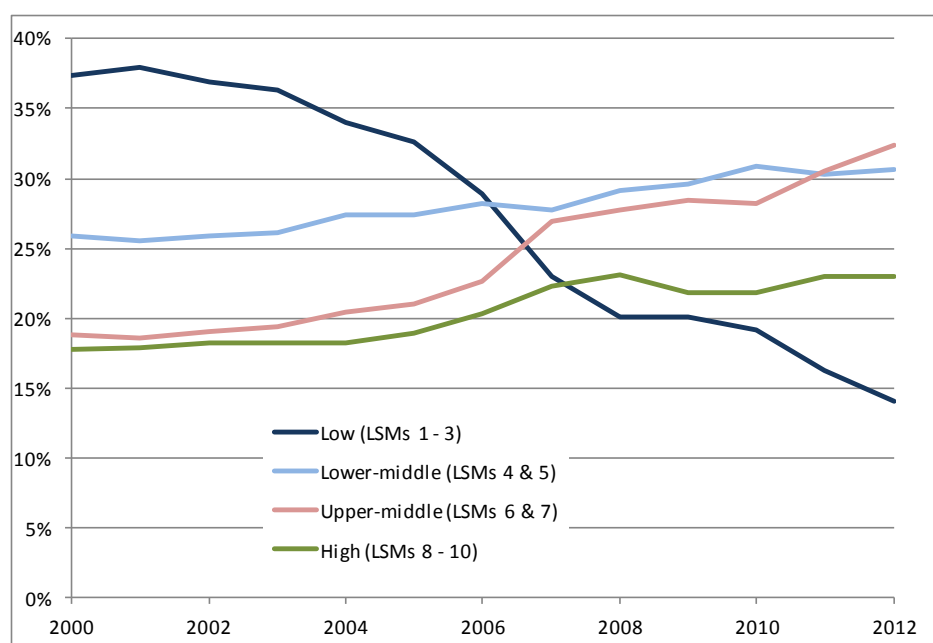


Figure 18 Distribution of households by LSM band, 2000-2012

ENERGY CONSUMPTION PATTERNS

The following sub-sections describe the patterns of energy consumption among South African households. The results presented here are derived from the 2015 household energy survey described above. The 2015 survey was broader in both size and geographical scope than either of

²⁵ Note that these figures differ from those reported in the Energy Balance Tables because (i) figures for coal consumption have been adjusted to address some identified anomalies; and (ii) figures of consumption of biomass fuels have been omitted.

the two previous surveys, and also used a more rigorous sampling protocol. The results from this survey are considered to be much more representative of the whole population than those from the 2013 and 2014 surveys, hence it would be misleading to compare the results of the three surveys alongside each other. For this reason, this current section is based only on the results from the 2015 survey.

The following sub-sections describe the results from the section of the survey where respondents were asked about the energy source used for each main energy-consuming activity in the home (cooking, water heating, space heating and lighting). The survey was designed to allow the LSM of each respondent household to be determined, so the results are disaggregated by LSM²⁶.

Cooking

Figure 19 and Table 11 below show the results of responses to the survey question on which energy source is the main one used for cooking in the respondent household. The results indicate that mains electricity dominates, being the primary cooking energy source for 82% of households overall and almost 90% of households in LSM 5 and above. Wood is the most widely used cooking fuel in LSMs 1 & 2, while LPG begins to play a significant role in the upper LSMs, being used as the main cooking fuel in 12% of LSM 10 households.

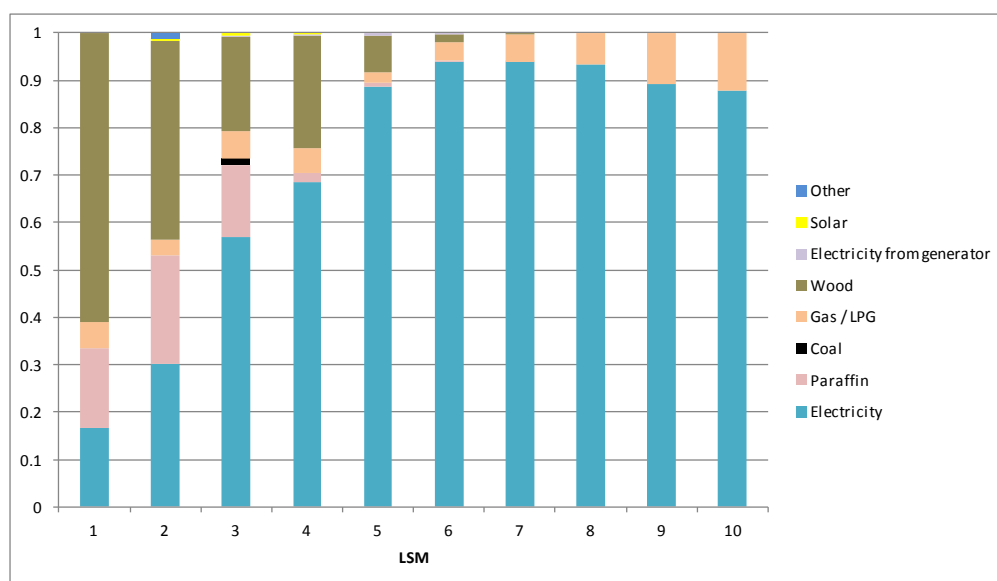


Figure 19 Fraction of households in each LSM using energy source as main cooking fuel

Table 11 Main energy source used for cooking (fraction of households by LSM)

ENERGY SOURCE	LSM										Overall
	1	2	3	4	5	6	7	8	9	10	
Electricity	0.167	0.301	0.568	0.685	0.887	0.939	0.938	0.933	0.893	0.879	0.818

²⁶ Note that only 18 respondent households fell into LSM 1, so the results for this LSM must be treated with caution.

Paraffin	0.167	0.230	0.154	0.019	0.007	0.001	0.002	0.000	0.000	0.000	0.033
Coal	0.000	0.000	0.012	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001
Gas / LPG	0.056	0.033	0.059	0.053	0.022	0.040	0.057	0.067	0.107	0.121	0.052
Wood	0.611	0.421	0.198	0.238	0.077	0.016	0.002	0.000	0.000	0.000	0.092
Elec. from generator	0.000	0.000	0.003	0.002	0.007	0.003	0.000	0.000	0.000	0.000	0.003
Solar	0.000	0.005	0.006	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.001
Other	0.000	0.011	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001

Note: totals may not sum to 1.00 because of rounding errors

The survey respondents were also asked to indicate which energy source was their secondary choice for cooking. These results are displayed in Figure 20 and Table 12 below. Across all households, 33% do not use any secondary energy source (i.e. they always use the main energy source only), a figure which rises to 61% in LSM 1. For those households where a secondary energy source is used, wood and paraffin are the most significant among lower LSMs, while LPG dominates in the higher LSMs. Wood also figures significantly as a secondary cooking fuel among the highest LSMs, but this is presumably a matter of lifestyle choice. Conversely, the 14% of LSM 10 households that report using electricity from a generator as their secondary energy source for cooking presumably do so out of necessity.

The household energy survey also asked respondents about any tertiary energy sources used for cooking. However, the number of households indicating that they use a tertiary energy source was too small to draw any useful conclusions.

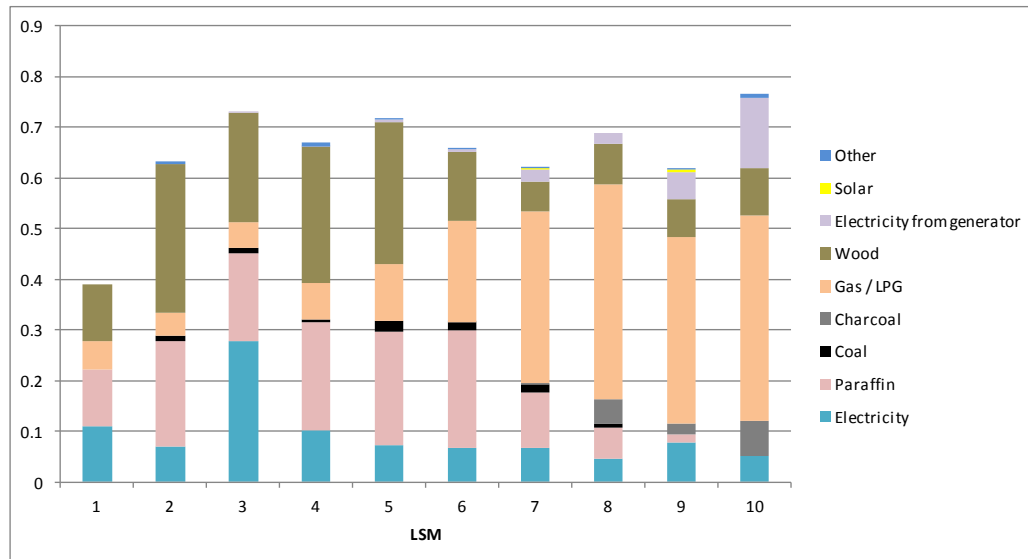


Figure 20 Fraction of households in each LSM using energy source as secondary cooking fuel

Table 12 Secondary energy source used for cooking (fraction of households by LSM)

ENERGY SOURCE	LSM										Overall
	1	2	3	4	5	6	7	8	9	10	
Electricity	0.111	0.071	0.278	0.101	0.073	0.069	0.067	0.046	0.079	0.052	0.093

Paraffin	0.111	0.208	0.175	0.214	0.224	0.230	0.110	0.063	0.017	0.000	0.170
Coal	0.000	0.011	0.009	0.007	0.020	0.016	0.015	0.008	0.000	0.000	0.012
Charcoal	0.000	0.000	0.000	0.000	0.000	0.001	0.002	0.046	0.021	0.069	0.008
Gas / LPG	0.056	0.044	0.050	0.070	0.113	0.199	0.339	0.425	0.368	0.405	0.197
Wood	0.111	0.295	0.216	0.269	0.281	0.137	0.060	0.079	0.074	0.095	0.174
Elec. from generator	0.000	0.000	0.003	0.002	0.004	0.006	0.022	0.021	0.054	0.138	0.015
Solar	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.000	0.004	0.000	0.001
Other	0.000	0.005	0.000	0.007	0.002	0.001	0.002	0.000	0.004	0.009	0.003

Water heating

It is common among low-income households for water to be heated using the main cooking appliance, rather than in a dedicated water-heating appliance. This is borne out by the responses to the survey question on the main energy source used for water heating. The results are shown in Figure 21 and Table 13 below, where it can be seen that the mix of energy sources among the lower LSMs very closely mirrors that seen for cooking. LSMs from 5 upwards are very strongly dependent on electricity for water heating, with solar energy playing a very small role²⁷.

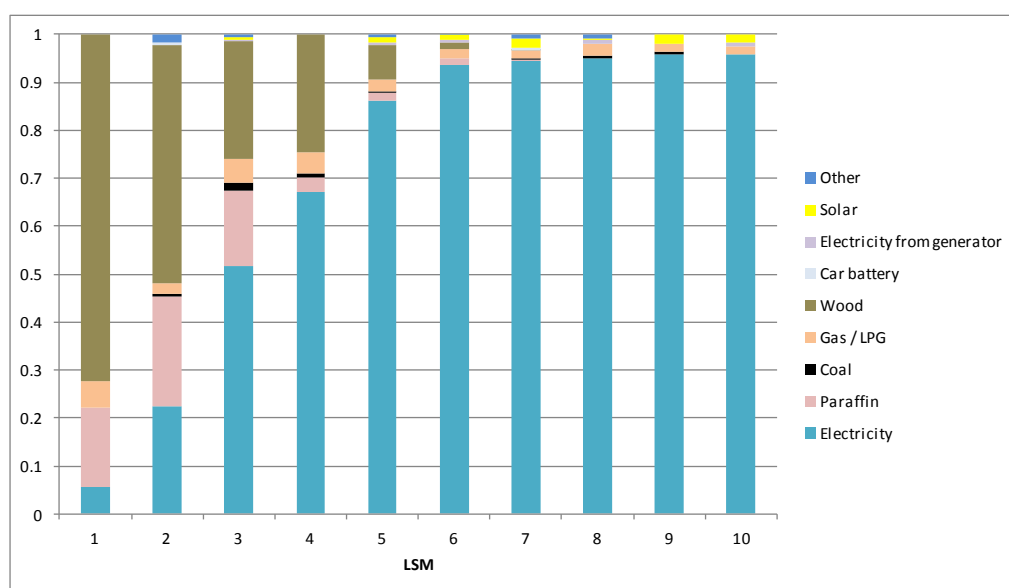


Figure 21 Fraction of households in each LSM using energy source as main fuel for water heating

Table 13 Main energy source used for water heating (fraction of households by LSM)

ENERGY SOURCE	LSM										Overall
	1	2	3	4	5	6	7	8	9	10	
Electricity	0.056	0.224	0.518	0.671	0.860	0.935	0.945	0.950	0.959	0.957	0.810

²⁷ It is notable that the fraction of households citing solar as their main energy source for water heating is considerably lower than the fraction that report owning a solar geyser (see “Driving forces” section below). This suggests that the solar geyser does not provide all of the hot water needs in those households.

Paraffin	0.167	0.230	0.157	0.031	0.018	0.014	0.002	0.000	0.000	0.000	0.040
Coal	0.000	0.005	0.015	0.007	0.004	0.000	0.002	0.004	0.004	0.000	0.004
Gas / LPG	0.056	0.022	0.050	0.046	0.023	0.022	0.015	0.025	0.017	0.017	0.027
Wood	0.722	0.497	0.246	0.245	0.072	0.013	0.002	0.000	0.000	0.000	0.101
Car battery	0.000	0.005	0.000	0.000	0.000	0.000	0.005	0.000	0.000	0.000	0.001
Elec. from generator	0.000	0.000	0.003	0.000	0.005	0.005	0.000	0.008	0.000	0.009	0.003
Solar	0.000	0.000	0.006	0.000	0.011	0.011	0.020	0.004	0.021	0.017	0.010
Other	0.000	0.016	0.006	0.000	0.007	0.001	0.007	0.008	0.000	0.000	0.004

Figure 22 and Table 14 below show the responses to the survey question on the secondary energy source used for water heating. Almost half of households surveyed reported that they do not use any secondary energy source for water heating. In general, the results closely mirror those obtained from the question on secondary energy source for cooking.

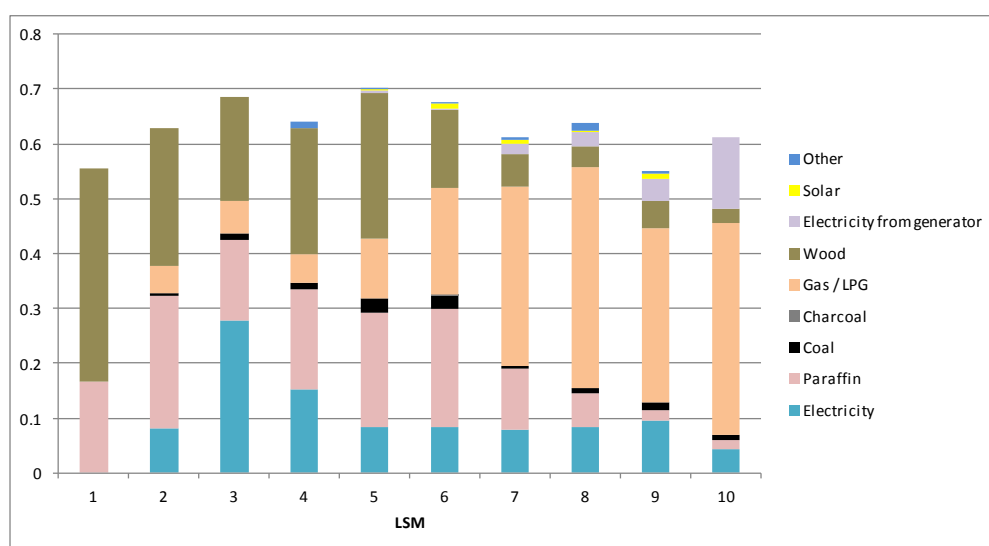


Figure 22 Fraction of households in each LSM using energy source as secondary fuel for water heating

Table 14 Secondary energy source used for water heating (fraction of households by LSM)

ENERGY SOURCE	LSM										Overall
	1	2	3	4	5	6	7	8	9	10	
Electricity	0.000	0.082	0.278	0.151	0.084	0.085	0.080	0.083	0.095	0.043	0.110
Paraffin	0.167	0.240	0.148	0.183	0.208	0.215	0.110	0.063	0.021	0.017	0.160
Coal	0.000	0.005	0.012	0.012	0.027	0.023	0.005	0.008	0.012	0.009	0.016
Charcoal	0.000	0.000	0.000	0.000	0.000	0.002	0.000	0.000	0.000	0.000	0.001
Gas / LPG	0.000	0.049	0.059	0.053	0.109	0.196	0.327	0.404	0.318	0.388	0.187
Wood	0.389	0.251	0.189	0.231	0.263	0.141	0.060	0.038	0.050	0.026	0.157
Elec. from generator	0.000	0.000	0.000	0.000	0.005	0.003	0.020	0.025	0.041	0.129	0.013
Solar	0.000	0.000	0.000	0.000	0.004	0.008	0.007	0.004	0.008	0.000	0.004
Other	0.000	0.000	0.000	0.012	0.002	0.005	0.005	0.013	0.004	0.000	0.005

Space heating

The responses given to the survey question on the main energy source used for space heating are summarised in Figure 23 and Table 15 below. Overall, 65% of the households surveyed have any space heating. Electricity dominates in LSMs 8-10, with LPG also significant, while wood is by far the most widely used space heating fuel in the lower LSMs. Paraffin is significant in the middle LSMs, being used as the main space heating fuel by as many as 18% of households in LSM 5.

