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DEPARTMENT OF ENERGY

SOUTH AFRICA'S ENERGY EFFICIENCY TARGETS

FIRST ANNUAL MONITORING REPORT

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This publication combines data and consultations from a two-phase project, the first supported a pilot phase to develop the Energy Efficiency Target Monitoring System and the second to operationalise it. The Department of Energy has worked closely with key stakeholders in the industrial, residential, and commercial & public sectors in defining a suitable and effective system and collecting data, whom we would like to thank for their cooperation and input.

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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 report presents the main results obtained from this system for the period up to 2011 – the latest date for which comprehensive data is currently available.

Between 2000 and 2011, the energy intensity (energy consumed per unit of value-added) of the economically productive sectors reduced by almost 17%, while that of the residential sector (measured in terms of energy consumption per household) remained almost unchanged. Using the process of decomposition analysis reveals that efficiency changes accounted for a 26% reduction in economy-wide energy consumption relative to the 2000 baseline. Against a general trend of improving efficiency, there have been small reversals in some years, the most notable of which was a year-on-year fall in energy efficiency of 6.0% for 2008-09, 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 29.9% between 2000 and 2011. 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 34.4% relative to the 2000 baseline. 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 2010-12. This was used to conduct a bottom-up analysis of energy efficiency trends, which indicates that efficiency fell by about 4.7% 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 bottom-up process. However, for the single year for which both analyses could be conducted (2010-11) the top-down analysis indicated an improvement of 7.6%, while the bottom-up analysis showed a 2.6% improvement. This difference in result is not unexpected, given the significant increase in the price of many metals that occurred over that period, which would have the effect of accentuating improvements in energy per unit of value-added.

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 2010. This analysis suggests that electricity efficiency over this period declined by 2.9% (the NEES target for the sector is a 12% improvement by 2015 relative to 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 ten bands according to the 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 2011 have resulted in a fall in consumption of 29.5% relative to the 2000 baseline, 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 4-7 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 apparent fall in efficiency may in fact be due to factors not connected with efficiency that are hidden from the current analysis because of a lack of detailed data. In both the commercial & public and the residential sectors, there is an urgent need for initiating the regular collection of consistent and comprehensive data on energy consumption, 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 being revised to correct for some inconsistencies, and the revised versions of the aggregated energy balances were not available at the time the current analysis was conducted. The figures used in this analysis were therefore derived from the raw disaggregated data on which the Energy Balances are based. Because this data is itself only available at present for years up to 2011, it has only been possible to conduct an analysis for the period 2000-11.

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 2011, 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 2011, 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.

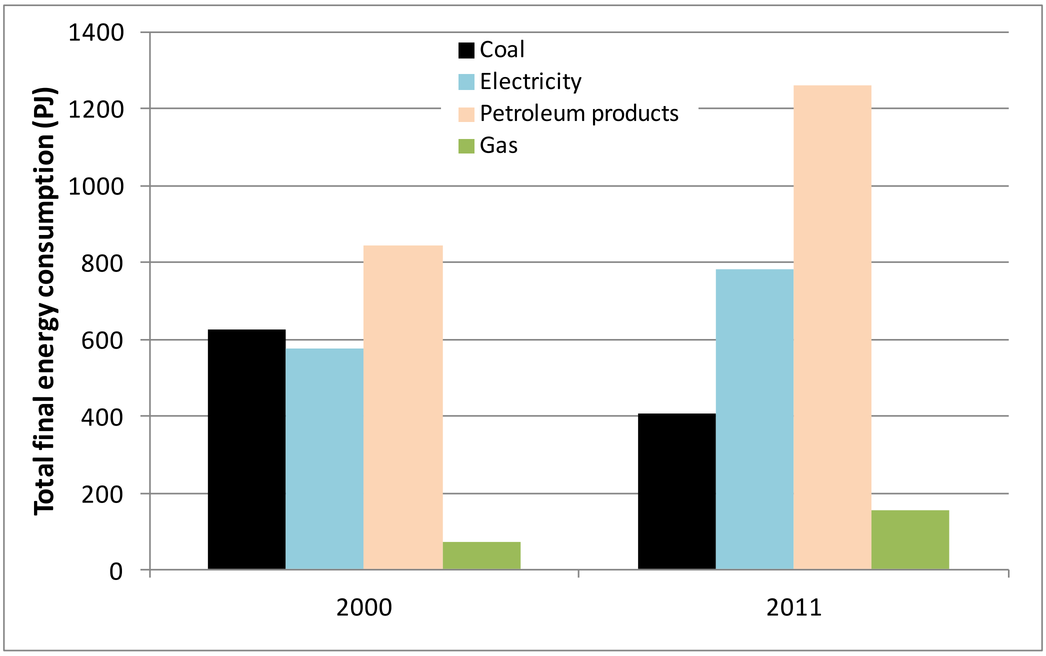

Figure 1 Fuel mix of final energy consumption for the South African economy – 2000 versus 2011

Table 1 Composition of total final energy consumption (PJ) by energy carrier, 2000 and 2011

	2000	2011	% change in consumption
Coal	624 (29%)	405 (16%)	-35%
Petroleum products	843 (40%)	1,259 (48%)	+49%
Gas	73 (3%)	155 (6%)	+112%
Electricity	577 (27%)	782 (30%)	+36%
TOTAL	**2,117**	**2,601**	**+23%**

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 2011 (the most recent year for which aggregate data is currently available), the total final energy consumption of the South African economy stood at about 2,601 PJ, an overall increase of 23% from its 2000 baseline of 2,117 PJ. Over the same period, the total GVA[1] of South Africa's productive sectors increased by about 47%, from about R1,138 billion up to R1,674 billion, while the number of households increased by about 38% from an estimated 10.3 million in 2000 up to 14.2 million in 2011. Considering the productive sectors alone, energy intensity decreased from 1.86 MJ/R in 2000 to 1.55 MJ/R in 2011, equivalent to an annual compounded reduction in energy intensity of about 1.6%.

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 residential and commercial & public sectors have seen moderate increases in their energy intensity, while the energy intensity of the other three sectors has fallen by significant and similar amounts, with the average energy intensity over the five years to 2011 being approximately 20% lower than for the five years to 2004.

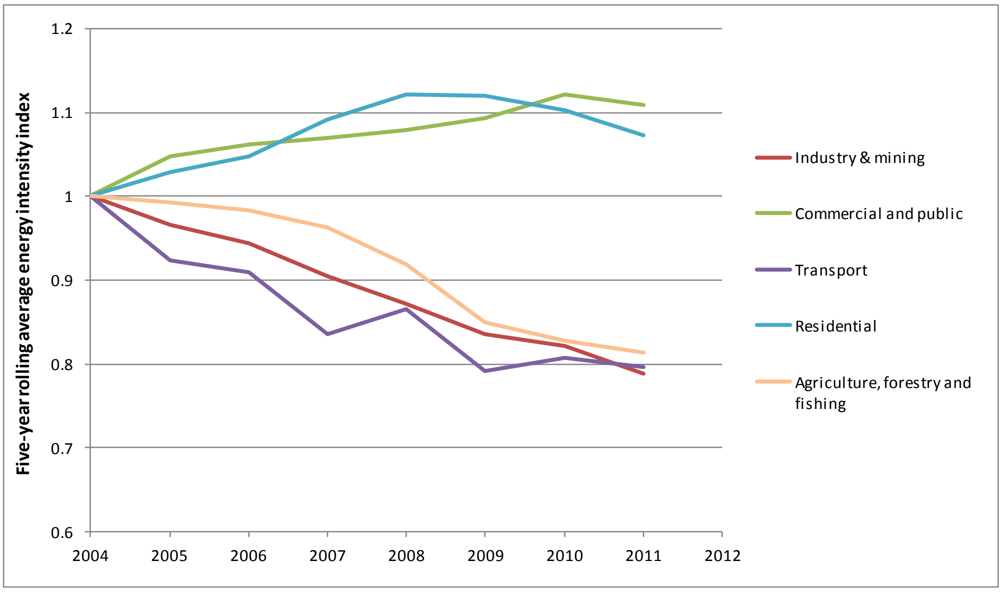

Figure 2 Trends in sector energy intensity. For clarity, five-year rolling average figures are shown in order to smooth out sharp fluctuations. Figures are expressed as an index relative to the value for 2004