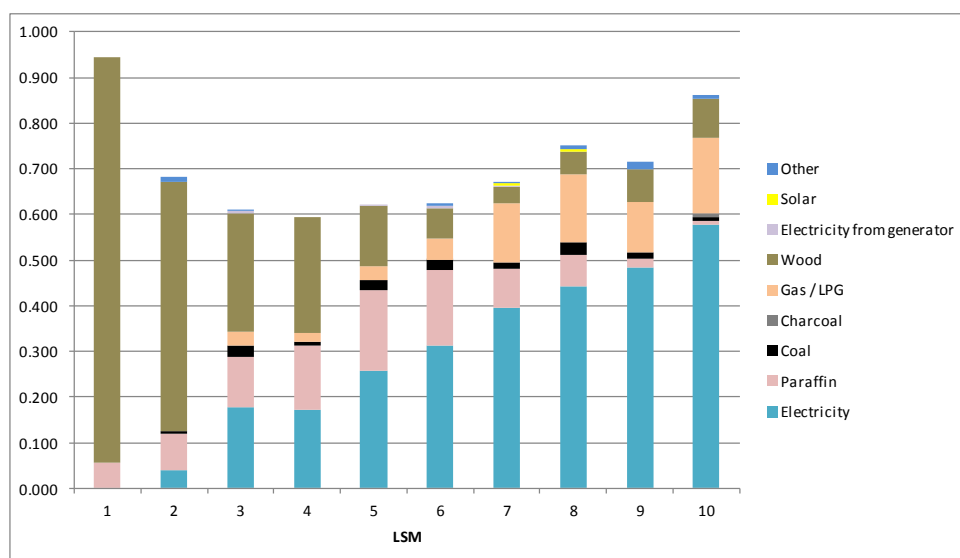


Figure 23 Fraction of households in each LSM using energy source for space heating

Table 15 Main energy source used for space heating (fraction of households by LSM)

ENERGY SOURCE	LSM										Overall
	1	2	3	4	5	6	7	8	9	10	
Electricity	0.000	0.038	0.178	0.171	0.258	0.312	0.397	0.442	0.483	0.578	0.297
Paraffin	0.056	0.082	0.109	0.142	0.176	0.166	0.085	0.071	0.021	0.009	0.122
Coal	0.000	0.005	0.027	0.010	0.022	0.021	0.012	0.025	0.012	0.009	0.017
Charcoal	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.009	0.001
Gas / LPG	0.000	0.000	0.030	0.019	0.030	0.046	0.130	0.150	0.112	0.164	0.062
Wood	0.889	0.546	0.260	0.252	0.133	0.068	0.037	0.050	0.070	0.086	0.146
Elec. from generator	0.000	0.000	0.003	0.000	0.004	0.005	0.002	0.000	0.000	0.000	0.002
Solar	0.000	0.000	0.000	0.000	0.000	0.000	0.005	0.004	0.000	0.000	0.001
Other	0.000	0.011	0.003	0.000	0.000	0.007	0.002	0.008	0.017	0.009	0.005

Lighting

As shown in Figure 24 and Table 16 below, less than 10% of all surveyed households use a main energy source other than electricity for lighting. These are predominantly households that rely on candles, falling mostly in LSMs 1 – 3. For LSMs 5 and above, electricity is almost universally used as

the main energy source for lighting. Paraffin lighting is used by a small number of households in LSMs 1 – 3, while solar lanterns are the main source of lighting for 3-5% of households in LSMs 2 – 4.

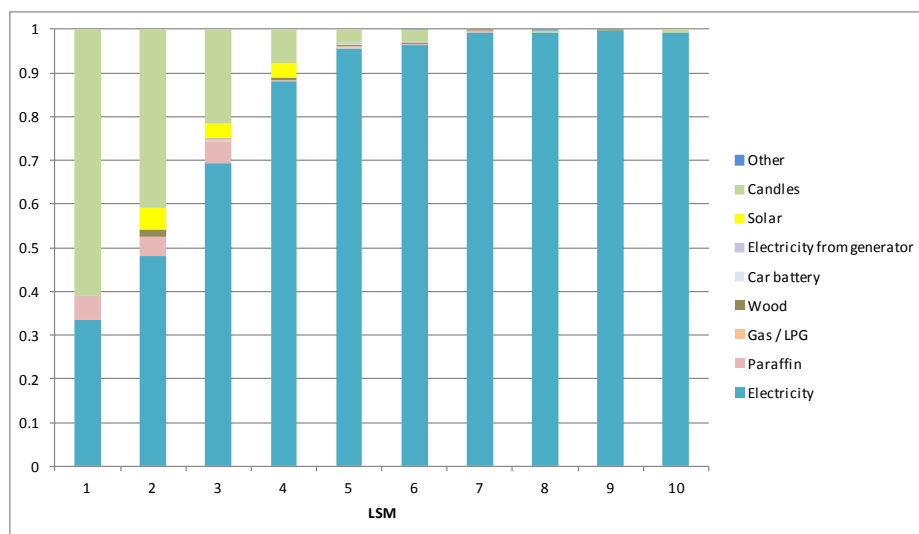


Figure 24 Fraction of households in each LSM using energy source for lighting

Table 16 Main energy source used for lighting (fraction of households by LSM)

ENERGY SOURCE	LSM										Overall
	1	2	3	4	5	6	7	8	9	10	
Electricity	0.333	0.481	0.692	0.880	0.955	0.965	0.993	0.992	0.996	0.991	0.904
Paraffin	0.056	0.044	0.050	0.005	0.004	0.001	0.005	0.000	0.000	0.000	0.010
Gas / LPG	0.000	0.000	0.003	0.000	0.002	0.001	0.000	0.000	0.000	0.000	0.001
Wood	0.000	0.016	0.000	0.005	0.002	0.001	0.002	0.000	0.004	0.000	0.003
Car battery	0.000	0.000	0.000	0.000	0.004	0.000	0.000	0.000	0.000	0.000	0.001
Elec. from generator	0.000	0.000	0.006	0.000	0.004	0.003	0.000	0.000	0.000	0.000	0.002
Solar	0.000	0.049	0.033	0.034	0.000	0.000	0.000	0.000	0.000	0.000	0.010
Candles	0.611	0.410	0.216	0.077	0.030	0.027	0.000	0.004	0.000	0.009	0.069
Other	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.004	0.000	0.000	0.001

DECOMPOSITION ANALYSIS

Methodological overview

A detailed description of the decomposition analysis approach is provided in Annex A. In its most common form, decomposition analysis breaks down changes in energy consumption into factors attributable to activity level changes, structural changes and changes in efficiency. For the economically productive sectors, structural changes are shifts in the relative size of the different sub-sectors measured in terms of GDP. In the residential sector, this definition of structural change is not applicable, but an analogous concept can instead be applied.

It is clear that increasing living standards are hugely important in determining energy consumption in the residential sector, and the SAARF LSM stratification provides a convenient and widely recognised means of quantifying these trends. By treating each LSM band as a 'sub-sector' of the residential sector, it is possible to conduct a decomposition analysis where changing living standards become exactly analogous to structural changes. Under this treatment, a growth in the size of the higher (and more energy intensive) LSMs relative to the lower LSMs in the residential sector is equivalent to a growth in iron & steel making relative to financial services in the economy as a whole. Both changes result in increased energy consumption even though efficiency itself may not have changed, hence both changes need to be identified and quantified in order to estimate the extent of efficiency changes.

As with the other sectors, conducting a decomposition analysis requires data on changes in the relative size of the different sub-sectors, as well as data on the characteristic energy intensity of each sub-sector. The first set of data is available from SAARF, and has been discussed above. However, in order to conduct an analysis dating back to 2000, estimates must be made of the historical relationship between energy intensity and LSM. The nature of this relationship was estimated using household survey data.

Survey respondents were asked to estimate (either in physical units or in terms of expenditure) their consumption over the previous month of a range of non-biomass energy sources. Estimates of expenditure were converted to physical consumption units using current prices for the various energy carriers²⁸. For a limited number of households, data on actual metered energy consumption was provided by the municipality – where available, this data was used in preference to the householders' estimates.

Results from all three surveys (2013, 2014 and 2015) were combined. In order to derive a characteristic annual energy consumption per household (energy intensity) for each of the four LSM bands (see Figure 25). The assumption was then made that the *shape* of this relationship remained the same over the period 2000-12, with the relationship being scaled for each separate year according to the total energy consumption as reported in the Energy Balance Tables. The resulting year-by-year sets of figures for household energy intensity by LSM band were then used as the basis for a standard decomposition analysis.

²⁸ The prices used were as follows:

- electricity - the current tariff structures for the respective municipalities;
- paraffin - the single national maximum retail price
- LPG – average of Gauteng and coastal retail prices
- coal – estimates of retail prices taken from a range of literature sources

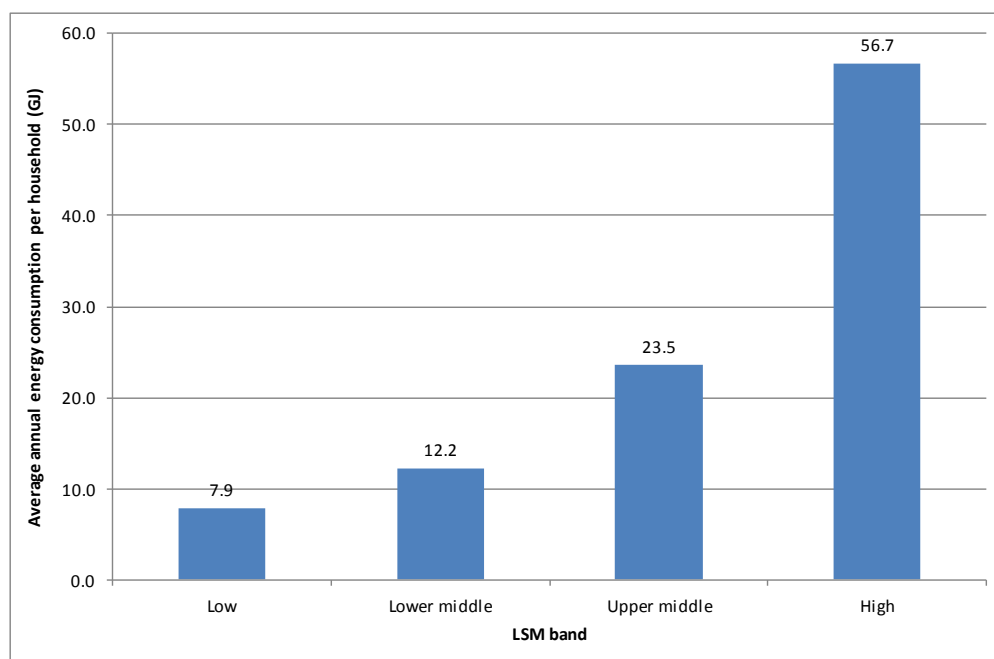


Figure 25 Relationship between household energy intensity and LSM band derived from combined results from 2013, 2014 and 2015 household surveys.

Decomposition analysis results

Using the data sources described above, a standard top-down decomposition analysis was conducted following the process described in *Annex A: Decomposition methodology*. The results of this analysis are shown in Table 17 while Figure 26 shows the cumulative improvement in energy efficiency relative to 2000, expressed in terms of the fractional change in total energy consumption that can be attributed to efficiency changes.

The analysis results show that, between 2000 and 2012, energy efficiency improved significantly, but with the entire improvement occurring in the years after 2004. Over the whole twelve-year period, if other factors had remained constant, improvements in efficiency would have led to an 81 PJ fall in energy consumption, which is 28.2% of the projected 2000 baseline figure. This is equivalent to a compounded annual fall of about 2.7% in energy consumption attributable to efficiency improvements. This is well in excess of the rate of improvement in energy efficiency needed to achieve the sectoral target as set out in the Energy Efficiency Strategy, indicated by the red line in Figure 26. It can also be seen from Figure 26 that the cumulative improvement in efficiency only exceeded the target level from 2006 onwards.

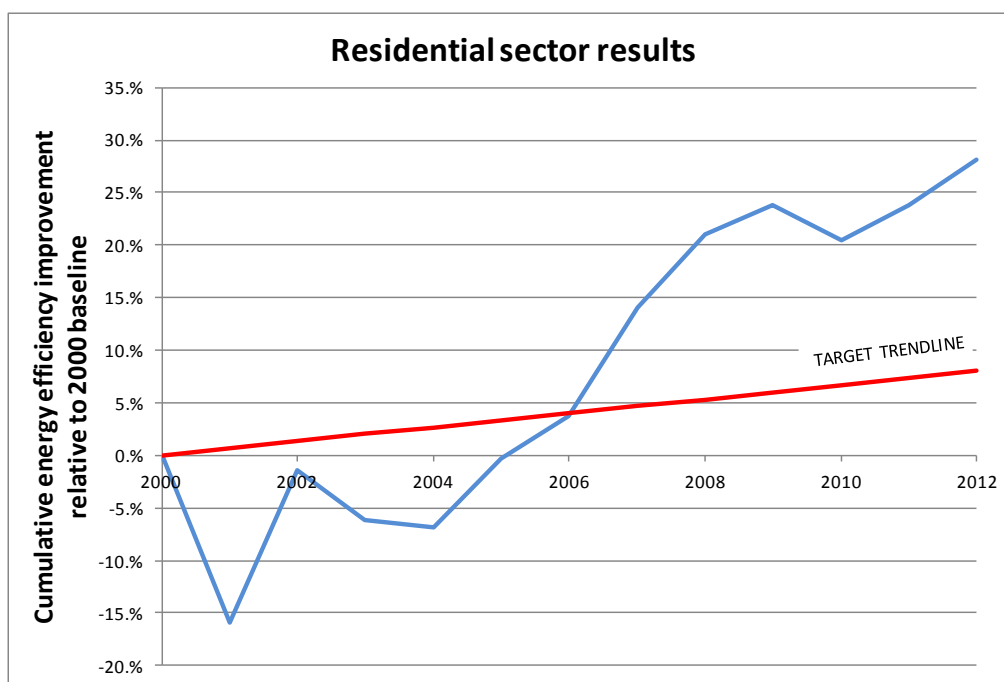


Figure 26 Cumulative change in residential sector energy consumption attributable to efficiency changes, expressed as a percentage of the total sectoral electricity consumption in the projected 2000 baseline

Figure 27 provides a graphical representation of the full decomposition results for 2012 relative to the 2000 projected baseline. Total energy consumption in the residential sector in 2012 had increased by 34.3 PJ relative to 2000. This change is composed of the sum of:

- a 71.4 PJ increase due to greater levels of activity (i.e. increased number of households);
- a 44.2 PJ increase due to structural changes (i.e. increases in living standards);
- an 81.4 PJ decrease due to efficiency improvements (encompassing behavioural and lifestyle changes as well as technological changes).

The effect of efficiency changes alone is illustrated in Figure 28, where the green curve (“With efficiency changes”) is the actual observed change in the total energy consumption of the sector from 2000-2012, while the red curve (“Without efficiency changes”) is the trend in total energy consumption that would have been observed if the efficiency components revealed by the decomposition analysis had been absent. The green shaded areas indicate periods when efficiency had improved relative to the baseline, while red shaded areas are periods when efficiency was worse than the baseline.

Table 17 Results of decomposition analysis of changes in residential sector energy consumption, 2000-2011

YEAR-ON-YEAR CHANGES												
	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
CHANGE IN FINAL ENERGY CONSUMPTION (TJ)	32,233	-18,729	15,166	9,680	-2,922	6,552	-4,383	-8,326	-5,128	13,742	2,071	-5,634
ACTIVITY LEVEL EFFECT	4,270	4,728	5,286	5,712	5,953	6,257	6,530	6,519	6,354	6,452	6,707	6,676
STRUCTURAL EFFECT	-120	2,058	767	2,107	4,169	9,294	15,042	4,582	-3,989	312	7,341	2,671
EFFICIENCY EFFECT	28,083	-25,515	9,113	1,861	-13,044	-8,999	-25,955	-19,427	-7,493	6,977	-11,977	-14,981
% CHANGE IN ENERGY CONSUMPTION DUE TO EFFICIENCY CHANGES	15.9%	-12.0%	4.7%	0.9%	-5.9%	-4.0%	-11.0%	-8.8%	-3.7%	3.4%	-5.3%	-6.7%

CUMULATIVE CHANGES (2000 base year)												
	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
CHANGE IN FINAL ENERGY CONSUMPTION (TJ)	32,233	13,504	28,670	38,350	35,428	41,981	37,598	29,272	24,143	37,885	39,956	34,322
ACTIVITY LEVEL EFFECT	4,270	8,998	14,284	19,996	25,949	32,206	38,736	45,255	51,609	58,061	64,768	71,445
STRUCTURAL EFFECT	-120	1,938	2,705	4,812	8,981	18,275	33,318	37,899	33,910	34,222	41,564	44,235
EFFICIENCY EFFECT	28,083	2,568	11,681	13,542	498	-8,501	-34,456	-53,883	-61,376	-54,399	-66,376	-81,357
% CHANGE IN ENERGY CONSUMPTION DUE TO EFFICIENCY CHANGES	15.9%	1.4%	6.2%	6.9%	0.2%	-3.8%	-14.1%	-21.0%	-23.8%	-20.5%	-23.8%	-28.2%

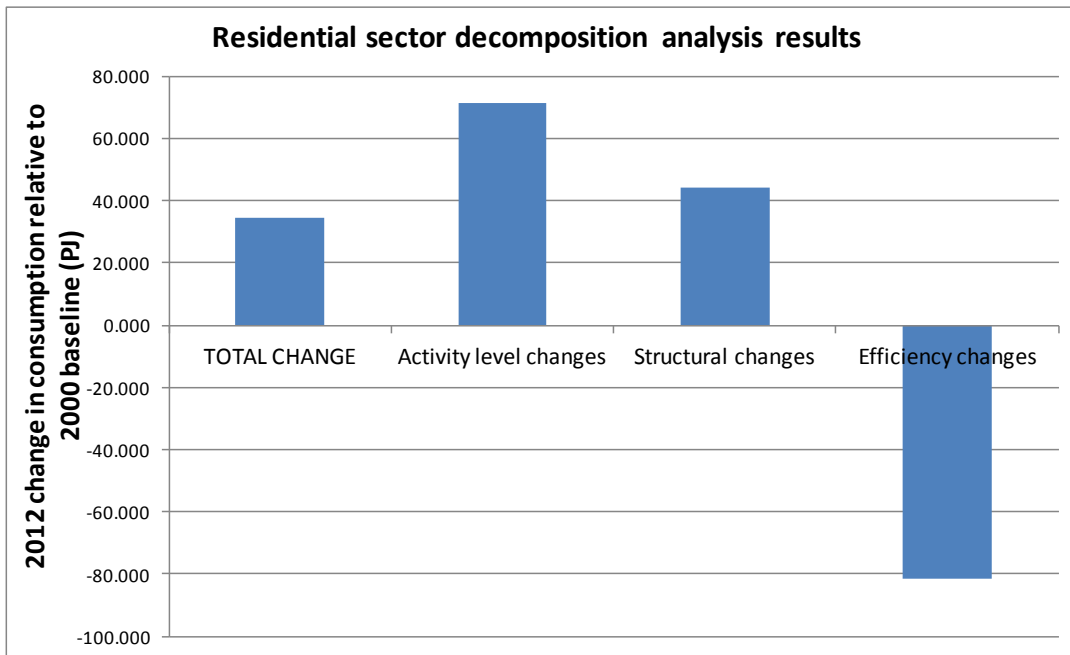


Figure 27 Cumulative change in residential sector energy consumption between 2000-2012 decomposed into three main components

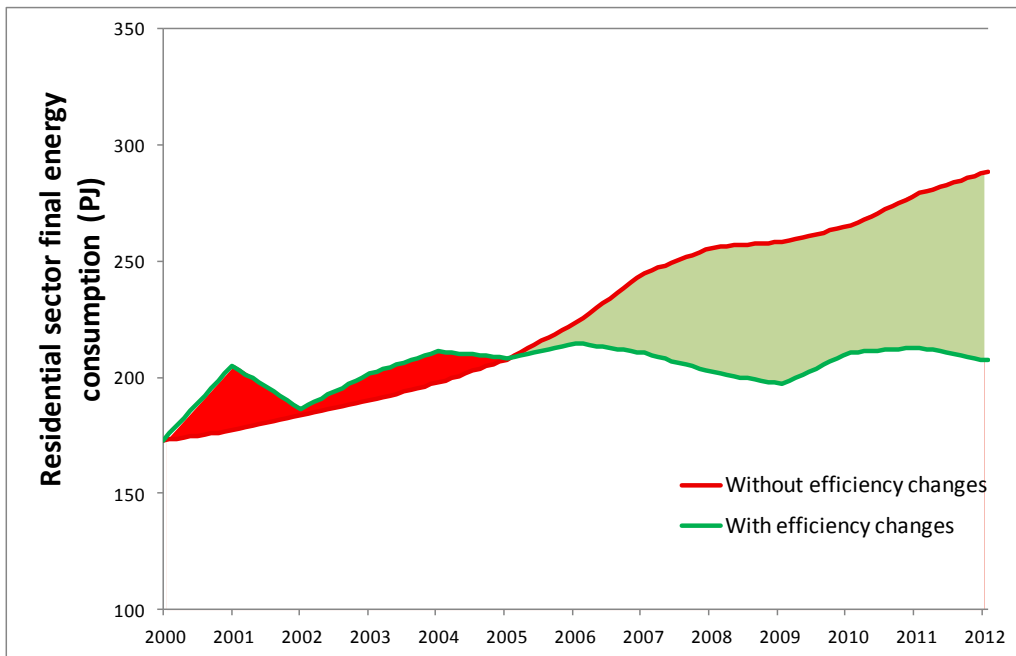


Figure 28 Comparison of actual observed trends in energy consumption of the residential sector (green trace) versus trends that would have occurred with no efficiency change (red trace).

DRIVING FORCES

Observing past trends in energy efficiency provides only a partial picture of whether energy efficiency targets are likely to be met. For a more complete picture, it is also necessary to understand the factors that are currently influencing the direction and magnitude of changes in energy efficiency – the ‘driving forces’. The household energy survey included questions designed to estimate the magnitude of these driving forces. The questions can be divided into four categories representing different factors that help to drive improvements in energy efficiency.

- Awareness – purposeful improvements in energy efficiency can only occur if there is awareness both of the possibility for improvement and of the opportunities available. One group of questions was therefore designed to determine this level of awareness among respondents.
- Incentive – awareness alone will not necessarily lead a household to improve its energy efficiency if it lacks the motivation to do so. Because of the need to keep the household survey relatively simple, the only aspect of motivation that was considered was financial, namely the extent to which respondents felt that current energy costs are a significant burden on household finances.
- Behaviour – even if awareness and incentive are both present, behavioural change will not necessarily result, as it depends also on the presence of a wide range of other factors. The survey therefore contained questions aimed at discovering the extent to which households are actually behaving in ways that might be expected to lead to improved energy efficiency.
- Rate of turnover of the stock of energy-using appliances – the rate at which energy efficiency can improve is affected to an extent by the rate at which energy-using appliances are replaced, since it can generally be assumed that a newly purchased appliance will be more efficient than the one it replaces. Questions relating to the age of appliances were therefore included in the survey. Although the frequency of replacement of appliances is an aspect of behaviour, it is treated separately because it is not *purposefully* directed towards improving energy efficiency. It is considered unlikely that a household would consider energy efficiency when deciding *whether* to replace an appliance, although efficiency may well be taken into account when deciding *which* model of appliance to choose.

Since there is no significant historical data on this subject, the data collected in the three household energy surveys conducted between 2013 and 2015 can provide only snapshots. Furthermore, the 2013 and 2014 surveys covered only limited geographical areas with relatively small sample sizes, so the results from those surveys cannot be considered statistically representative of the whole country. It would therefore be incorrect to interpret any differences between the results of the three surveys as being indicative of real trends through time. Because of this, the results of the previous surveys have not been reproduced here – the following sub-sections describe only the results obtained from the current survey.

Incentives

As described above, only one aspect was considered relating to the incentive that households have to improve energy efficiency, namely the financial incentive presented by unaffordable energy bills. Survey respondents were asked to state their level of agreement²⁹ with the statement:

“The cost of energy (cooking fuels, electricity etc.) is a burden and you struggle to afford it”

The responses to this question are summarised in Figure 29 below. About 39% of households agree strongly with the statement, and a further 20% agree, making a total of 59% of households that struggle to some extent with energy costs. This contrasts with a total of only 21% of households for whom energy is comfortably affordable. The breakdown of average responses by LSM shown in Figure 30 suggests that, somewhat counter intuitively, it is the higher LSMs that feel the burden of energy costs most strongly. The average response in the lowest three LSMs is around 3, which is the neutral position, whereas from LSMs 5 upwards, the average response approaches 4.

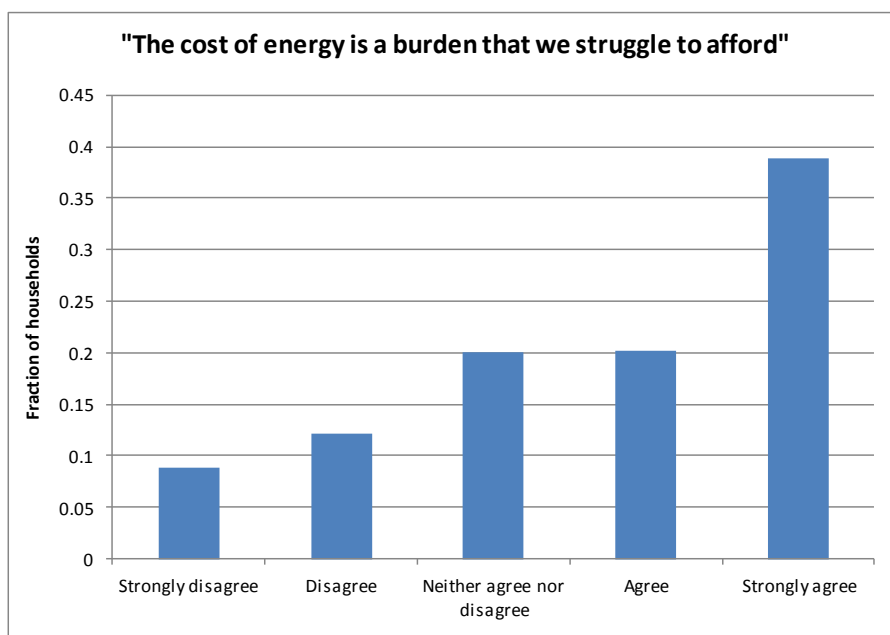


Figure 29 Aggregated responses to question on affordability of energy

²⁹ On a scale of 1 to 5, where 1=strongly disagree, 2=disagree, 3=neither agree nor disagree, 4=agree and 5=strongly agree.

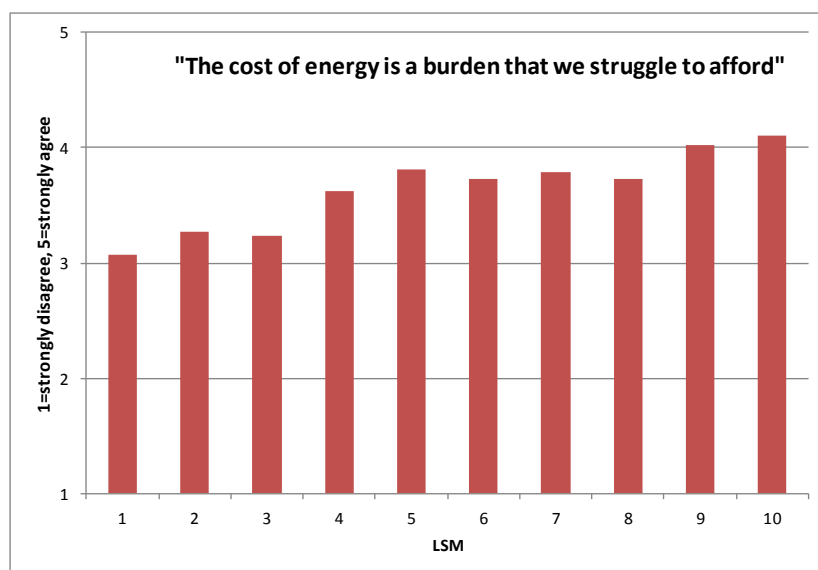


Figure 30 Breakdown by LSM of the responses to survey question on the affordability of energy

Awareness

Three questions in the survey aimed to establish the respondents' general level of awareness of their energy consumption and of opportunities for saving energy. Again, these questions took the form of statements, to which the respondent was asked to state the degree to which they agreed:

"As a household, you are always aware of how much energy you are using"

"You are very aware of what opportunities there are to save energy around the home"

"You always behave in ways that save energy (for example, switching off unnecessary lights and appliances etc.)"

Although the third question might appear to be more concerned with behaviour rather than awareness, it is included here because it relates only to the householders' own *perception* of how they behave – clearly it would not be possible in a simple survey to determine whether actual behaviour matched the respondents' perception.

The results from these questions are presented in Figure 31 below. About 69% of households perceive that they behave in ways that save energy, either agreeing or strongly agreeing with the relevant statement. For the two questions on awareness of consumption and awareness of energy saving opportunities, the total fraction of households agreeing or strongly agreeing was 59% and 63% respectively. Only about 15% of households profess a lack of awareness in respect of any of the three questions.

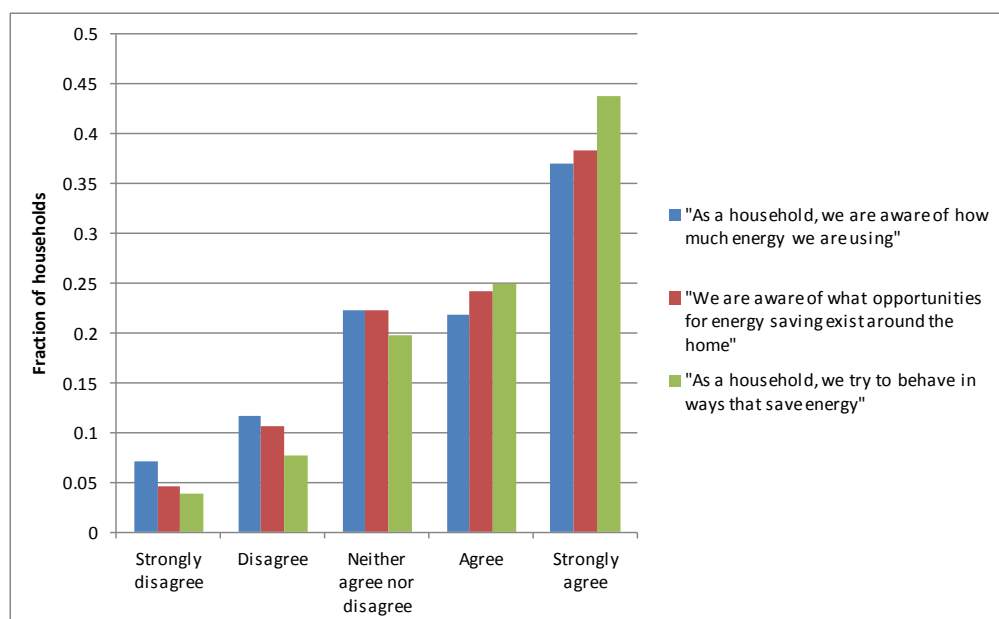


Figure 31 Aggregated survey responses relating to awareness of energy consumption

Figure 32 illustrates the variation in householders' perception of their awareness of energy across the LSM bands. As with the question relating to affordability of energy, the levels of awareness appear to increase with LSM, with LSMs 1 – 3 having a neutral position on average, and LSMs 6 – 10 agreeing with the statements on their awareness.

Further questions in the survey aimed to establish whether respondents were aware of a number of specific energy efficiency technologies. For these questions, awareness is indicated by a simple Yes/No response³⁰, and the fraction of households in each LSM that indicated an awareness was calculated. The results are shown in Figure 33, which shows a clear trend of increasing awareness in line with living standard. Energy efficient lamps are clearly the most familiar of the technologies, with roof / wall insulation and geyser blankets also achieving somewhat higher levels of awareness than the other technologies, particularly among upper-mid range of LSMs.