[1] At constant 2005 prices

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 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 2011, with the results shown in Table 2 below. As discussed in "Methodological overview" 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 other chapters of this report. The analysis indicates that total final energy consumption increased by 235,288 TJ between 2000 and 2011, with this overall change being composed of:

- an <u>increase</u> in total final energy consumption of 835,862 TJ due to increased overall activity levels in the economy;
- a <u>decrease</u> in total final energy consumption of 58,470 TJ due to structural changes in the economy
- a <u>decrease</u> in total final energy consumption of 542,104 TJ due to improvements in energy efficiency

These results are displayed graphically in Figure 3 below.

Of the 58,470 TJ total reduction in energy consumption due to structural changes, this was composed of a much larger reduction attributable to structural changes *between* the main sectors, offset by a substantial increase in consumption due to structural changes *within* the residential 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, or for the period 2010-11, 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 2011 of 25.9%, 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 fall in energy efficiency between 2007-09.

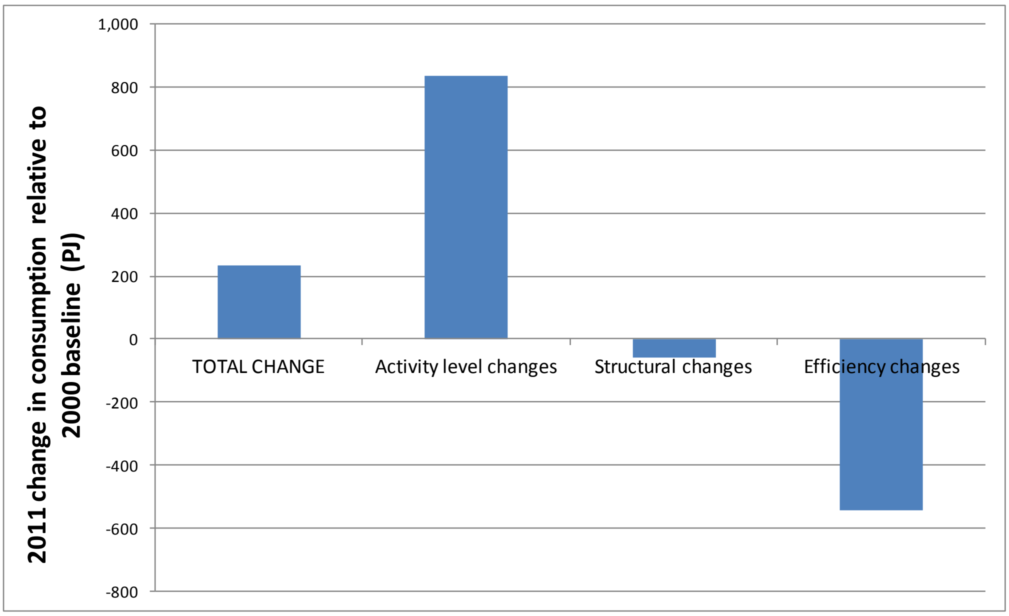

Figure 3 Decomposition analysis of cumulative change in total final energy consumption, 2000-11.

Table 2 Results of decomposition analysis of changes in total final energy consumption in South Africa between 2000-2011

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
CHANGE IN FINAL ENERGY CONSUMPTION (TJ)	85,175	33,908	46,208	19,550	-154,418	117,562	21,729	86,767	16,240	-142,602	105,170
ACTIVITY LEVEL EFFECT	60,181	74,860	65,092	92,113	104,210	107,867	113,484	84,340	-10,288	67,028	76,976
STRUCTURAL EFFECTS	-2,861	16,164	-4,875	13,430	-5,856	274	27,461	-9,774	-113,899	10,438	11,028
Inter-sectoral	-2,887	-4,227	997	1,035	-11,945	-24,771	-7,918	-26,672	-58,331	-3,664	-6,057
Intra-sectoral (industry & mining sector)	1,372	15,119	-7,228	2,676	-3,862	2,215	-2,028	4,494	-43,158	12,981	-2,968
Intra-sectoral (residential sector)	-1,346	5,272	1,356	9,862	9,981	23,147	37,637	12,732	-12,519	1,060	20,054
Intra-sectoral (commercial & public sector)				-144	-30	-317	-230	-328	109	60	0
EFFICIENCY EFFECT	27,855	-57,116	-14,009	-85,993	-252,772	9,422	-119,217	12,201	140,427	-220,067	17,166
% CHANGE IN ENERGY CONSUMPTION DUE TO EFFICIENCY CHANGES	1.3%	-2.6%	-0.6%	-3.8%	-11.1%	0.4%	-5.3%	0.5%	6.0%	-9.3%	0.8%

CUMULATIVE CHANGES (2000 base year)

	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
CHANGE IN FINAL ENERGY CONSUMPTION (TJ)	85,175	119,083	165,291	184,841	30,423	147,985	169,713	256,480	272,720	130,118	235,288
ACTIVITY LEVEL EFFECT	60,181	135,041	200,133	292,246	396,455	504,322	617,805	702,146	691,858	758,886	835,862
STRUCTURAL EFFECTS	-2,861	13,304	8,429	21,859	16,003	16,277	43,738	33,964	-79,935	-69,498	-58,470
Inter-sectoral	*-2,887*	*-7,113*	*-6,116*	*-5,081*	*-17,026*	*-41,797*	*-49,715*	*-76,387*	*-134,718*	*-138,382*	*-144,440*
Intra-sectoral (industry & mining sector)	*1,372*	*16,491*	*9,263*	*11,940*	*8,078*	*10,293*	*8,265*	*12,759*	*-30,398*	*-17,417*	*-20,385*
Intra-sectoral (residential sector)	*-1,346*	*3,926*	*5,282*	*15,144*	*25,125*	*48,271*	*85,909*	*98,641*	*86,121*	*87,181*	*107,235*
Intra-sectoral (commercial & public sector)	*0*	*0*	*0*	*-144*	*-174*	*-491*	*-721*	*-1,049*	*-940*	*-880*	*-880*
EFFICIENCY EFFECT	27,855	-29,261	-43,270	-129,263	-382,035	-372,614	-491,830	-479,629	-339,202	-559,270	-542,104
% CHANGE IN ENERGY CONSUMPTION DUE TO EFFICIENCY CHANGES	1.3%	-1.4%	-2.1%	-6.2%	-18.2%	-17.8%	-23.5%	-22.9%	-16.2%	-26.7%	-25.9%

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. Until 2003, the economy was lagging behind the rate of improvement needed to meet the NEES target. Since then, apart from a significant decline in efficiency in 2008-09, efficiency improvements have more than kept pace with the target level.

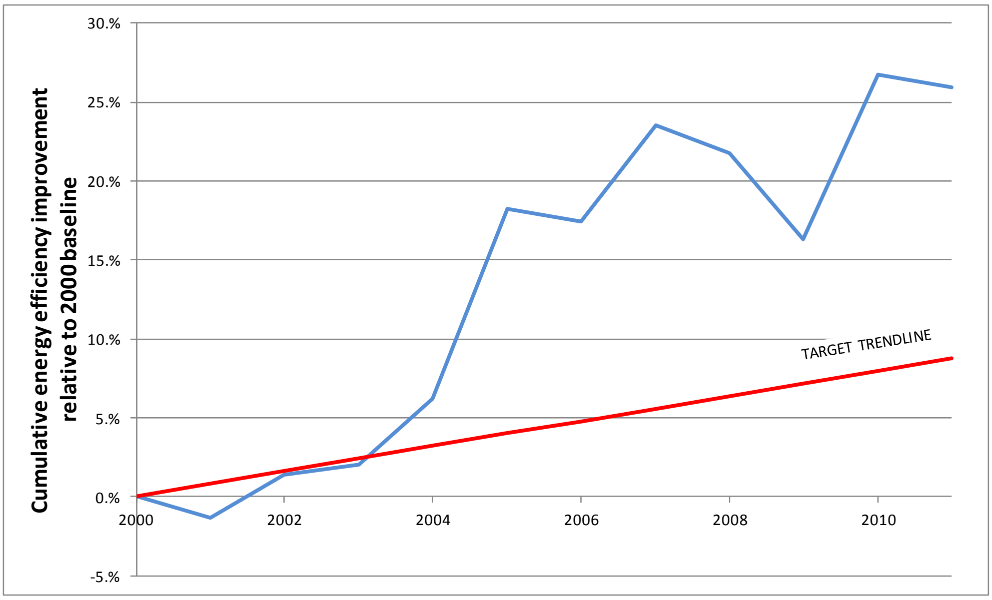

Figure 4 Trend through time of the cumulative improvement in energy efficiency relative to 2000

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 2011, 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.

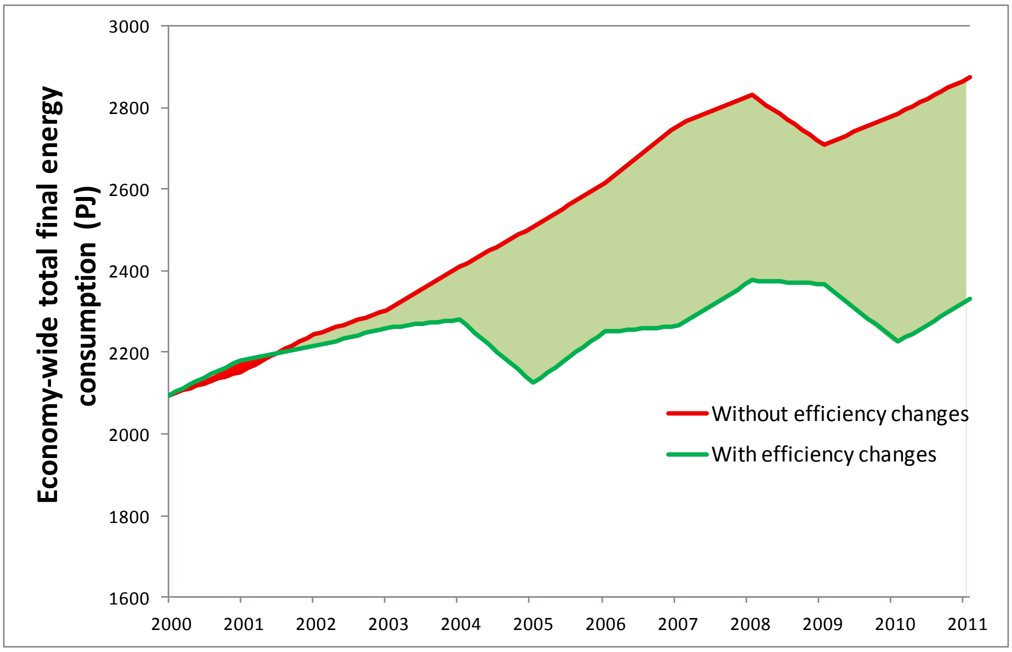

Figure 5 Impact of energy efficiency changes on total final energy consumption

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 2000-11 has been relatively small, but this is because two competing effects have largely cancelled each other out. Inter-sectoral structural changes alone have exerted a large 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 largely 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 26% between 2000 and 2011. Although the effect of the economic crisis has been an apparent fall in efficiency between 2007-09, the trend of increasing efficiency returned in 2010. A further slight fall in efficiency occurred in 2011, and the necessary data is not available to continue the analysis to the present. However, the analysis suggests significant improvements in energy efficiency up to 2011 which are sufficient to suggest that the country is comfortably on track to achieve the economy-wide NEES target.

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. Furthermore, the Energy Balances which provided much of the data on which this analysis is based are currently under revision. These results should be regarded as provisional, and subject to further refinement as the availability of data improves.

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 2000-2011, 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 2000-2011 (Department of Energy)
- Gross Domestic Product Annual Estimates 2000-2011 (Statistics South Africa Statistical Release P0441)
- Bulletin of Statistics 2000-2011 (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 Non-ferrous metals Machinery	}	Metals, metal products, machinery and equipment
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 wood products	}	Wood and paper, publishing and printing
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 60 firms / facilities, which together account for approximately one-third of the total energy consumption of the industry & mining sector.

SECTOR OVERVIEW

Trends in energy consumption

As of 2011 (the most recent year for which aggregate data is currently available), the total final energy consumption[2] of the industry & mining sector stood at 931 PJ, an overall decrease of 10.3% from its 2000 baseline of 1,038 PJ. The fuel mix consumed by the industry & mining sector has changed significantly between 2000 and 2011. As shown in Figure 6 below, coal and electricity remain the dominant energy carriers, but the share of coal has fallen from 54% in 2000 to 37% in 2011. Over the same period, the share of electricity in industry & mining total energy consumption has increased from 35% to 46%. The share of petroleum products has remained almost constant at about 5%, while the share of gas has increased significantly from 7% to 11%.

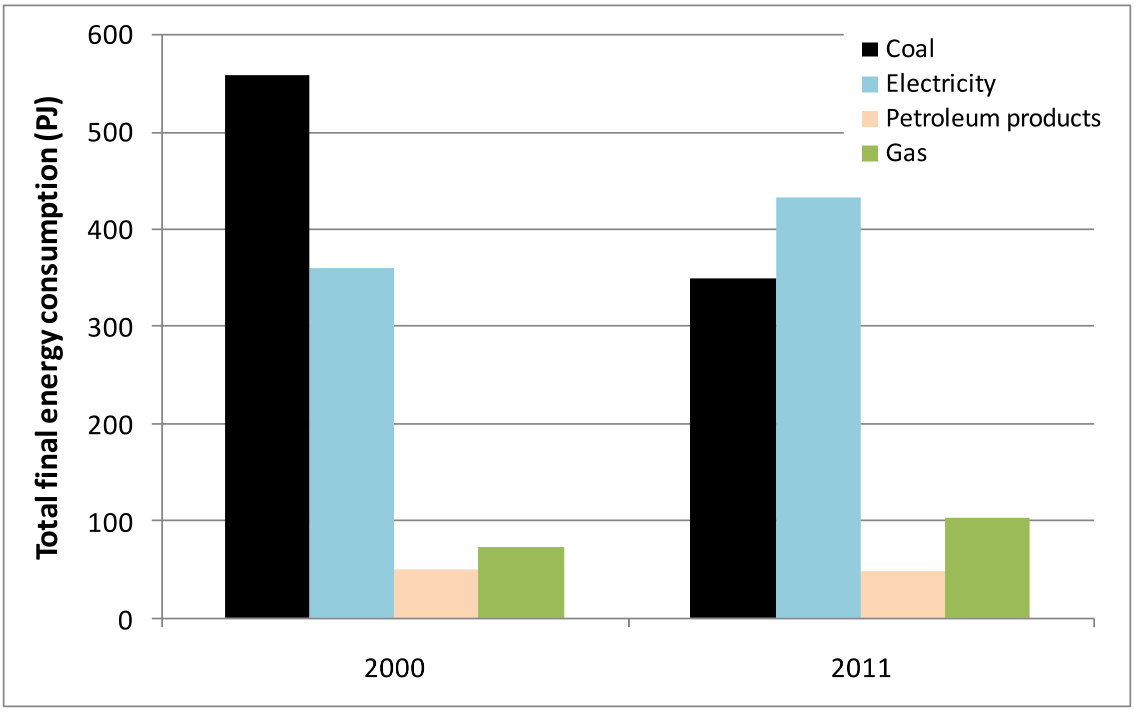

Figure 6 Total final energy consumption of industry & mining sector disaggregated by energy carrier, 2000 and 2011

Trends in gross value-added[3] (GVA)

Over the period of analysis 2000-11, the total gross value-added[4] (GVA) of South Africa's industry & mining sector increased by about 29%, from about R337 billion up to R431 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 29.4% to 23.1%, and construction, whose share increased from 7.8% to 13.5%. Given that mining is a more energy intense

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[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 2005 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.