³⁰ In fact, the same questions were used to determine adoption levels of the technologies (see next section).

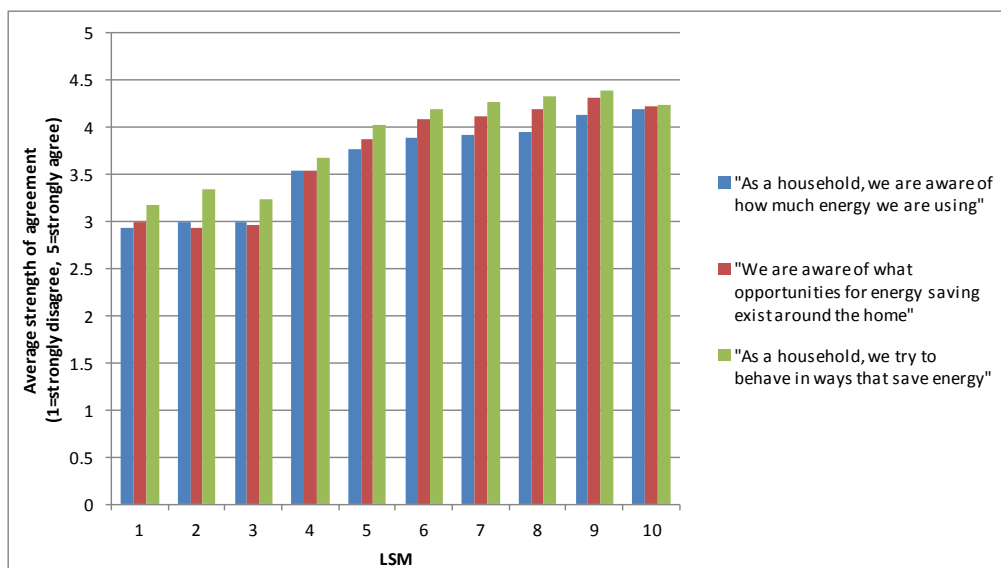


Figure 32 Breakdown by LSM of survey responses relating to awareness of energy consumption

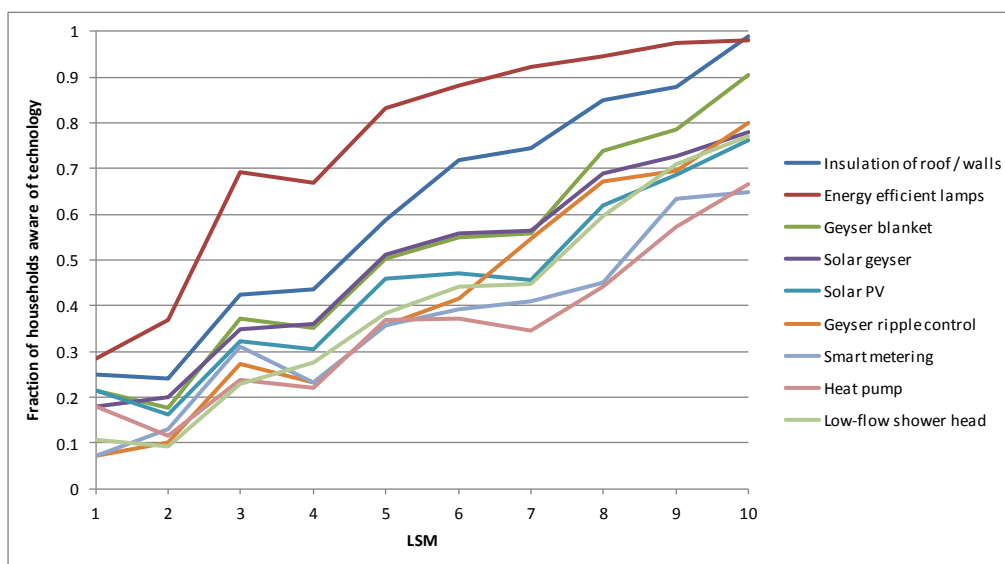


Figure 33 Level of awareness of a range of energy efficiency technologies

Behaviour

A set of survey questions aimed to discover whether households are actually behaving in ways that are likely to result in improved energy efficiency. The first of these questions was on the level of adoption of a range of energy efficiency technologies. The results of this question are presented in Figure 34 below. Adoption levels of energy efficient lamps approach 90% for LSMs 7-10, and are above 50% for LSMs 4 and above. Roof / wall insulation also has high adoption rates in the higher LSMs, with levels exceeding 50% for LSMs 7 and above.

Significant adoption of three other energy saving technologies (geyser blankets, geyser ripple control and low-flow shower heads) begins to appear at LSM 7 and above, reaching adoption levels of 30-

50% in LSM 10. In general, adoption levels of other technologies do not exceed about 10% across the LSM spectrum, and are mostly below 5% for LSMs 5 and below.

Questions were included in the survey to determine the length of time that householders have been using each of the energy saving technologies. The responses are summarised in Figure 35 and Figure 36 below – the results are separated between two charts for clarity. A striking feature of these results is the relatively high proportion of those households that are using the technologies that have adopted them in the last year. With the exception of roof / wall insulation and geyser ripple control, at least one-third of current users of each technology are new adopters.

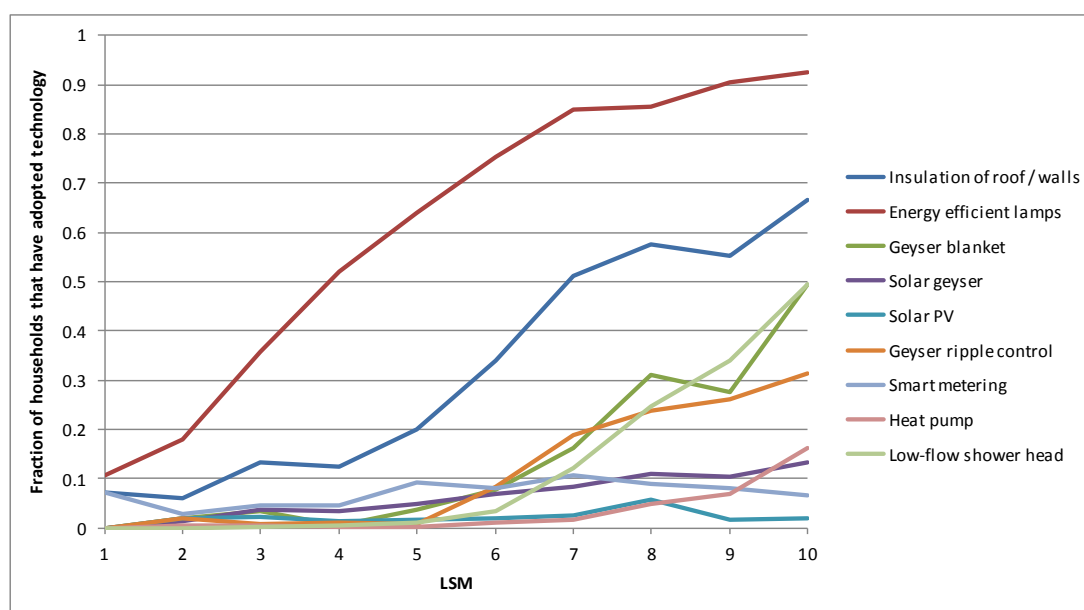


Figure 34 Adoption levels of a range of energy efficiency technologies

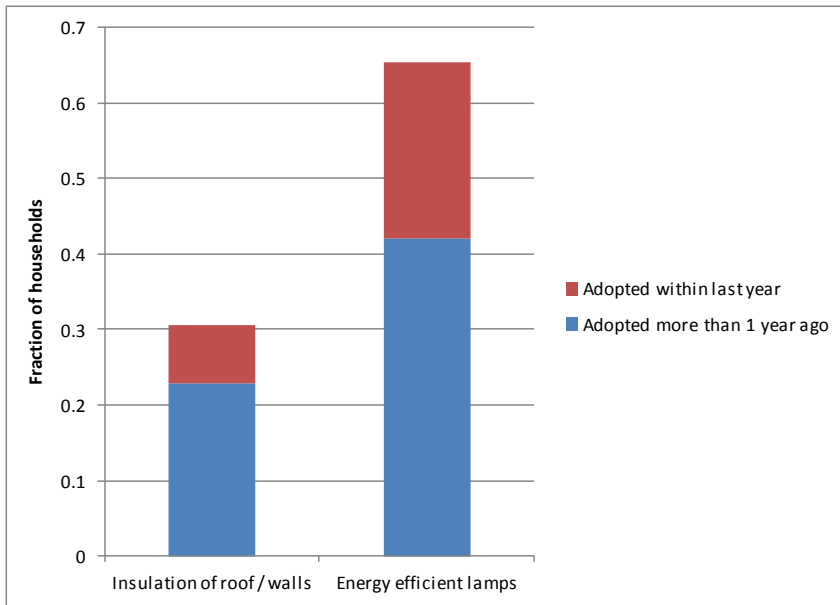


Figure 35 Overall adoption rates for the two most popular energy efficiency technologies

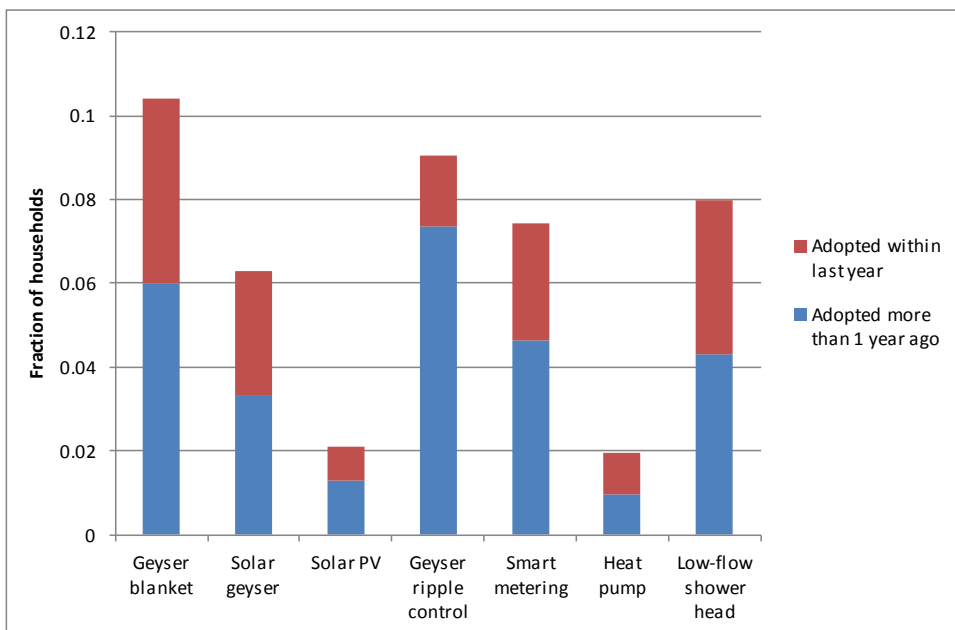


Figure 36 Overall adoption rates for other energy efficiency technologies

The final aspect of behaviour that was explored in the household survey related to whether energy efficiency is considered by households when purchasing electrical appliances. Responses to this question are summarised in Figure 37 below, where it can be seen that about 44% of households overall either agree or strongly agree that energy efficiency is a consideration. About one-third of households in the survey do not consider the energy efficiency of appliances they are buying, while the remaining 23% are neutral.

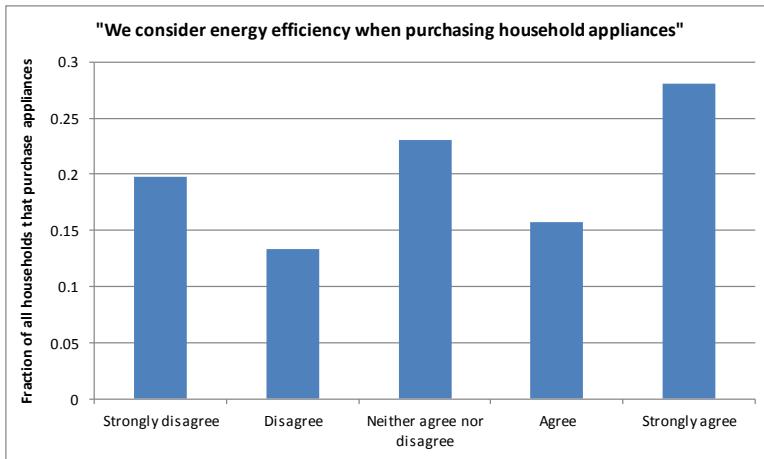


Figure 37 Extent to which energy efficiency influences appliance purchasing decisions

Figure 38 shows the responses to this question broken down by LSM, where it can be seen that only in LSMs 6 and above does the average response exceed the neutral level. These results are understandable in the context where many appliance purchases in the lower LSMs represent first-time acquisitions. For these households, the initial purchase price of an appliance is likely to be the main criterion considered.

Because of the need to keep the survey relatively simple, it was not possible to build up a complete picture of how appliance purchasing decisions are made. A future more comprehensive survey would ideally include questions on which other criteria respondents consider when purchasing appliances, how important these criteria are relative to each other, and whether householders are able to interpret appliance energy labels.

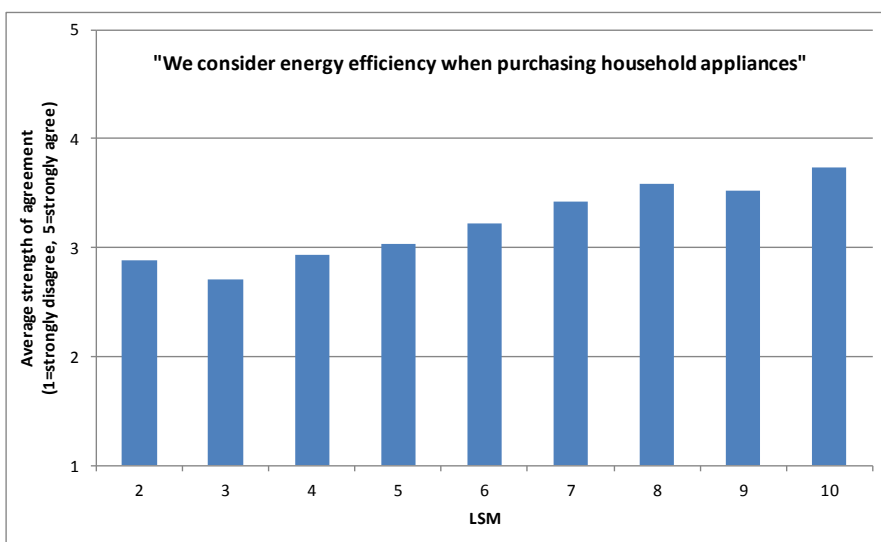


Figure 38 Breakdown by LSM of the extent to which energy efficiency influences appliance purchasing decisions. Note that LSM 1 is omitted since no respondents in that LSM had purchased appliances.

Rate of turnover of appliances

Although improving appliance efficiency standards is an important component of efforts to improve the overall energy efficiency of the residential sector, the rate at which this can occur is limited by the rate at which the less efficient appliances currently in use are replaced. At the same time, the energy use patterns of the residential sector are being strongly influenced by the large number of households who are acquiring energy-using domestic appliances for the first time. A full understanding of the energy efficiency trends in the residential sector therefore requires a detailed picture of the evolution of the stock of domestic appliances.

The household survey included questions on the ownership rates of appliances, as well as their average age which can provide some indication of the rate of turnover. Note however that the average age of appliances only correlates closely with the rate of turnover in situations where ownership levels are close to saturation. For the lower LSMs, many households have only recently acquired various appliances for the first time, so a low average age does not necessarily indicate a rapid rate of turnover.

Figure 39 below shows the ownership rates for a range of energy-using household appliances by LSM. As expected, ownership rates increase with LSM – an inevitable result, since LSM categorisation is based in part on appliance ownership. However, this graph also provides a clear indication of the order in which households tend to acquire appliances as their living standard increases. Note that, because of the importance of appliance ownership rates in the definition of LSM bands, the patterns seen here are unlikely to change significantly through time. It would be very difficult for general ownership levels of appliances in a particular LSM to increase significantly, because this would in itself result in many of those households being reassigned to a higher LSM.