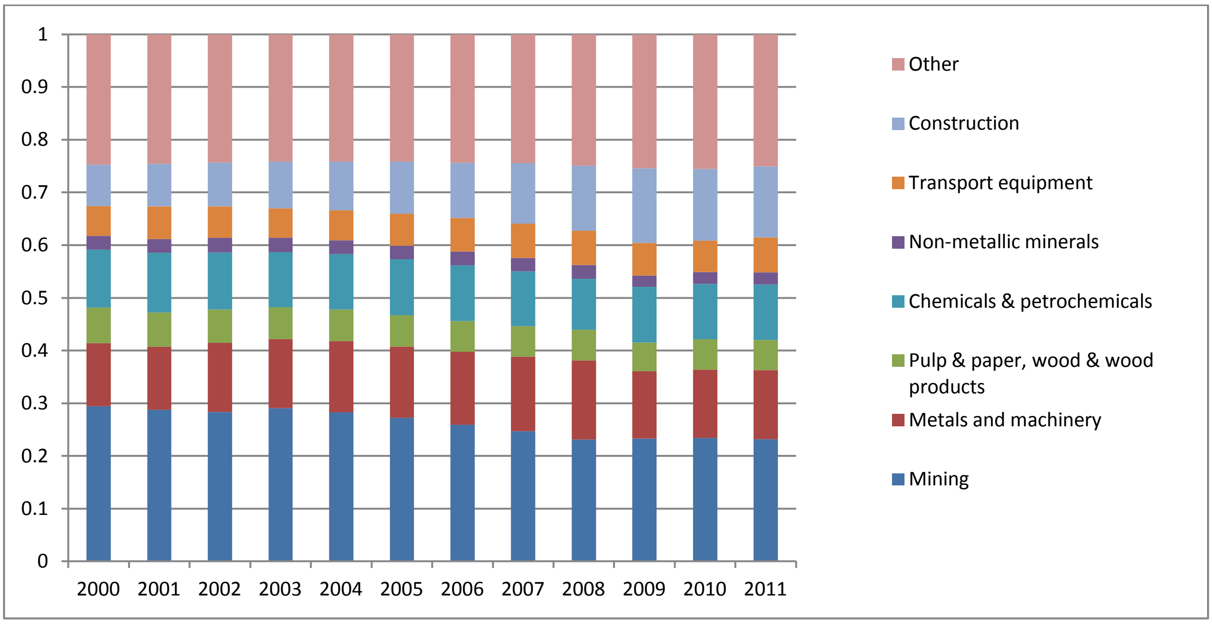

Figure 7 Share of total GVA by sub-sector (2000-2011)

Energy intensity trends

The energy intensity (the ratio of energy consumption to GVA) of the industry & mining sector decreased from 3.08 MJ/R in 2000 to 2.16 MJ/R in 2011. This represents a compounded annual reduction of 3.2% 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 30% in the energy intensity of the non-metallic minerals sub-sector until 2008[5]; (ii) a smaller but still significant increases in the energy intensity of pulp & paper and the 'Non-specified' category; (iii) a fall of almost 60% in energy intensity of the chemicals & petrochemicals sub-sector; (iv) significant decreases of 20-40% in the energy intensity of metals & machinery, transport equipment and construction. The energy intensity of mining when calculated as a five-year rolling average has remained fairly constant.

[5] Because of data anomalies for the non-metallic minerals sub-sector, figures for 2009 onwards have not been used in this analysis

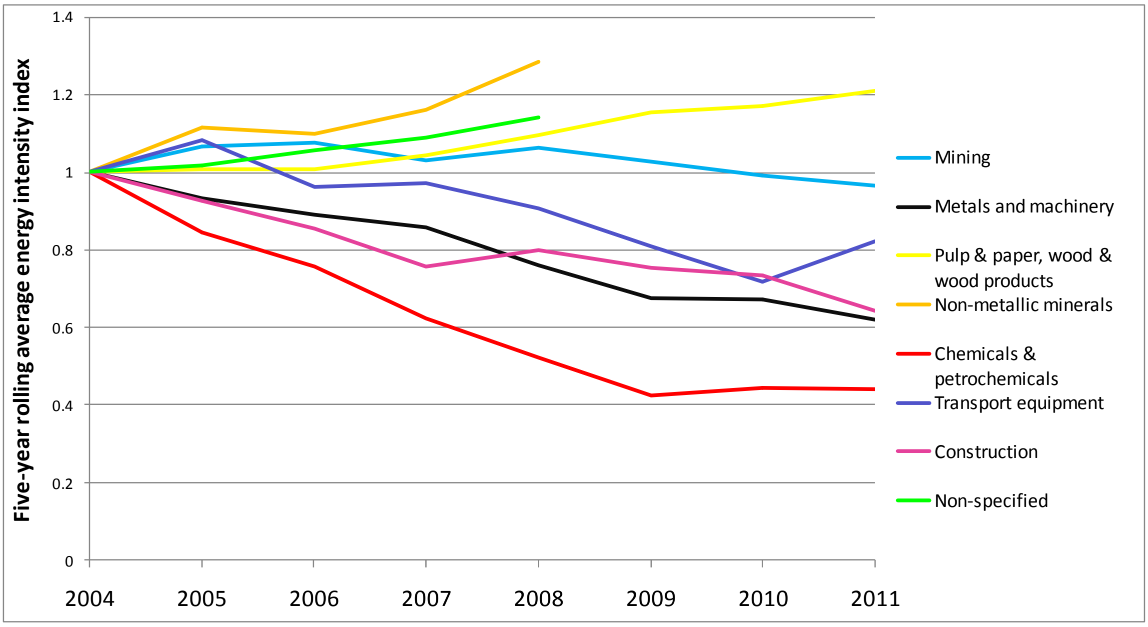

Figure 8 **Trends in sub-sector energy intensity. For greater clarity, five-year rolling average figures are shown in order to smooth out sharp fluctuations. Figures are expressed as an index relative to the value for 2004.**

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 in an imperfect proxy for energy efficiency. The most important of these is that it includes the effect of structural change[6], 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.

6 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 outputs[7]. 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 from 2000-08 is based on data for all industry & mining sub-sectors, while for the period 2009-11, the non-metallic minerals sub-sector and the 'non-specified industry' category were omitted from the analysis because of data anomalies[8].

The analysis results show that, between 2000 and 2011, energy efficiency improved significantly albeit very unevenly. Over the eleven-year period, if other factors had remained constant, improvements in efficiency would have led to a 343 PJ fall in energy consumption, which is 34.3% of the 2000 baseline figure. This is equivalent to a compounded annual fall of about 3.8% 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.

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7 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.

8 Because the results for these years are based on a reduced data-set and are therefore considered less robust, these are shown as a dashed line in Figure 9, and with a different coloured shading in Table 4.

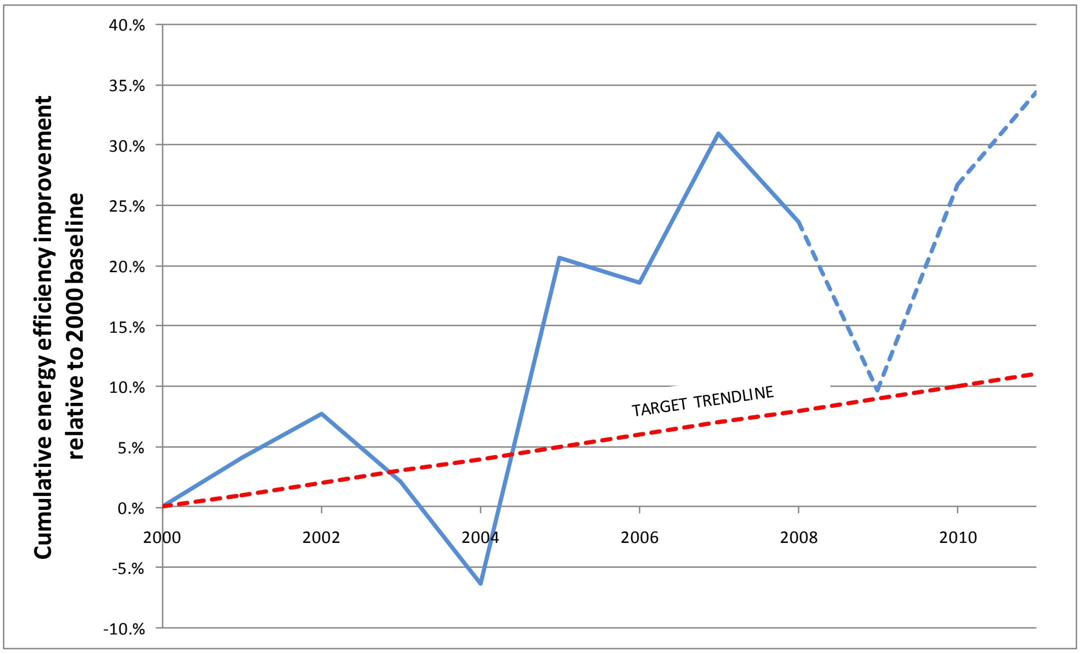

Figure 9 **Cumulative change in energy consumption attributable to energy efficiency changes, expressed as a percentage of the total sectoral energy consumption in 2000. The dashed line for the years after 2008 indicates that these estimates are subject to a higher level of uncertainty, as they are based on incomplete data.**

Figure 10 provides a graphical representation of the full decomposition results for 2011 relative to a 2000 baseline. Total energy consumption in the industry & mining sector in 2011 had decreased by 106.4 PJ relative to 2000. This change is composed of the sum of:

- a 257 PJ increase due to greater levels of activity;
- a 20.4 PJ decrease due to structural changes;
- a 343 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 2000-2011, 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, while red shaded areas are periods when efficiency was worse that the baseline.

Table 4 Results of decomposition analysis of changes in industry & mining sector energy consumption, 2000-2011

YEAR-ON-YEAR CHANGES

	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
CHANGE IN FINAL ENERGY CONSUMPTION (TJ)	-17,828	6,080	57,325	133,540	-219,591	67,719	-76,040	86,334	27,880	-107,706	-64,088
ACTIVITY LEVEL EFFECT	21,742	26,874	8,539	47,040	53,590	44,702	49,790	8,287	-68,076	49,858	14,562
STRUCTURAL EFFECT	1,372	15,119	-7,228	2,676	-3,862	2,215	-2,028	4,494	-43,158	12,981	-2,968
EFFICIENCY EFFECT	-40,942	-35,913	56,013	83,823	-269,319	20,803	-123,802	73,552	139,114	-170,546	-75,681
% CHANGE IN ENERGY CONSUMPTION DUE TO EFFICIENCY CHANGES	-3.9%	-3.5%	5.5%	7.7%	-22.1%	2.1%	-11.6%	7.4%	12.9%	-15.5%	-7.6%

CUMULATIVE CHANGES (2000 base year)

	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
CHANGE IN FINAL ENERGY CONSUMPTION (TJ)	-17,828	-11,748	45,577	179,117	-40,474	27,245	-48,794	37,539	65,420	-42,287	-106,374
ACTIVITY LEVEL EFFECT	21,742	48,616	57,156	104,196	157,786	202,488	252,278	260,565	192,489	242,347	256,909
STRUCTURAL EFFECT	1,372	16,491	9,263	11,940	8,078	10,293	8,265	12,759	-30,398	-17,417	-20,385
EFFICIENCY EFFECT	-40,942	-76,855	-20,842	62,981	-206,338	-185,535	-309,337	-235,785	-96,671	-267,216	-342,898
% CHANGE IN ENERGY CONSUMPTION DUE TO EFFICIENCY CHANGES	-4.1%	-7.7%	-2.1%	6.3%	-20.7%	-18.6%	-31.0%	-23.6%	-9.7%	-26.8%	-34.4%

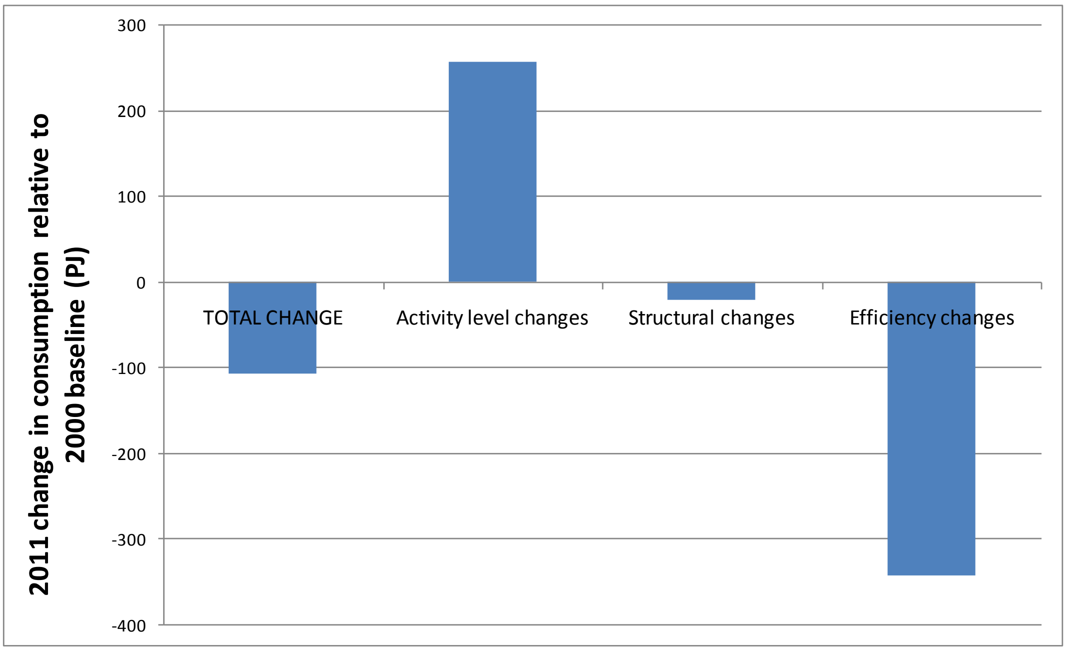

Figure 10 Cumulative change in energy consumption between 2000-2011 decomposed into three main components

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-sectors[9] 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.