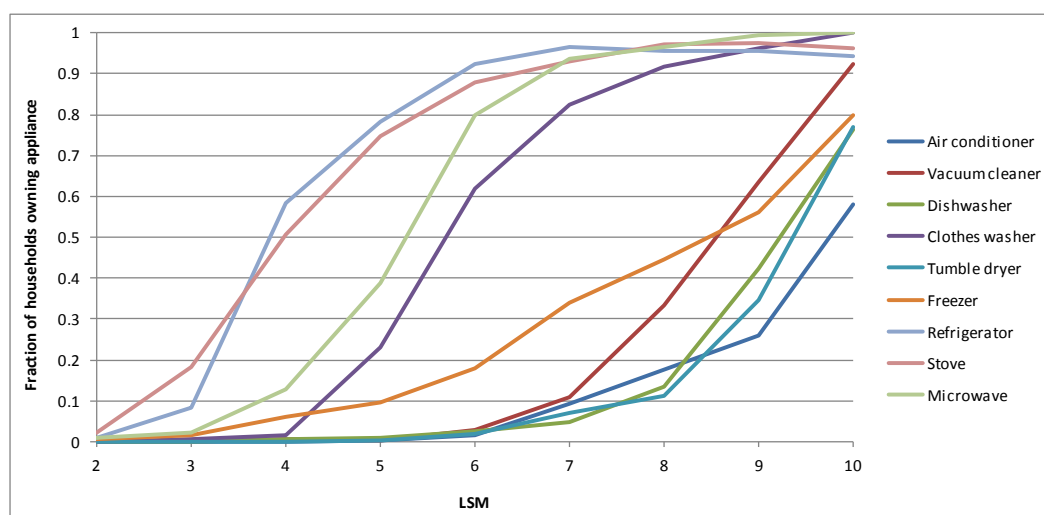


Figure 39 Ownership rates of a range of household appliances

Figure 39 indicates that there is a distinct group of early-adopted appliances (stove, refrigerator, microwave oven and washing machine) that reach adoption levels of 60-90% by LSMs 6. Conversely, the group of late-adopted appliances (tumble dryer, vacuum cleaner, dishwasher and air-conditioner) start to show significant adoption only in LSM 8 and, with the exception of vacuum

cleaners, are only owned by 60-80% of households even in LSM 10. Adoption patterns of freezers appear to follow a different pattern, with ownership levels rising more gradually through the LSMs. This may be because of ambiguities as to whether the survey question referred only to ownership of a separate freezer or included combined fridge-freezers.

Survey respondents were asked about the age of the different household appliances they own. Figure 40 below shows the results broken down by LSM for six appliance types, including the four that tend to be the first that households adopt as their living standards improve. For the other appliance types, no clear trends emerged across LSMs, so this data has been omitted from the graph. Results for all appliance types are also shown in Table 18 below, aggregated across all surveyed households.

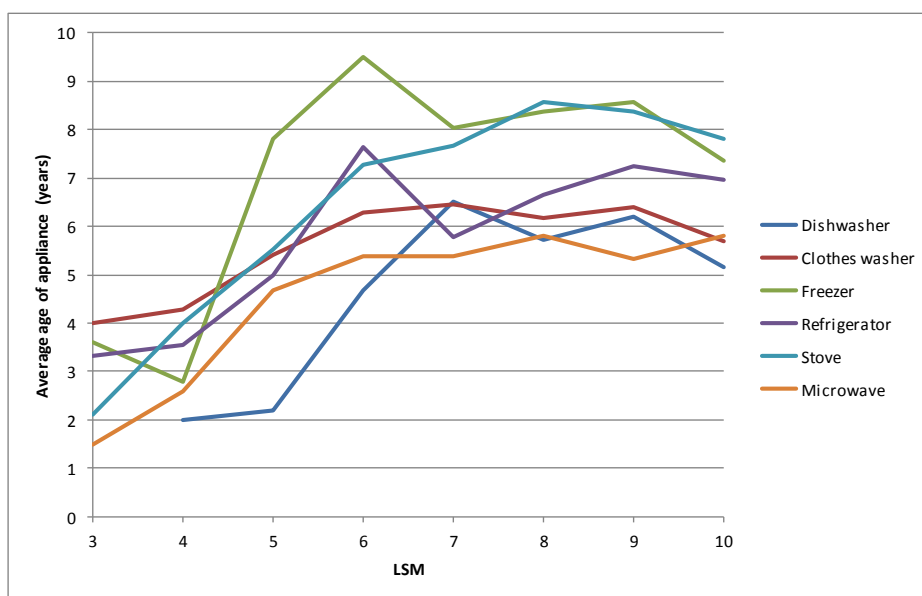


Figure 40 Average age of selected appliance types by LSM

Figure 40 shows a clear trend towards an increase of appliance age with LSM, reflecting the fact that a significant fraction of owners in lower LSMs have only recently acquired that type appliance for the first time. For the early-adopted appliances that have reached saturation levels in the higher LSMs, the average age in those LSMs provides an indication of typical rates of turnover – this appear to be in the range of 6-8 years.

Table 18 Average age of appliances owned by survey respondents

Appliance	Average age (years)
Dishwasher	5.6
Washing machine	6.2
Freezer	8.2
Refrigerator	6.2
Stove	6.8
Microwave oven	5.3

CONCLUSIONS

Using decomposition analysis to quantify and allow for the effects of increasing living standards, it appears that South Africa is comfortably on track to achieve its residential sector target under the National Energy Efficiency Strategy. The best estimate based on available data is that the cumulative improvement in energy efficiency in the residential between 2000-2012 has been about 28%. However, resource constraints mean that the data on which this analysis was based was very limited; hence the margin of error on any conclusions drawn is relatively large. In order for a more robust analysis of this type to be conducted at regular intervals moving forward, there is an urgent need for the collection of comprehensive and consistent data on household energy through regular surveys. Such data should aim not only to enable analysis of part trends to be tracked, but also to provide a picture of the current driving forces that will determine the future evolution of energy consumption patterns in South Africa's households.

The analysis indicates that by far the strongest influence on energy consumption in the residential sector from 2000-12 has been the increase in the total number of households. However, the rapid rate at which households' living standards are improving is also a strong influence. Increases in living standards are associated with the acquisition of increasing numbers of energy-using household appliances. Ownership of refrigerators increases from less than 10% at LSM 3 to over 90% at LSM 6, while ownership of washing machines increases from near zero to over 80% between LSMs 4 and 7. Given that the fraction of households in LSMs 1-3 has fallen from over 37% in 2000 to less than 13% today, this illustrates the huge number of households that have acquired energy-using household appliances for the first time during this period.

The analysis of the driving forces behind improved energy efficiency indicates that overall awareness among householders is relatively good. The important exception to this, however, is the relatively small proportion of households that consider the energy efficiency of household appliances when purchasing, particularly in the LSM 3-6 range where first-time appliance purchases are so prevalent. There would appear to be a huge opportunity both for increasing the level of awareness of householders about appliance labelling, and for improving the level of understanding among purchasers of the long-term financial benefits of more efficient appliances.

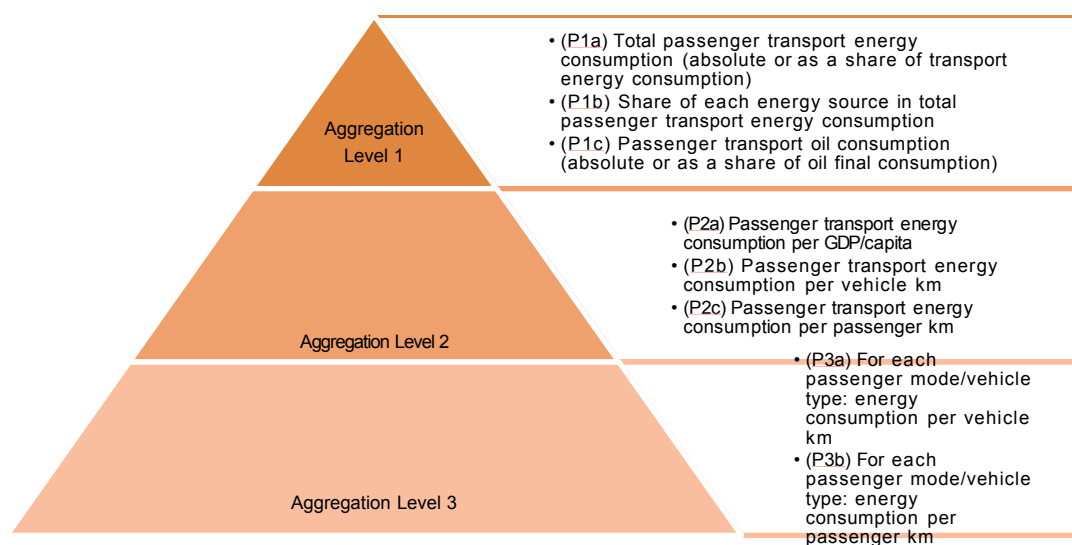
TRANSPORT SECTOR

INTRODUCTION

The National Energy Efficiency Strategy (2005) targeted a 9% decrease in energy demand by 2015 for the transport sector. However, the initial phase of development of the EETMS deliberately omitted the transport sector, largely due to the complexity of the sector and the resources required to routinely collect data across the various modes of transport to inform a meaningful decomposition analysis. As the EETMS is being scaled up, the commitment to include the transport sector has increased, primarily due to the contribution of the sector to overall energy consumption (xx% of Total Final Energy Consumption in 2012).

In defining the EETMS methodology for the transport sector, it is necessary to weigh up the degree of disaggregation that will provide meaningful analysis against the resources implications of obtaining that data. According to international best practice, the level of ambition varies depending on data availability and the costs of data collection. Using the International Energy Agency's (IEA) definition of aggregation levels for passenger and freight transport indicators, as illustrated in **Fejl! Hensvingskilde ikke fundet.** and Figure 42 respectively, the implications of disaggregation are evident.

Figure 41: Energy Efficiency Indicators Pyramid for Passengers (Source: IEA 2014)

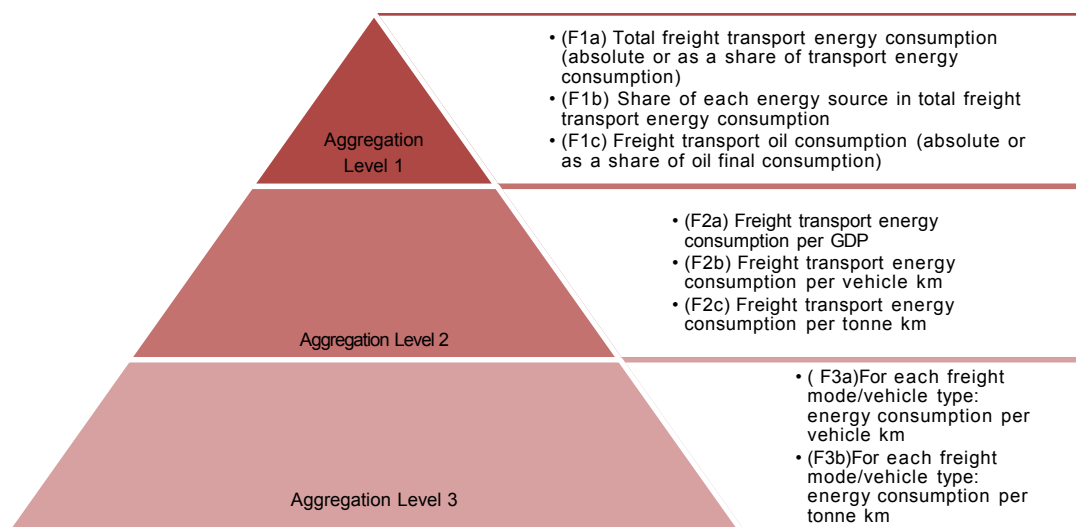


Level 1 indicator definition: Amount of total passenger transport energy consumption per passenger-kilometre or per GDP per capita. The preferred indicator is energy consumption per passenger-kilometre.

Level 2 indicator definition: For each mode of transportation (road, rail, water and air), energy consumption per passenger-kilometre.

Level 3 indicator definition: For each road vehicle type (e.g. SUV, bus, Taxi), energy consumption per passenger-kilometre or share of energy consumption for road vehicles by type of vehicle.

Figure 42: Energy Efficiency Indicators Pyramid for Freight (Source: IEA 2014)



Level 1 indicator definition: Total energy consumption on freight transport per tonne-kilometre or per GDP.

Level 2 indicator definition: For each mode of transportation (road, rail, ships), amount of energy consumed per tonne-kilometre.

Level 3 indicator definition: For each road vehicle type, the amount of energy consumed per tonne-kilometre.

The ideal scenario is therefore to measure energy efficiency using Level 3 indicators in order to be able to identify trends that cannot be attributed to structural or activity changes. However, the data collection and the maintenance required for Level 3 indicators entail significant data collection exercises, extensive coordination mechanisms, and systems to host the data.

According to the International Energy Agency (IEA), the measurement of energy efficiency for the transport sector covers only transportation within national boundaries, excluding consumption for international aviation bunkers and international marine bunkers. Further, consumption in the transport sector excludes the following:

- Fuel delivered for off-road use and stationary engines,
- Military consumption,
- Pipeline transport and transport not elsewhere specified.

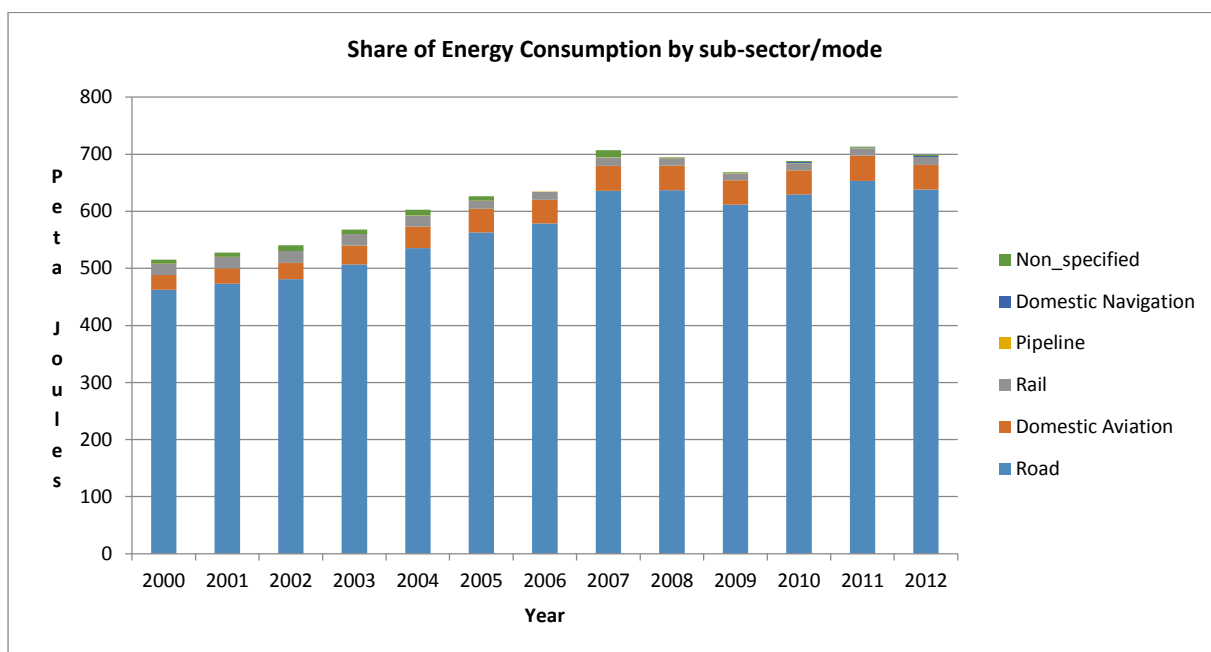
Even if these activities are considered to be significant in other countries, they are excluded in the determination of energy efficiency indicators.

OVERVIEW OF TRENDS IN CONSUMPTION AND ENERGY INTENSITY

At the level of national energy balances, transport is generally disaggregated into four sub-sectors: road, rail, domestic aviation and domestic navigation. These four sub-sectors are also used as categories or sub-sectors in the energy efficiency indicators defined in similar systems.

Worldwide, in 2011 the transport sector accounted for 27% of the Total Final Consumption (TFC) - up from 23% in 1973. At least 75% of this consumption is due to road transport alone. It is expected that the transport sector will maintain a very prominent role within the global energy demand of the next few decades. In the South African context, the transport sector accounts for at least 27% of TFC relative to other sectors based on the Energy Balance Tables from 2012 (Refer to Figure 43).