As mentioned previously, the analysis for the years 2009 onwards omits the non-metallic minerals sub-sector and the 'non-specified industry' category, because anomalies were identified in the data on coal consumption for those two branches. The effect of this is that the estimates of energy efficiency change for these years are less robust than would otherwise be the case, but the results presented nevertheless still represent the best estimate of efficiency change given the data available.

Analysis of energy intensive branches 2010-12

Data was obtained for the years 2010-12 on energy consumption and physical production from a total of 66 firms and facilities 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 slightly more than one-third of the total energy consumption of the whole industry & mining sector, and over 50% of the energy consumption of those energy intensive sub-sectors from which data was sought. Because of some as-yet unresolved inconsistencies in the data provided by firms in the chemicals industry, this data has not been used in this analysis.

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 facilities[10]. 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.

[9] 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.

[10] 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.

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
Manufacture of aluminium	tonnes of primary aluminium
Manufacture of iron & steel	tonnes of crude steel
Manufacture of non-metallic minerals	tonnes of clinker
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 that 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 changes[11].

The total energy consumption of the entities that provided data was 355 TJ in 2010, falling to 330 TJ in 2012. The results of the decomposition analysis indicate that there was an improvement in energy efficiency of 2.63% for the year from 2010-11, but this was followed by a fall in efficiency of 7.67% between 2011-12. Over the whole two year period, the total cumulative change has been a fall in efficiency of 4.66%. 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 of 4.66% relative to the 2010 level among those entities that reported data.

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 that provided data was a reduction of 24.55 PJ. Over this period, changes in activity level and structural effects combined were responsible for a decrease in total final energy consumption of 41.66 PJ. This decrease was offset by a fall in efficiency that was responsible for an increase in total final energy consumption of 16.52 PJ, The overall efficiency reduction was made up of an improvement in

[11] 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.

efficiency between 2010-11 (accounting for a decrease in total final consumption of 9.33 PJ) followed by a larger fall in efficiency between 2011-12 (which contributed a net increase of 25.48 PJ to total final consumption).

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

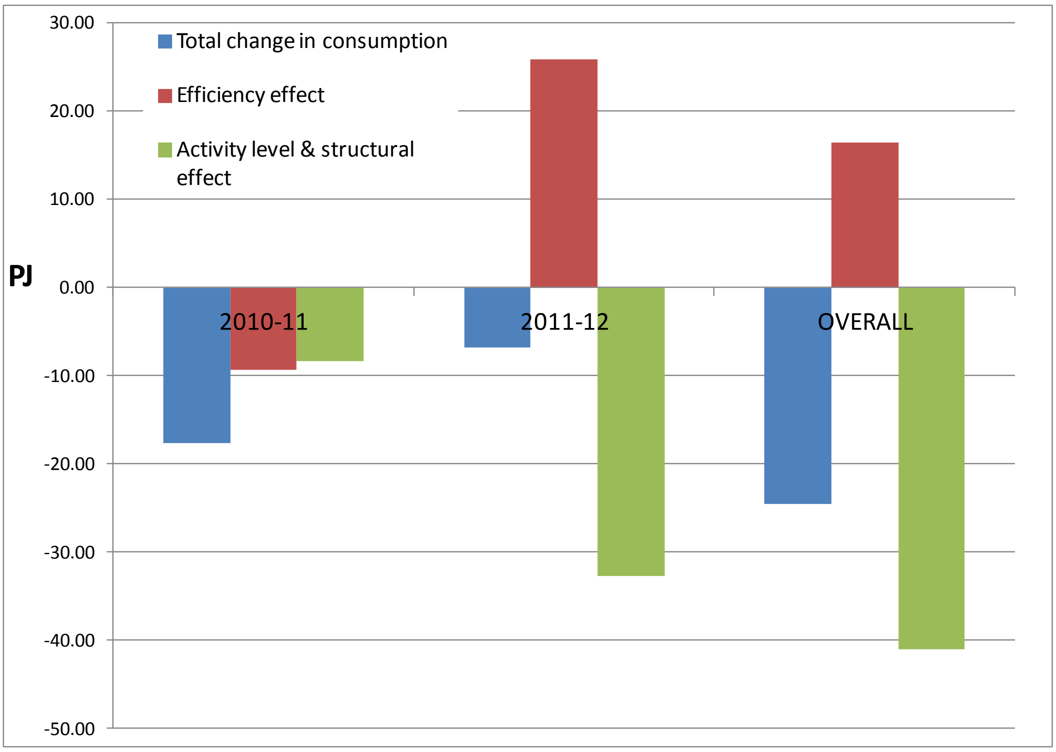

Table 6 Summary results of analysis based on detailed energy consumption and output data provided by firms and facilities

	2010-11	2011-12	OVERALL
Total change in energy consumption (PJ)	-17.70	-6.84	-24.55
Portion attributable to efficiency changes	-9.33	25.84	16.52
Portion attributable to activity level & structural effects	-8.37	-32.69	-41.06

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 2000-11 (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 ealy 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 2009-11 has left the industry & mining sector more energy efficient in 2011 than it had been in 2007. Although this analysis cannot provide conclusive evidence of causality, it is likely that this improvement was due at least in part to 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 2000 baseline. The bottom-up analysis indicates an improvement in efficiency that is substantially smaller than that indicated by the top-down analysis for the single year from 2010 to 2011 – the only period for which both analyses can be compared given current data availability.

The bottom-up analysis also indicates a subsequent significant fall in efficiency between 2011 and 2012, of about 7.7%. The reasons for this apparent fall in efficiency cannot be determined from the analysis that was possible using the available data. This highlights the need to broaden the collection of data from industrial firms and facilities to include more data on the driving forces behind changes in energy efficiency, including narrative information from representatives of the key energy intensive industry branches.

It remains to be seen whether the fall in efficiency between 2011-12 as revealed by the bottom-up analysis will be corroborated by the top-down analysis based on aggregate level GVA data, as the corresponding aggregate level energy consumption data for 2012 is not yet available. However, even if this fall in efficiency is confirmed by a future top-down analysis, the cumulative improvement in efficiency relative to the 2000 baseline will remain comfortably above the target trendline.

Sub-sector trends

Figure 13 below shows the extent to which each sub-sector contributed[12] towards the cumulative sector-level improvement in energy efficiency between 2000 and 2011, 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. The mining and pulp & paper sub-sectors have shown declines in energy efficiency under the top-down analysis, hence they are shown below

[12] 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

the x-axis in Figure 13 as having made a negative contribution to the overall improvement in energy efficiency[13]. The contributions of construction, non-metallic minerals and transport equipment have been positive but small.

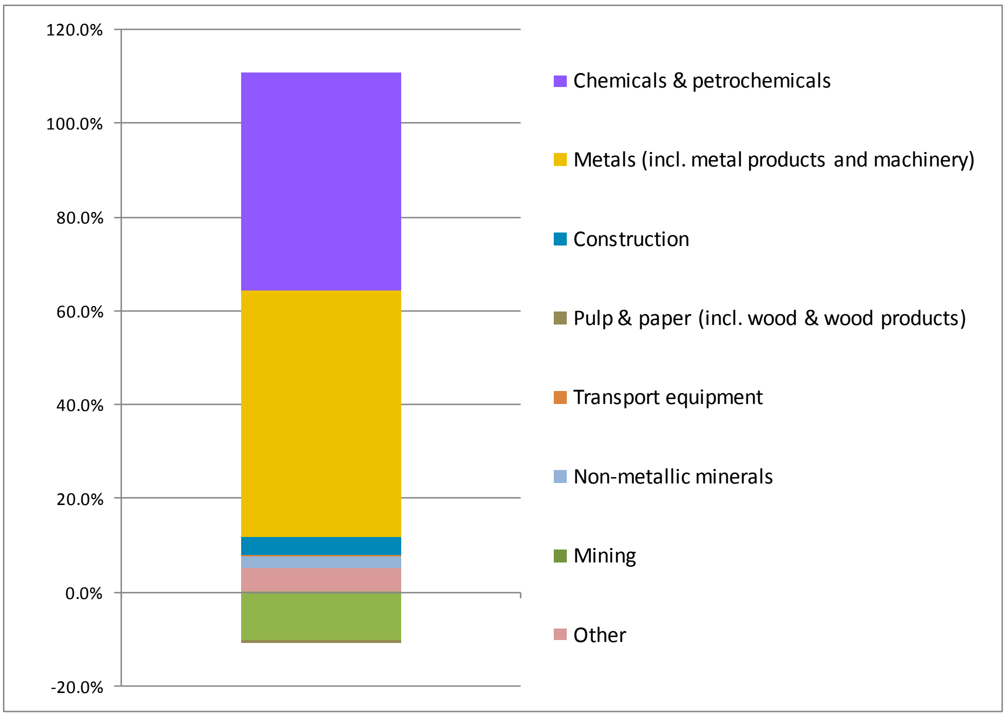

Figure 13 Contribution of each sub-sector to the overall sector-level change in energy efficiency between 2000-2011. The y-axis represents the fraction of the total calculated change in efficiency that can be attributed to each sub-sector.

The bottom-up analysis conducted for the period 2010-12 indicates that the strongest influence on the observed changes arose from the iron & steel industry, which provided the biggest contribution to both the improvement in efficiency seen from 2010-11 as well as the decline in efficiency the following year. The ferro-alloys industries appear to have shown an opposite trend, with a small fall in efficiency during 2011 followed by a significant improvement during 2012. Both non-metallic minerals and pulp & paper showed significant improvements in efficiency throughout the whole period, while gold mining, diamond mining and the aluminium industry declined in efficiency during both years of the period analysed.

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 one-year interval from 2010 to 2011. 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 2011. For the year 2010-11, the top-down analysis shows a 7.6% improvement in energy efficiency, while the bottom-up analysis shows a substantially smaller improvement in efficiency of 2.6%. There are several reasons why the results obtained may be expected to differ between the two analyses, which are discussed in more detail in the following sections.

[13] Note however that due to data anomalies, this figure shows the contributions of non-metallic minerals and 'Non-specified industry' only for the period 2000-08

Representativeness of the energy intensive sub-sectors

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. While it is true to say that the 2.6% improvement calculated using the bottom-up analysis represents the best estimate for the change in efficiency from 2010-11 *among the industry & mining sector branches from which data was obtained*, this result cannot necessarily be extrapolated to the sector as a whole, because these branches may not be representative of the whole industry & mining sector.

However, closer examination of the results suggests that this lack of representiveness is unlikely to account for the difference in the estimate of energy efficiency change obtained from the two analyses. Figure 14 below shows the extent to which each sub-sector contributed to the total calculated change in energy efficiency for the single year interval from 2010-11. Sub-sectors above the x-axis are those that made a net positive contribution to the total sectoral energy efficiency change, while those below the x-axis are sub-sectors whose energy efficiency has declined. It can be seen from Figure 14 that those sub-sectors that are not represented in the bottom-up analysis (construction and chemicals) actually had the net *negative* contribution[14] to the overall change in efficiency as calculated by the top-down analysis.

The omission of these sub-sectors from the bottom-up analysis would therefore be expected to result in that analysis showing a slightly *larger* improvement in energy efficiency than that obtained from the top-down analysis. By a similar argument, the omission of the non-metallic minerals sub-sector from the top-down analysis for 2010-11 would also be expected to result in an under-estimate of the improvement in efficiency from that analysis. It can therefore be concluded that the incomplete sub-sectoral coverage by both the top-down and the bottom-up analyses does not account for the difference in the results obtained.

[14] Although the contribution of construction is slightly positive, this is more than offset by the larger negative contribution from chemicals

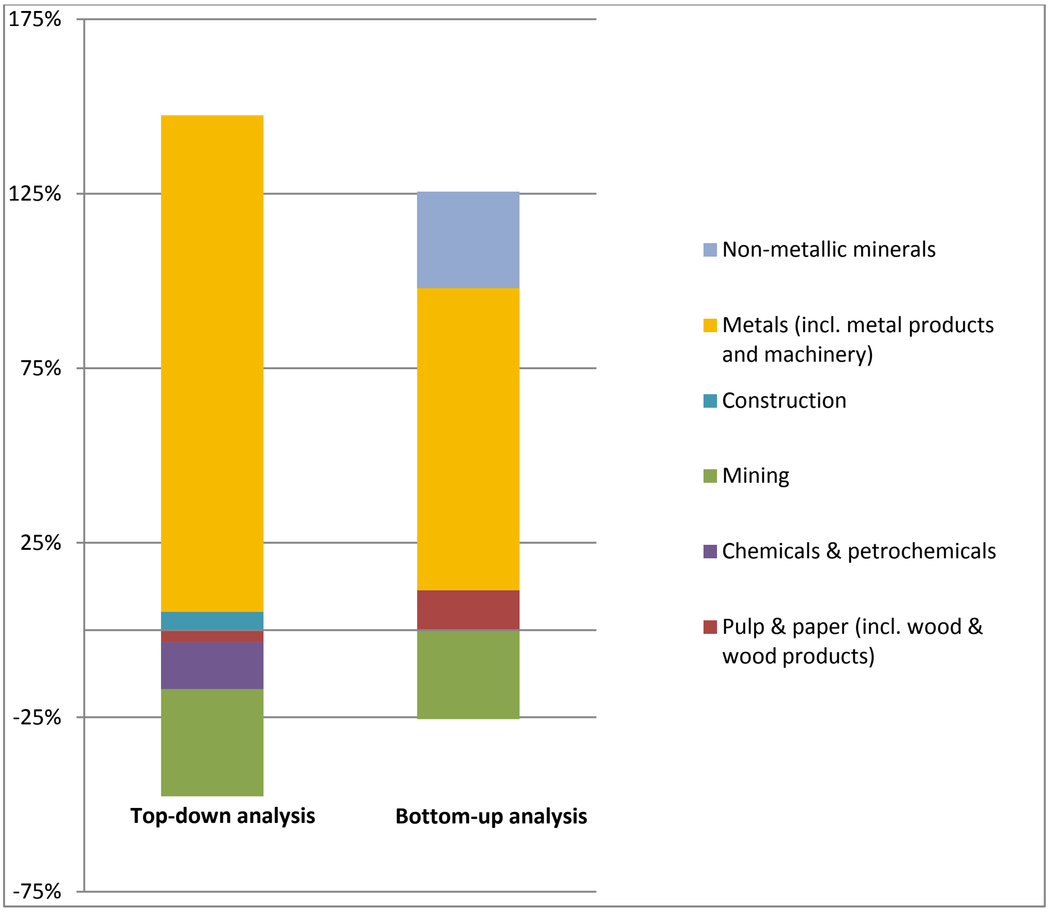

Figure 14 Contribution by sub-sector to the total energy efficiency change for the single year period 2010-11 as calculated using two different types of analysis.

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 2010-11. For example, measured in terms of gross output[15], 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 small reduction in overall

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

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

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

Changes in the economic value of outputs

Potentially one of the biggest sources of a difference 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 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 metals produced in South Africa increased significantly[16]. Hence the improvement in the energy efficiency of the metals & machinery sub-sector estimated by a top-down analysis was greater than that estimated by a bottom-up analysis. For the same reason, the fall in the energy efficiency of the mining sub-sector was smaller when estimated using a top-down approach. The difference in the results obtained from the two analyses was therefore at least partly due to the effect of increasing metals prices through 2011, although insufficient data exists to determine the exact strength of this effect.