Figure 43: Share of Total Final Consumption by sub-sector



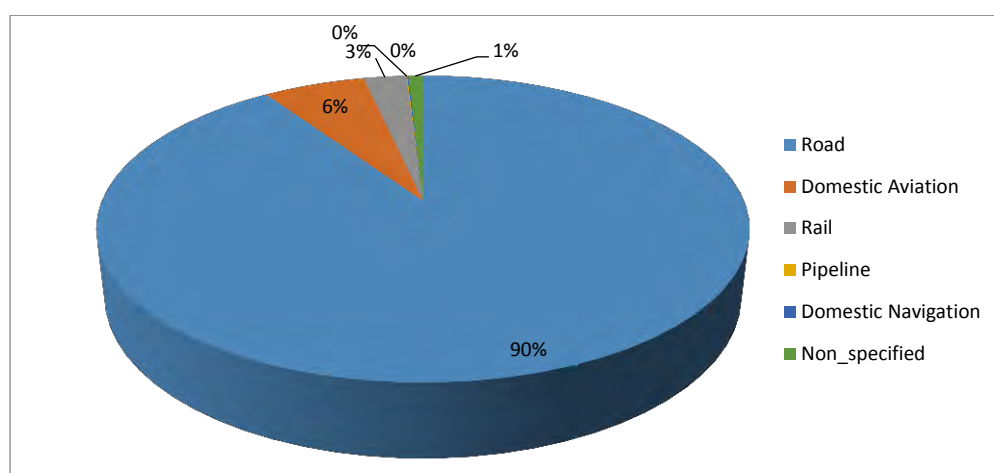
Source: International Energy Agency, Energy Balance Tables for South Africa

It is evident that the road sub-sector follows the global trend where it accounts for at least 75% of the TFC in the transport sector. It is worth noting that since the baseline year in 2000, energy consumption in this sector has been gradually increasing – an overall increase of 183.2 PJ. There was a slight decrease in energy consumption from 2008 to 2009, most likely due the global economic recession and thereafter a return to 2007 average levels.

The energy consumption for Domestic Navigation has been registered as zero PJ between 2000 and 2009. From 2010 to 2012, the energy consumption in this sub-sector ranged between 1.1 PJ to 1.9 PJ, a very small proportion of the overall TFC for the sector. Non-Specified energy consumption ranges between 0 PJ in 2006 to 12.7 PJ in 2007, with an overall average of 5.4 PJ. Pipeline energy consumption ranges between 0.2 PJ and 0.4 PJ. Therefore, these sub-sectors collectively are not considered to be the most critical in understanding energy efficiency trends for the transport sector, accounting for only 1% in total of TFC in 2012.

Hence, it seems that sub-sectors contributing the most to the TFC in this sector are Road, Domestic Aviation and Rail, as illustrated below. At least 90% of total consumption is attributable to road sub-sector or mode. Domestic aviation accounts for 6% of TFC and rail which 3% (Refer to Figure 44). However, despite the relative proportion of energy consumed on the non-road modes, analysing energy efficiency on these modes is still important to understand patterns of modal shift and its impact.

Figure 44: Share of TFC by sub-sector



FUTURE ANALYSIS OF ENERGY EFFICIENCY TRENDS

Based on the outcome of the data mapping exercise that was undertaken by the Department of Energy, there are some significant data gaps, as summarised in the table below. It is clear that there is limited data currently available, and specifically in terms of one of the most energy intensive sub-sectors: passenger road transport.

Table 19: Summary of Data Sources Identified

Freight/Passenger	Sub Sector	Mode	Activity	Consumption	Driving Force
Freight	Rail		A	A	A
Freight	Road		A	P	P
Freight	Air		A	A	A
Freight	Shipping (Maritime)		P	P	P
Passenger	Rail		P	P	P
Passenger	Road	Private Car	P	P	P
Passenger		Bus	P	P	P
Passenger		Bus Rapid System	P	P	P
Passenger		Taxi	P	P	P
Passenger		Metered taxi	No Data	No Data	No Data
Passenger	Air		A	A	A
Passenger	Shipping (Maritime)		A	No Data	No Data

From this table, it is evident that the data collection, processing and analysis for Level 3 indicators will require significant resources. Thus, in selecting the indicators for the EETMS transport sector, this should be kept in mind.

As a result of the data mapping there are a number of key recommendations that will need to be taken into consideration in establishing a routine data collection mechanism for the transport sector:

1. Based on the NHTS data, it is clear that it is necessary to drill down to level 3 for road and rail transport based on the proportion of energy consumption attributable to that activity, and to understand the structural and activity changes – in order to isolate the efficiency trends within the sub-sectors.
2. Whilst focusing on road transport should be prioritised, specifically as this is projected to be a significant growth area, it is also necessary to ensure that data is collected on other modes in order to understand any modal shifts that may occur.
3. It will be necessary to establish a phased plan for the introduction of routine data collection mechanisms to obtain adequate information on the main modes of transport. The preliminary phase should be to obtain the existing data that is available and to incorporate additional indicators in existing data collection activities, such as the General Household Survey, the NHTS, aviation data collection and freight databank development.
4. **Passenger Transport:**
 - a. *Road:* In the interests of obtaining some specific data on passenger road transport, it will be necessary to obtain data as to the proportion of fuel sales that are attributable to the various vehicle types. Based on this, a model can be established taking into consideration the current vehicle stock, which can be obtained from e-Natis.
 - *Private vehicles:* estimating the vehicle occupancy of private vehicles remains a problem but can be mitigated through repeated surveys of vehicle occupancy in the provinces that have the highest trip occurrences.
 - *Mini-bus taxi:* this mode contributes significantly to fuel consumption and transports most public transport users in South Africa. Detailed data pertaining to the efficiency of this mode is collected but not submitted to a central repository from where it can be analysed. The submission of current public transport records to the DoT will assist in this data collection process.
 - b. *Passenger rail:* the data is collected but the regularity or process submission of the data needs to be formalised.
 - c. *Air:* the domestic aviation industry is extremely well regulated and airline companies have confirmed that the data required for the EETMS is readily available. Therefore, this data can be obtained with relatively little effort and will help the DoE to understand the efficiencies that are being put in place by the aviation industry.
 - d. *Maritime:* the data available for passenger, domestic navigation could be obtained on request although there is currently no centralised, routine data submission mechanism. However, the proportion of energy consumed in this activity mainly covers tourism and does not justify the effort to collect this data.

5. Freight Transport:

- a. *Road*: It is imperative that at this stage that the required variables for the EETMS are incorporated in to the update of the freight databank. This would solve the issue of routine, resource optimised data collection.
- b. *Rail and airfreight*: data can be collected from single sources or could be collected by Airport Companies South Africa (ACSA) as part of their routine data collection for the GHG emissions inventory. The variables currently available from airlines are reportedly in line with the EETMS indicators.
- c. *Maritime*: The collection of data needs to be included into the data collection process and will require additional surveys from maritime authorities. The collection and surveys needs more investigation.
- d. *International aviation and shipping* are considered to be outside the scope of the EETMS, in line with international practice, although this is primarily due to the challenges of attributing energy consumption for international aviation and shipping to national activity. There is some potential for misreporting based on the fact that international ships do carry freight domestically before continuing on however the proportion of energy consumed in this activity is considered to be less than 1% of total consumption for the transport sector and therefore not deemed worth the effort in obtaining the data.

The next steps for incorporating the transport sector into the EETMS will be to develop a prioritised matrix of indicators in collaboration with the Department of Transport and its agencies, and establish a routine data collection mechanism that will inform the decomposition analysis for the transport sector. Based on this analysis, for the various modes for which data is or becomes available, it will be possible to strip out the modal shifts and merely the amount of movement from efficiency improvements, i.e. how much energy is being consumed in undertaking activities. The Department of Energy aims to include a more extensive decomposition analysis in the Annual Monitoring Report 2016.

ANNEX A DECOMPOSITION METHODOLOGY

Note that, although the description of the decomposition methodology in this Annex uses illustrative examples from the industrial sector, the same general principles may be applied to any sector.

The purpose of decomposition is to apportion an observed change in total energy consumption to different causal factors. In its most commonly used form, the causal factors to which decomposition analysis attributes changes in total energy consumption are: (i) changes in the overall level of economic activity; (ii) changes in the structure of the economy; (iii) changes in the efficiency with which energy is used. Expressed as an equation:

$$\Delta E = \Delta A + \Delta S + \Delta Q$$

ΔE (change in total energy consumption) is equal to ΔA (portion attributable to change in activity level) plus ΔS (portion attributable to structural change) plus ΔQ (portion attributable to intensity change)

Decomposition is by definition a top-down process, which has the advantage that the depth of analysis can be adjusted to an appropriate level for each sector and sub-sector, according to the availability of data. Because a great deal of currently available data is in a very aggregated form, a top-down approach means that a basic analysis can be conducted using existing data. This basic analysis can then be successively refined both according to perceived need and as new, improved data becomes available.

Table A1 below presents some simplified hypothetical data at the level of the whole economy. The total GVA has increased from \$100 billion in Year 0 to \$105 billion in Year 1. Over the same time period, the total energy consumption for the economy increased from 1,000 TJ to 1,020 TJ. From this data, the aggregate energy intensity of the economy can be calculated – this has decreased from 10 kJ/\$ to 9.714 kJ/\$ over the course of the year depicted.

As described above, the process of decomposition takes the observed 20 TJ increase in total energy consumption and attributes it to different causal factors. Note however that, because data is available only at the economy-wide level in this example, it is not possible to identify any structural effects. With the available data, the process of decomposition is only able to attribute changes in total energy consumption to two possible causes – changes in the overall level of economic activity and changes in energy intensity (which is taken to be a proxy for changes in efficiency).

Table A1 Illustrative economy-wide data for a hypothetical economy

	Year 0	Year 1	% change
Gross Value-Added (billion \$)	100	105	+5.00%
Energy consumption (TJ)	1000	1020	+2.00%
Energy intensity (kJ/\$)	10.000	9.714	-2.86%

[Note: in this table, and in all those that follow, original data is shown in normal typeface while *italics* are used for figures that are derived from the original data]

It might be thought that the ΔA term in the above equation would be equal to 50 TJ in this example, because if the energy intensity of the economy had not changed, the increase in GDP of 5% would have led to a corresponding increase of 5% in total energy consumption. In other words, total energy consumption would have increased by 50 TJ, from 1,000 TJ to 1,050 TJ.

However, by the same logic, it might be thought that the ΔQ term would be equal to -28.6 TJ, because if the GDP of the economy had remained constant, the 2.86% reduction in energy intensity would have led to a corresponding 28.6 TJ reduction in total energy consumption, from 1,000 TJ to 971.4 TJ. Unfortunately, the sum of +50 TJ and -28.6 TJ is not equal to the observed change of +20 TJ, indicating that this simple approach is not adequate for fully accounting for changes in total energy consumption. Although the error is small for a simple, single-year analysis such as this, if the analysis is repeated over several consecutive years (as would be the case in a fully-functioning target monitoring system) these small errors would accumulate into a significant figure.

For this reason, it is necessary to use a more mathematically rigorous process of decomposition, which eliminates these 'residual' terms. The process used is known as 'log-mean Divisia' (LMD) decomposition, and is the approach already well-established in New Zealand and Canada, and increasingly being favoured in the USA and the International Energy Agency. Where data is available only in aggregated form for the whole economy, but not for individual sectors, the equations for decomposing changes in total energy consumption using LMD are as follows:

$$\Delta E = \Delta Q + \Delta A$$

ΔE (change in total energy consumption) is equal to ΔQ (portion of change attributable to efficiency change) plus ΔA (portion of change attributable to change in activity level)

$$\Delta Q = W \times \ln\left(\frac{EI_1}{EI_0}\right)$$

ΔQ is equal to W (a weighting factor – see below) multiplied by the natural logarithm of the ratio of EI_1 (energy intensity in Year 1) to EI_0 (energy intensity in Year 0)

$$\Delta A = W \times \ln\left(\frac{GVA_1}{GVA_0}\right)$$

ΔA is equal to W (a weighting factor – see below) multiplied by the natural logarithm of the ratio of GVA_1 (gross value-added in Year 1) to GVA_0 (gross value-added in Year 0)

$$W = \frac{(E_1 - E_0)}{\ln(E_1 / E_0)}$$

W , the weighting factor, is equal to the 'logarithmic mean' of E_1 (total energy consumption in Year 1) and E_0 (total energy consumption in Year 0). The logarithmic mean of two numbers is defined as the difference between them divided by the natural logarithm of their ratio.

It is beyond the scope of this brief description to present derivations of these equations. For more information on the theoretical background to LMD decomposition analysis, interested readers are referred to "Monitoring Energy Efficiency Performance in New Zealand: A Conceptual and Methodological Framework" by J Lermitt and N Jollands (2001).

Substituting the figures from Table 1 into these equations gives:

$$W = \frac{(1020 - 1000)}{\ln(1020/1000)} = 1009.967$$

$$\Delta Q = 1009.967 \times \ln\left(\frac{9.714}{10.000}\right) = -29.276$$

$$\Delta A = 1009.967 \times \ln\left(\frac{105}{100}\right) = 49.276$$

Thus, the observed increase in total energy consumption of 20 TJ can be attributed to two causes:

- an increase in the overall level of economic activity, to which can be attributed an increase of 49.276 TJ in total final energy consumption
- a reduction in energy intensity (which may or may not result from efficiency improvements), to which can be attributed a decrease of 29.276 TJ in total final energy consumption

Note that this analysis accounts entirely for the observed change in total final energy consumption, leaving no residual.

The 29.276 TJ decrease in total energy consumption that was attributed to reduction in energy intensity in the above example serves as a proxy for the improvement in energy efficiency that has taken place over the year. It clearly represents a very poor estimate of genuine efficiency changes, but with the data available in the example, this is the best estimate that can be made.

Separating out structural effects

The first step in improving the extent to which intensity changes serve as a proxy for efficiency changes is to separate out the effects of structural change. In the next example, shown in Table A2 below, the aggregate figures are the same as in the previous example, but additional data is available on the energy consumption and GVA of the sectors which make up the economy. For simplicity, the economy represented in this hypothetical example consists of just two sectors.

Table A2 Hypothetical example expanded to include sector-level data

	Year 0		Year 1	
	Sector A	Sector B	Sector A	Sector B
GVA (billion \$)	60	40	66	39
Share of GVA	0.6000	0.4000	0.6286	0.3714
Energy consumption (TJ)	500	500	570	450
Energy intensity (kJ/\$)	8.333	12.500	8.636	11.538

With the additional sector-level data, it is now possible to see that some of the change in total energy consumption that had been attributed to energy intensity change in the previous example is actually due to structural change. The share of Sector A has increased between Year 0 and Year 1 at the expense of Sector B. Because Sector A is intrinsically less energy intensive, this structural change will have led to a decrease in total energy consumption.

The additional sector-level data means that it is now possible to attribute changes in total energy consumption to three different causal factors: intensity changes, activity level changes and structural

changes. The equations describing how this disaggregation is performed using LMD decomposition are as follows:

$$\Delta E = \Delta Q + \Delta A + \Delta S$$

ΔE (change in total energy consumption) is equal to ΔQ (portion attributable to intensity change) plus ΔA (portion attributable to change in activity level) plus ΔS (portion attributable to structural change)

$$\Delta Q = \sum_n \left[W_n \times \ln \left(\frac{EI_{n,1}}{EI_{n,0}} \right) \right]$$

ΔQ is equal to the sum, over all n sectors, of the sector weighting factor multiplied by the natural logarithm of the ratio of the Year 1 and Year 0 sector energy intensities

$$\Delta A = \left[\sum_n W_n \right] \times \ln \left(\frac{GVA_1}{GVA_0} \right)$$

ΔA is equal to the sum of all the sector weighting factors, multiplied by the natural logarithm of the ratio of the Year 1 and Year 0 GVAs

$$\Delta S = \sum_n \left[W_n \times \ln \left(\frac{SH_{n,1}}{SH_{n,0}} \right) \right]$$

ΔS is equal to the sum, over all n sectors, of the sector weighting factor multiplied by the natural logarithm of the ratio of the Year 1 and Year 0 sector shares of GVA

$$W_n = \frac{(E_{n,1} - E_{n,0})}{\ln(E_{n,1} / E_{n,0})}$$

A separate weighting factor W is calculated for each of the n sectors, using the same formula as in the previous example.

Substituting the figures from Table 2 into these equations gives:

$$W_{Sector A} = \frac{(570 - 500)}{\ln(570 / 500)} = 534.236$$

$$W_{Sector B} = \frac{(450 - 500)}{\ln(450 / 500)} = 474.561$$

$$\Delta Q = \left[534.236 \times \ln \left(\frac{8.636}{8.333} \right) \right] + \left[474.561 \times \ln \left(\frac{11.538}{12.500} \right) \right] = -18.903$$

$$\Delta A = (534.236 + 474.561) \times \ln \left(\frac{105}{100} \right) = 49.219$$

$$\Delta S = \left[534.236 \times \ln \left(\frac{0.6286}{0.6000} \right) \right] + \left[474.561 \times \ln \left(\frac{0.3714}{0.4000} \right) \right] = -10.316$$

Thus, the observed increase in total energy consumption of 20 TJ can be attributed to three causes:

- an increase in the overall level of economic activity, to which can be attributed an increase of 49.219 TJ in total final energy consumption
- a reduction in energy intensity (which may or may not result from efficiency improvements), to which can be attributed a decrease of 18.903 TJ in total final energy consumption
- structural change, to which can be attributed a decrease of 10.316 TJ in total final energy consumption

Note that the portion of the change in energy consumption that is attributed to activity level changes is the same as in the first example, which is to be expected since the overall change in activity level is the same in the two examples. However, the availability of additional data means it is

now possible to correctly attribute part of the change in total energy consumption to structural effects.

This more detailed analysis that allows structural change to be correctly separated from genuine efficiency improvements can be continued to successively greater levels of disaggregation, depending on the availability of data. Table A3 shows the same example as previously, but where additional data is available on two sub-sectors (Sub-sector i and Sub-sector ii) that make up Sector A.

Table A3 Hypothetical example expanded to include sub-sectoral data

	Year 0			Year 1		
	Sector A		Sector B	Sector A		Sector B
	Sub-sector i	Sub-sector ii		Sub-sector i	Sub-sector ii	
GVA (billion \$)	45	15	40	51	15	39
Share of GVA	0.4500	0.1500	0.4000	0.4857	0.1429	0.3714
Energy consumption (TJ)	300	200	500	340	230	450
Energy intensity (kJ/\$)	6.667	13.333	12.500	6.667	15.333	11.538

The sub-sectors are treated in exactly the same way in a decomposition analysis as the sectors were in the previous example. The equations for identifying the different causal factors behind the change in total energy consumption are the same as previously, with the difference being that the summations must now be performed across three 'components': Sub-sector i, Sub-sector ii and Sector B. Three weighting factors must also be calculated, one for each of these components.

Substituting the figures from Table 3 into the equations gives:

$$W_{Subsector\ i} = \frac{(340 - 300)}{\ln(340 / 300)} = 319.583$$

$$W_{Subsector\ ii} = \frac{(230 - 200)}{\ln(230 / 200)} = 214.651$$

$$W_{Sector\ B} = \frac{(450 - 500)}{\ln(450 / 500)} = 474.561$$

$$\Delta Q = \left[319.583 \times \ln\left(\frac{6.667}{6.667}\right) \right] + \left[214.651 \times \ln\left(\frac{15.333}{13.333}\right) \right] + \left[474.561 \times \ln\left(\frac{11.538}{12.500}\right) \right] = -7.985$$

$$\Delta A = (319.583 + 214.651 + 474.561) \times \ln\left(\frac{105}{100}\right) = 49.219$$

$$\Delta S = \left[319.583 \times \ln\left(\frac{0.4857}{0.4500}\right) \right] + \left[214.651 \times \ln\left(\frac{0.1429}{0.1500}\right) \right] + \left[474.561 \times \ln\left(\frac{0.3714}{0.4000}\right) \right] = -21.234$$

The earlier analysis, which looked only at sector-level effects, indicated that a decrease in total energy consumption of 18.903 TJ could be attributed to energy intensity improvements. However, this current analysis, which is able to 'see' sub-sectoral effects, shows that most of this apparent reduction in energy intensity is actually attributable to structural shifts between sub-sectors – namely, a growth in the less energy intensive Sub-sector i relative to Sub-sector ii.

Overall, the observed increase in total energy consumption of 20 TJ can now be attributed to the three main causal factors as follows:

- an increase in the overall level of economic activity, to which can be attributed an increase of 49.219 TJ in total final energy consumption
- a reduction in energy intensity (which may or may not result from efficiency improvements), to which can be attributed a decrease of 7.985 TJ in total final energy consumption
- structural change, to which can be attributed a decrease of 21.234 TJ in total final energy consumption

This example illustrates an analysis where the economy consists of just two sectors, and where one of those sectors is divided into two sub-sectors. In a real-world analysis, this process of sub-dividing the economy into successively smaller components for the purpose of decomposition analysis can be continued, disaggregating sub-sectors into industries, industries into firms and, in principle, firms into individual facilities. As the decomposition analysis becomes successively more detailed, increasingly subtle structural effects can be identified, and the extent to which energy intensity represents a good proxy for energy efficiency improves. However, a decision must be made as to what level of detail is sufficient. Two factors should inform this decision: the availability of data (or the cost of obtaining it) at greater levels of detail, and the amount of extra useful information that a more detailed analysis would yield. In particular, if the sub-divisions used for decomposition analysis are similar to each other in terms of their energy use, there will be no structural effects because a change in the relative sizes of similar sub-divisions would have no effect on total energy consumption. That extra depth of analysis would therefore yield no useful information.

ANNEX B HOUSEHOLD ENERGY SURVEY QUESTIONNAIRE

Question ID	Question	Answer
1	Section 1: Household background	
2	Name of respondent	
	<i>[T_2_1] Name of respondent</i>	
	<i>[T_2_2] Surname of respondent</i>	
3	[Q_3] Contact number of respondent	
4	[Q_4/Q_4_S] Respondent's role within household	<1> Head of household <2> Spouse/partner <3> Other family member (child, parent, grandparent, sibling etc.) <4> Employee of household <5> Tenant (no family ties) <6> Other
5	[Q_5/Q_5_S] Population group of respondent	<1> African <2> Indian/Asian <3> Coloured <4> White <5> Other
6	Physical address (as appearing on electricity bill if applicable)	
	<i>[T_6_1] House number or street number</i>	
	<i>[T_6_2] Street name</i>	
	<i>[T_6_3] Suburb/township extension</i>	
	<i>[T_6_4] Stand/erf number</i>	
7	[Q_7] Ward number	
8	[Q_8] Description of dwelling	<1> House, town house or cluster <2> Flat/apartment <3> Cottage/granny flat (permanent dwelling on the grounds of a larger permanent property) <4> Informal dwelling/shack (including backyard shack)
9	[Q_9] Number of rooms (not including bathrooms, toilets, hallways or corridors) for the MAIN DWELLING	
10	Number of people for whom this is their main place of residence (including respondent)	
	<i>[T_10_1] Number of toddlers/infants</i>	

	<i>aged under 5</i>	
	<i>[T_10_2] Number of children aged between 5 - 17</i>	
	<i>[T_10_3] Number of adults aged 18 and over</i>	
11	[Q_11] Are there any other dwellings on the property?	<1> Yes <2> No
12	[Q_12] Are you staying in the main dwelling?	<1> Yes <2> No
13	[Q_13] How many OTHER dwellings are on this property (not including the one you live in)	
14	[Q_14] How many people live in the OTHER dwellings/buildings (all the people in all the OTHER dwellings combined)	
15	Section 2: Ownership of electric, electronic and other appliances	
16	[Q_16] Which of the following does the household own (in working condition) and use on a regular basis?	<1> Domestic workers and gardeners (live-in and part-time) <2> Home security service <3> Swimming pool <4> Motor vehicle <5> TV set <6> Radio <7> DVD/Blu Ray player <8> Pay TV (M-Net, DSTV, Top TV) <9> Home theatre system/hi-fi system <10> Landline telephone (Telkom/Neotel) <11> Cell phone <12> Computer (desktop/laptop) <13> Printer/fax/scanner <14> Air conditioner (excluding fans) <15> Vacuum cleaner/floor polisher <16> Dishwashing machine <17> Washing machine <18> Tumble dryer <19> Deep freezer (free standing) <20> Refrigerator or combined fridge/freezer <21> Electric or gas stove <22> Microwave oven <23> Built-in kitchen sink <24> Tap water in house/on property <25> Hot running water from a geyser

		<26> Flush toilet in/outside house <27> None of the above
17	[Q_17] How many vehicles does the household own?	
18	[Q_18] How many TV sets does the household own?	
19	[Q_19] How many radios does the household own?	
20	[Q_20] How many cell phones does the household own?	
21	[Q_21] How old is your air conditioner (in years)?	
22	[Q_22] How old is your vacuum cleaner/floor polisher (in years)?	
23	[Q_23] How old is your dishwashing machine (in years)?	
24	[Q_24] How old is your washing machine (in years)?	
25	[Q_25] How old is your tumble dryer (in years)?	
26	[Q_26] How old is your deep freezer (in years)?	
27	[Q_27] How old is your refrigerator or combined fridge/freezer (in years)?	
28	[Q_28] How old is your stove (in years)?	
29	[Q_29] How old is your microwave oven (in years)?	
30	[Q_30/Q_30_S] Do you run any of these income activities (jobs/work) from home that require electricity?	<1> Fast food/catering/cooking/baking <2> Hairdressing/beauty treatments <3> Spaza shop/shop from home <4> Automotive repairs/maintenance <5> Sewing/tailoring <6> Computer/internet based work <7> Other <8> None of the above
31	Section 3: Type and amount of energy used	
32	[Q_32/Q_32_S] What is the MAIN energy source used for COOKING?	<1> Electricity <2> Paraffin <3> Coal <4> Charcoal <5> Gas <6> Wood <7> Car battery <8> Generator

		<9> Solar power <10> Candles <11> Other
33	[Q_33] How often do you use ELECTRICITY for cooking?	<1> More than once a day <2> Once a day <3> Less than once a day
34	[Q_34] How often do you use PARAFFIN for cooking?	<1> More than once a day <2> Once a day <3> Less than once a day
35	[Q_35] How often do you use COAL for cooking?	<1> More than once a day <2> Once a day <3> Less than once a day
36	[Q_36] How often do you use CHARCOAL for cooking?	<1> More than once a day <2> Once a day <3> Less than once a day
37	[Q_37] How often do you use GAS for cooking?	<1> More than once a day <2> Once a day <3> Less than once a day
38	[Q_38] How often do you use WOOD for cooking?	<1> More than once a day <2> Once a day <3> Less than once a day
39	[Q_39] How often do you use a CAR BATTERY for cooking?	<1> More than once a day <2> Once a day <3> Less than once a day
40	[Q_40] How often do you use a GENERATOR for cooking?	<1> More than once a day <2> Once a day <3> Less than once a day
41	[Q_41] How often do you use SOLAR POWER for cooking?	<1> More than once a day <2> Once a day <3> Less than once a day
42	[Q_42] How often do you use CANDLES for cooking?	<1> More than once a day <2> Once a day <3> Less than once a day
43	[Q_43] How often do you use OTHER ENERGY SOURCE for cooking?	<1> More than once a day <2> Once a day <3> Less than once a day
44	[Q_44/Q_44_S] What is the SECONDARY energy source used for COOKING?	<1> Electricity <2> Paraffin <3> Coal <4> Charcoal <5> Gas <6> Wood <7> Car battery <8> Generator <9> Solar power <10> Candles <11> Other <12> None of the above
45	[Q_45] How often do you use ELECTRICITY for cooking?	<1> Several times a week <2> Several times a month <3> Once a month or less

46	[Q_46] How often do you use PARAFFIN for cooking?	<1> Several times a week <2> Several times a month <3> Once a month or less
47	[Q_47] How often do you use COAL for cooking?	<1> Several times a week <2> Several times a month <3> Once a month or less
48	[Q_48] How often do you use CHARCOAL for cooking?	<1> Several times a week <2> Several times a month <3> Once a month or less
49	[Q_49] How often do you use GAS for cooking?	<1> Several times a week <2> Several times a month <3> Once a month or less
50	[Q_50] How often do you use WOOD for cooking?	<1> Several times a week <2> Several times a month <3> Once a month or less
51	[Q_51] How often do you use a CAR BATTERY for cooking?	<1> Several times a week <2> Several times a month <3> Once a month or less
52	[Q_52] How often do you use a GENERATOR for cooking?	<1> Several times a week <2> Several times a month <3> Once a month or less
53	[Q_53] How often do you use SOLAR POWER for cooking?	<1> Several times a week <2> Several times a month <3> Once a month or less
54	[Q_54] How often do you use CANDLES for cooking?	<1> Several times a week <2> Several times a month <3> Once a month or less
55	[Q_55] How often do you use OTHER ENERGY SOURCE for cooking?	<1> Several times a week <2> Several times a month <3> Once a month or less
56	[Q_56] Do you operate any of your cooking stoves even when you are not cooking, in order to keep your house warm?	<1> Yes <2> No
57	[Q_57/Q_57_S] What is the MAIN energy source used for SPACE HEATING your home? (Especially during the winter months)	<1> Electricity <2> Paraffin <3> Coal <4> Charcoal <5> Gas <6> Wood <7> Car battery <8> Generator <9> Solar power <10> Candles <11> Other <12> None of the above
58	[Q_58] How often do you use ELECTRICITY for space heating?	<1> On a daily basis <2> Several times a week <3> Several times a month
59	[Q_59] How often do you use PARAFFIN for space heating?	<1> On a daily basis <2> Several times a week

		<3> Several times a month
60	[Q_60] How often do you use COAL for space heating?	<1> On a daily basis <2> Several times a week <3> Several times a month
61	[Q_61] How often do you use CHARCOAL for space heating?	<1> On a daily basis <2> Several times a week <3> Several times a month
62	[Q_62] How often do you use GAS for space heating?	<1> On a daily basis <2> Several times a week <3> Several times a month
63	[Q_63] How often do you use WOOD for space heating?	<1> On a daily basis <2> Several times a week <3> Several times a month
64	[Q_64] How often do you use CAR BATTERY for space heating?	<1> On a daily basis <2> Several times a week <3> Several times a month
65	[Q_65] How often do you use a GENERATOR for space heating?	<1> On a daily basis <2> Several times a week <3> Several times a month
66	[Q_66] How often do you use SOLAR POWER for space heating?	<1> On a daily basis <2> Several times a week <3> Several times a month
67	[Q_67] How often do you use CANDLES for space heating?	<1> On a daily basis <2> Several times a week <3> Several times a month
68	[Q_68] How often do you use OTHER ENERGY SOURCE for space heating?	<1> On a daily basis <2> Several times a week <3> Several times a month
69	[Q_69/Q_69_S] What is the SECONDARY energy source used for SPACE HEATING in your home? (Especially during the winter months)	<1> Electricity <2> Paraffin <3> Coal <4> Charcoal <5> Gas <6> Wood <7> Car battery <8> Generator <9> Solar power <10> Candles <11> Other <12> None of the above
70	[Q_70] How often do you use ELECTRICITY for space heating?	<1> Several times a week <2> Several times a month <3> Once a month or less
71	[Q_71] How often do you use PARAFFIN for space heating?	<1> Several times a week <2> Several times a month <3> Once a month or less
72	[Q_72] How often do you use COAL for space heating?	<1> Several times a week <2> Several times a month <3> Once a month or less
73	[Q_73] How often do you use CHARCOAL for space heating?	<1> Several times a week <2> Several times a month

		<3> Once a month or less
74	[Q_74] How often do you use GAS for space heating?	<1> Several times a week <2> Several times a month <3> Once a month or less
75	[Q_75] How often do you use WOOD for space heating?	<1> Several times a week <2> Several times a month <3> Once a month or less
76	[Q_76] How often do you use CAR BATTERY for space heating?	<1> Several times a week <2> Several times a month <3> Once a month or less
77	[Q_77] How often do you use a GENERATOR for space heating?	<1> Several times a week <2> Several times a month <3> Once a month or less
78	[Q_78] How often do you use SOLAR POWER for space heating?	<1> Several times a week <2> Several times a month <3> Once a month or less
79	[Q_79] How often do you use CANDLES for space heating?	<1> Several times a week <2> Several times a month <3> Once a month or less
80	[Q_80] How often do you use OTHER ENERGY SOURCE for space heating?	<1> Several times a week <2> Several times a month <3> Once a month or less
81	[Q_81/Q_81_S] What is the MAIN energy source used for WATER HEATING?	<1> Electricity <2> Paraffin <3> Coal <4> Charcoal <5> Gas <6> Wood <7> Car battery <8> Generator <9> Solar power <10> Candles <11> Other
82	[Q_82] How often do you use ELECTRICITY for heating water?	<1> On a daily basis <2> Several times a week <3> Several times a month
83	[Q_83] How often do you use PARAFFIN for heating water?	<1> On a daily basis <2> Several times a week <3> Several times a month
84	[Q_84] How often do you use COAL for heating water?	<1> On a daily basis <2> Several times a week <3> Several times a month
85	[Q_85] How often do you use CHARCOAL for heating water?	<1> On a daily basis <2> Several times a week <3> Several times a month
86	[Q_86] How often do you use GAS for heating water?	<1> On a daily basis <2> Several times a week <3> Several times a month
87	[Q_87] How often do you use WOOD for heating water?	<1> On a daily basis <2> Several times a week <3> Several times a month

88	[Q_88] How often do you use a CAR BATTERY for heating water?	<1> On a daily basis <2> Several times a week <3> Several times a month
89	[Q_89] How often do you use GENERATOR for heating water?	<1> On a daily basis <2> Several times a week <3> Several times a month
90	[Q_90] How often do you use SOLAR POWER for heating water?	<1> On a daily basis <2> Several times a week <3> Several times a month
91	[Q_91] How often do you use CANDLES for heating water?	<1> On a daily basis <2> Several times a week <3> Several times a month
92	[Q_92] How often do you use OTHER ENERGY SOURCE for heating water?	<1> On a daily basis <2> Several times a week <3> Several times a month
93	[Q_93/Q_93_S] What is the SECONDARY energy source used for WATER HEATING?	<1> Electricity <2> Paraffin <3> Coal <4> Charcoal <5> Gas <6> Wood <7> Car battery <8> Generator <9> Solar power <10> Candles <11> Other <12> None of the above
94	[Q_94] How often do you use ELECTRICITY for heating water?	<1> Several times a week <2> Several times a month <3> Once a month or less
95	[Q_95] How often do you use PARAFFIN for heating water?	<1> Several times a week <2> Several times a month <3> Once a month or less
96	[Q_96] How often do you use COAL for heating water?	<1> Several times a week <2> Several times a month <3> Once a month or less
97	[Q_97] How often do you use CHARCOAL for heating water?	<1> Several times a week <2> Several times a month <3> Once a month or less
98	[Q_98] How often do you use GAS for heating water?	<1> Several times a week <2> Several times a month <3> Once a month or less
99	[Q_99] How often do you use WOOD for heating water?	<1> Several times a week <2> Several times a month <3> Once a month or less
100	[Q_100] How often do you use a CAR BATTERY for heating water?	<1> Several times a week <2> Several times a month <3> Once a month or less
101	[Q_101] How often do you use GENERATOR for heating water?	<1> Several times a week <2> Several times a month <3> Once a month or less

102	[Q_102] How often do you use SOLAR POWER for heating water?	<1> Several times a week <2> Several times a month <3> Once a month or less
103	[Q_103] How often do you use CANDLES for heating water?	<1> Several times a week <2> Several times a month <3> Once a month or less
104	[Q_104] How often do you use OTHER ENERGY SOURCE for heating water?	<1> Several times a week <2> Several times a month <3> Once a month or less
105	[Q_105/Q_105_S] What is the MAIN energy source used for LIGHTING?	<1> Electricity <2> Paraffin <3> Coal <4> Charcoal <5> Gas <6> Wood <7> Car battery <8> Generator <9> Solar power <10> Candles <11> Other
106	[Q_106] How often do you use ELECTRICITY for lighting?	<1> On a daily basis <2> Several times a week <3> Several times a month
107	[Q_107] How often do you use PARAFFIN for lighting?	<1> On a daily basis <2> Several times a week <3> Several times a month
108	[Q_108] How often do you use COAL for lighting?	<1> On a daily basis <2> Several times a week <3> Several times a month
109	[Q_109] How often do you use CHARCOAL for lighting?	<1> On a daily basis <2> Several times a week <3> Several times a month
110	[Q_110] How often do you use GAS for lighting?	<1> On a daily basis <2> Several times a week <3> Several times a month
111	[Q_111] How often do you use WOOD for lighting?	<1> On a daily basis <2> Several times a week <3> Several times a month
112	[Q_112] How often do you use a CAR BATTERY for lighting?	<1> On a daily basis <2> Several times a week <3> Several times a month
113	[Q_113] How often do you use a GENERATOR for lighting?	<1> On a daily basis <2> Several times a week <3> Several times a month
114	[Q_114] How often do you use SOLAR POWER for lighting?	<1> On a daily basis <2> Several times a week <3> Several times a month
115	[Q_115] How often do you use CANDLES for lighting?	<1> On a daily basis <2> Several times a week <3> Several times a month
116	[Q_116] How often do you use	<1> On a daily basis

	OTHER ENERGY SOURCE for lighting?	<2> Several times a week <3> Several times a month
117	[Q_117/Q_117_S] What is the SECONDARY energy source used for LIGHTING?	<1> Electricity <2> Paraffin <3> Coal <4> Charcoal <5> Gas <6> Wood <7> Car battery <8> Generator <9> Solar power <10> Candles <11> Other <12> None of the above
118	[Q_118] How often do you use ELECTRICITY for lighting?	<1> Several times a week <2> Several times a month <3> Once a month or less
119	[Q_119] How often do you use PARAFFIN for lighting?	<1> Several times a week <2> Several times a month <3> Once a month or less
120	[Q_120] How often do you use COAL for lighting?	<1> Several times a week <2> Several times a month <3> Once a month or less
121	[Q_121] How often do you use CHARCOAL for lighting?	<1> Several times a week <2> Several times a month <3> Once a month or less
122	[Q_122] How often do you use GAS for lighting?	<1> Several times a week <2> Several times a month <3> Once a month or less
123	[Q_123] How often do you use WOOD for lighting?	<1> Several times a week <2> Several times a month <3> Once a month or less
124	[Q_124] How often do you use a CAR BATTERY for lighting?	<1> Several times a week <2> Several times a month <3> Once a month or less
125	[Q_125] How often do you use a GENERATOR for lighting?	<1> Several times a week <2> Several times a month <3> Once a month or less
126	[Q_126] How often do you use SOLAR POWER for lighting?	<1> Several times a week <2> Several times a month <3> Once a month or less
127	[Q_127] How often do you use CANDLES for lighting?	<1> Several times a week <2> Several times a month <3> Once a month or less
128	[Q_128] How often do you use OTHER ENERGY SOURCE for lighting?	<1> Several times a week <2> Several times a month <3> Once a month or less
129	Section 4: Electricity consumption	
130	[Q_130] Is your household supplied with electricity?	<1> Yes <2> No
131	[Q_131] What kind of electricity	<1> Monthly bill (credit meter)

	meter do you have?	<2> Pre-paid meter
132	[Q_132/Q_132_S] Who is your electricity supplier?	<1> Eskom <2> Local municipality <3> Other
133	[Q_133] How much electricity has your household used in the LAST MONTH? (Please refer to bills or written records if possible)	<1> Rand <2> kWh
134	[Q_134] How much electricity has your household used in the LAST MONTH? State in Rand	
135	[Q_135] How much electricity has your household used in the LAST MONTH? State in kWh	
136	[Q_136] How much electricity has your household used in the LAST 12 MONTHS? (Please refer to bills or written records if possible)	<1> Rand <2> kWh
137	[Q_137] How much electricity has your household used in the LAST 12 MONTHS? State in R	
138	[Q_138] How much electricity has your household used in the LAST 12 MONTHS? State in kWh	
139	[Q_139] Did the respondent refer to some form of documentation? (Bills, written records, etc.)	<1> Yes <2> No
140	Section 5: Alternative energy sources consumption	
141	[Q_141] Paraffin purchased/used over the last month	<1> Rand <2> Litres
142	[Q_142] Paraffin purchased/used in Rand	
143	[Q_143] Paraffin purchased/used in Litres	
144	[Q_144] Price of paraffin per Litre?	
145	[Q_145] Coal purchased/used over the last month	<1> Rand <2> Kg
146	[Q_146] Coal purchased/used in Rand	
147	[Q_147] Coal purchased/used in Kg	
148	[Q_148] Price of coal per Kg?	
149	[Q_149] Charcoal purchased/used over the last month	<1> Rand <2> Kg
150	[Q_150] Charcoal purchased/used in Rand	
151	[Q_151] Charcoal purchased/used in Kg	
152	[Q_152] Price of charcoal per Kg?	
153	[Q_153] Gas purchased/used over the last month	<1> Rand <2> Kg
154	[Q_154] Gas purchased/used in Rand	

155	[Q_155] Gas purchased/used in Kg	
156	[Q_156] Price of gas per Kg?	
157	[Q_157] Wood purchased/used over the last month	<1> Rand <2> Kg <3> Bundle
158	[Q_158] Wood purchased/used in Rand	
159	[Q_159] Wood purchased/used/collected in Kg	
160	[Q_160] Wood purchased/used/collected in number of bundles	
161	[Q_161] Price of wood per Kg?	
162	[Q_162] Price of wood per bundle?	
163	[Q_163] Fuel for generator (diesel/petrol) purchased/used over the last month	<1> Rand <2> Litres
164	[Q_164] Fuel for generator (diesel/petrol) purchased/used in Rand	
165	[Q_165] Fuel for generator (diesel/petrol) purchased/used in Litres	
166	[Q_166] Price of fuel for generator (diesel/petrol) per Litre?	
167	[Q_167] Candles purchased/used over the last month	<1> Rand <2> Packets
168	[Q_168] Candles purchased/used in Rand	
169	[Q_169] Candles purchased/used in packets	
170	[Q_170] Price of candles per packet?	
171	[Q_171] 'Other' energy source usage over the last month	<1> Rand <2> Litres <3> Kg <4> Bundle
172	[Q_172] 'Other' source used/purchased in Rand	
173	[Q_173] 'Other' source used/purchased in litres	
174	[Q_174] 'Other' source used/purchased in Kg	
175	[Q_175] 'Other' source used/purchased in bundles	
176	[Q_176] Price of 'other' source per unit (Kg/litre/bundle)?	
177	Section 6: Attitude and awareness regarding household energy usage	
178	[Q_178] The cost of energy (cooking fuels, electricity etc.) is a burden and you struggle to afford it	

179	[Q_179] As a household, you are always aware of how much energy you are using	
180	[Q_180] You are very aware of what opportunities there are to save energy around the home	
181	[Q_181] You always behave in ways that save energy (switch off unnecessary lights and appliances etc.)	
182	[Q_182] When buying an electrical appliance, you always consider the electricity consumption when deciding which model to buy	
183	Section 7: Energy saving technology	
184	Please answer whether you are aware of, or have the following technologies installed in your home	
	[T_184_1] Insulation of roof/ceiling/wall	<1> Present and installed more than a year ago <2> Present and installed recently <3> Not present, but IS aware of it <4> Not present and NOT aware of it
	[T_184_2] Energy efficient lights	<1> Present and installed more than a year ago <2> Present and installed recently <3> Not present, but IS aware of it <4> Not present and NOT aware of it
	[T_184_3] Insulating blanket of geyser/pipes	<1> Present and installed more than a year ago <2> Present and installed recently <3> Not present, but IS aware of it <4> Not present and NOT aware of it
	[T_184_4] Solar water heater/solar geyser	<1> Present and installed more than a year ago <2> Present and installed recently <3> Not present, but IS aware of it <4> Not present and NOT aware of it
	[T_184_5] Other solar system (lighting etc.)	<1> Present and installed more than a year ago <2> Present and installed recently <3> Not present, but IS aware of it <4> Not present and NOT aware of it
	[T_184_6] Ripple control on geysers (timer)	<1> Present and installed more than a year ago <2> Present and installed recently

		<p><3> Not present, but IS aware of it</p> <p><4> Not present and NOT aware of it</p>
	[T_184_7] Ripple control on other appliances (pool, air conditioner)	<p><1> Present and installed more than a year ago</p> <p><2> Present and installed recently</p> <p><3> Not present, but IS aware of it</p> <p><4> Not present and NOT aware of it</p>
	[T_184_8] Smart metering	<p><1> Present and installed more than a year ago</p> <p><2> Present and installed recently</p> <p><3> Not present, but IS aware of it</p> <p><4> Not present and NOT aware of it</p>
	[T_184_9] Heat pumps	<p><1> Present and installed more than a year ago</p> <p><2> Present and installed recently</p> <p><3> Not present, but IS aware of it</p> <p><4> Not present and NOT aware of it</p>
	[T_184_10] Low-flow shower head	<p><1> Present and installed more than a year ago</p> <p><2> Present and installed recently</p> <p><3> Not present, but IS aware of it</p> <p><4> Not present and NOT aware of it</p>
	[T_184_11] Other	<p><1> Present and installed more than a year ago</p> <p><2> Present and installed recently</p> <p><3> Not present, but IS aware of it</p> <p><4> Not present and NOT aware of it</p>
185	[Q_185] Please specify other solar systems used	
186	[Q_186] Please specify ripple control on other devices (apart from your geyser)	
187	[Q_187] How many of the lights present in your home are energy efficient lights?	<p><1> All of them</p> <p><2> Most of them</p> <p><3> Some of them</p>
188	[Q_188] Please specify other technologies used	
189	[Q_189] Since the installation of INSULATION (roof, ceiling, wall) how has it impacted your energy bill?	
190	[Q_190/Q_190_S] Since the installation of INSULATION (roof, ceiling, wall) does any of the following apply to you?	<p><1> House is warmer in winter/cooler in summer</p> <p><2> Reduced use of heater/fan/aircon/fire for heat</p> <p><3> High (initial) cost of insulation</p>

		<4> Other
191	[Q_191] Since the installation of ENERGY EFFICIENT LIGHTS how has it impacted your energy bill?	
192	[Q_192/Q_192_S] Since the installation of ENERGY EFFICIENT LIGHTS does any of the following apply to you?	<1> Longevity of lights (last longer) <2> Brightness of lights are better <3> Brightness of lights are worse <4> High (initial) cost of energy efficient lights <5> Long term savings on light bulbs and energy <6> Other
193	[Q_193] Since the installation of the SOLAR WATER HEATER/GEYSER how has it impacted your energy bill?	
194	[Q_194/Q_194_S] Since the installation of a SOLAR WATER HEATER/GEYSER does any of the following apply to you?	<1> Geyser is switched off during the day <2> High (initial) cost of installing solar geyser <3> Long term savings <4> Other
195	[Q_195] Since the installation of the GEYSER/PIPE BLANKETS how has it impacted your energy bill?	
196	[Q_196/Q_196_S] Since the installation of a GEYSER/PIPE BLANKETS, does any of the following apply to you?	<1> Water stays warm for longer <2> Geyser is switched off during the day <3> Less pipe burst <4> Geyser and pipes last longer <5> Protection against elements <6> Other
197	[Q_197] Since the installation of the RIPPLE CONTROL on the GEYSER how has it impacted your energy bill?	
198	[Q_198/Q_198_S] Since the installation of a RIPPLE CONTROL on the GEYSER does any of the following apply to you?	<1> Control and monitoring energy usage <2> High (initial) cost of ripple control <3> Other
199	[Q_199] Since the installation of the RIPPLE CONTROL how has it impacted your energy bill?	
200	[Q_200/Q_200_S] Since the installation of RIPPLE CONTROL does any of the following apply to you?	<1> Control and monitoring energy usage <2> High (initial) cost of ripple control <3> Other
201	[Q_201] Since the installation of the SMART METERING how has it impacted your energy bill?	
202	[Q_202/Q_202_S] Since the	<1> High (initial) cost of smart

	installation of SMART METERING, does any of the following apply to you?	metering <2> Monitoring and control of energy usage <3> Better energy usage and financial planning due to monitoring of energy usage <4> Other
203	[Q_203] Since the installation of a HEAT PUMP how has it impacted your energy bill?	
204	[Q_204/Q_204_S] Since the installation of a HEAT PUMP does any of the following apply to you?	<1> Water stays warm for longer <2> High (initial) cost of installing heat pump <3> Other
205	[Q_205] Since the installation of a LOW FLOW SHOWER HEAD how has it impacted your energy bill?	
206	[Q_206/Q_206_S] Since the installation of a LOW FLOW SHOWER HEAD does any of the following apply to you?	<1> Less usage of hot water <2> Other
207	[Q_207/Q_207_S] Does your household have any other significant issues regarding energy	<1> Power cuts <2> Fires <3> Paraffin poisoning <4> Access to power <5> Smoke inhalation <6> Other <7> None of the above
208	[Q_208] Would you be willing to allow your electricity supplier to pass data on your metered electricity consumption over the last year to a representative of the DEPARTMENT OF ENERGY?	<1> Yes <2> No
209	Please sign the consent form. Hand over the consent form to respondent to sign.	
210	[Q_210] Electricity meter number	
211	[Q_211] What is the total monthly income for the household (ALL sources incl. grants, pension, interest etc. of ALL the members of the household)	<1> No income <2> R1-R500 <3> R501-R1500 <4> R1501-R3000 <5> R3001-R5000 <6> R5001-R7000 <7> R7001-R10000 <8> R10001-R15000 <9> R15001-R25000 <10> R25001-R35000 <11> R35001-R50000 <12> More than R50000 <13> Refuse

212	[Q_212] This concludes the interview. Thank you for your cooperation! :) Before leaving, may I please take a picture of your home (for our records)	<1> Yes <2> No
213	Take a picture of the house/dwelling	
214	Was GPS captured until now: {0} End of the survey. This question has a validation check to make sure the GPS location info was captured	
215	This concludes the interview. Thank you for your cooperation! :)	