Recent changes in the cement industry would be expected to have a similar effect, although because the non-metallic minerals sub-sector was not included in the top-down analysis for the year 2010-11, this effect is not apparent in the results described here. An increasing shift towards blended products means that the clinker content of cementitious products is steadily declining. 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 will 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.

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.

[16] This includes the prices of gold, platinum, manganese and aluminium.

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. Where possible, the capacity utilisation data corresponding to the energy-intensive industry branch of interest was used, but in some cases this was not possible, and a more aggregated capacity utilisation figure has been used. Statistics South Africa's aggregated capacity utilisation figures are calculated as weighted means, using GVA as the weighting factor. Because of this, the greatest weight within a sub-sector is carried by those activities that generate the most economic value, which are very often *not* the most energy intensive. This would have the effect of weakening any correlation that might exist between energy intensity and capacity utilisation.

The results indicate no statistically significant correlation at the 95% level, except for two sub-sectors: metals & machinery and chemicals & petrochemicals[17]. Contrary to expectations, the correlation observed for the metals & machinery sub-sector is positive – in other words, energy intensity appears to increase with increased capacity utilisation. However, given the small number of data points and the weakness of the correlations seen even in these two sub-sectors, no conclusions will be drawn from this analysis.

Conclusions

Based only on a decomposition analysis from 2000-11 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 2000 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 2011-12, but following the cumulative increase in efficiency from 2000-11 this would still leave the industry & mining sector comfortably ahead of the level of improvement required to meet the NEES target.

The detailed analysis based on data from individual firms and facilities provides an estimate of the improvement in energy efficiency for the year from 2010-11 that is significantly smaller than that obtained from the aggregate level analysis. However, such a difference between the results from the two analyses is not unexpected, given the observed changes in the value of the outputs from the metals industries. Since 2010-11 is the only period for which the available data currently allows both analyses to be conducted in parallel, caution should be exercised in comparing the results from the two analyses.

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

[17] The values of r^2 for these sub-sectors were 0.370 and 0.350 respectively.

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 will be 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 2011, the energy consumption of the commercial & public sector increased by 86%, equivalent to a compounded annual growth rate of 5.8%. However, this same data also shows a fall in total energy consumption for the sector of 48% 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 (GVA[18]). The total increase over the whole period from 2000-2011 is a relatively modest 17% (from 0.12 MJ/R in 2000 up to 0.14 MJ/R by 2011), equivalent to a compounded annual increase of

18 Measured at constant 2005 Rand

only about 1.5%. However, this trend includes the anomalous 49% 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 levels[19] 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 only 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 2003-10), the electricity intensity of the commercial & public sector decreased slightly from 5.76 MWh/million R in 2003 to 5.62 MWh/million R in 2010, representing a compounded annual reduction of just 0.35%.

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 2003-10, the decomposition analysis described below covers only this period.

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:

[19] 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 2003-10. These results are shown in Table 7 below, while Figure 15 shows the cumulative improvement in electricity efficiency relative to 2003, expressed in terms of the fractional change in total electricity consumption that can be attributed to efficiency changes.

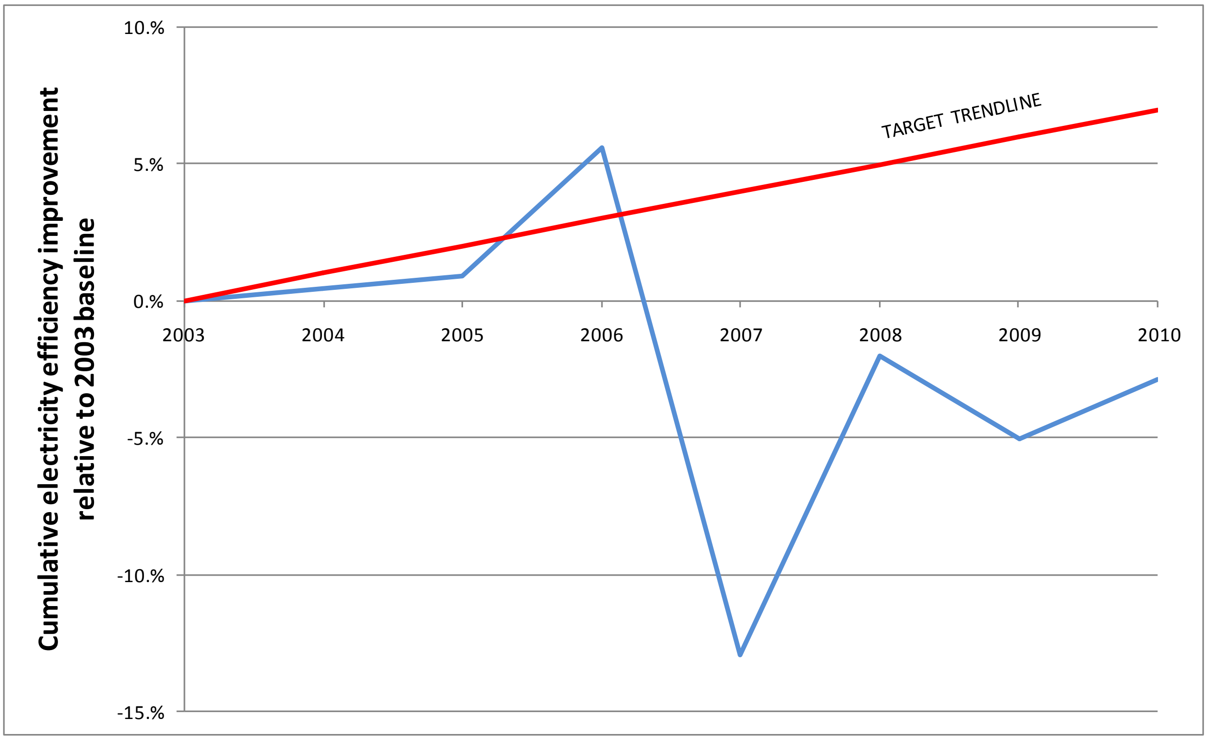

Figure 15 Cumulative change in electricity consumption attributable to energy efficiency changes, expressed as a percentage of the total sectoral electricity consumption in 2003

Table 7 Results of decomposition analysis of changes in commercial & public sector electricity consumption, 2003-2010

YEAR-ON-YEAR CHANGES

	2004	2005	2006	2007	2008	2009	2010
CHANGE IN FINAL ELECTICITY CONSUMPTION (GWh)	138.572	228.46	10.96	1064.216	-303.375	236.4438	76.30689
ACTIVITY LEVEL EFFECT	198.6731	256.203	305.8229	312.5873	269.3922	71.34723	155.2455
STRUCTURAL EFFECT	-39.91779	-8.3738	-87.9642	-63.8839	-91.18	30.24878	16.73599
EFFICIENCY EFFECT	-20.18332	-19.3692	-206.899	815.5124	-481.587	134.8478	-95.6746
% CHANGE IN ELECTRICITY CONSUMPTION DUE TO EFFICIENCY CHANGES	-0.46%	-0.43%	-4.35%	17.11%	-8.26%	2.44%	-1.66%

CUMULATIVE CHANGES (2003 base year)

	2004	2005	2006	2007	2008	2009	2010
CHANGE IN FINAL ELECTRICITY CONSUMPTION (GWh)	138.572	367.032	377.992	1442.208	1138.833	1375.277	1451.584
ACTIVITY LEVEL EFFECT	198.6731	454.8761	760.699	1073.286	1342.679	1414.026	1569.271
STRUCTURAL EFFECT	-39.91779	-48.2916	-136.256	-200.14	-291.32	-261.071	-244.335
EFFICIENCY EFFECT	-20.18332	-39.5526	-246.451	569.0611	87.47438	222.3221	126.6476
% CHANGE IN ELECTRICITY CONSUMPTION DUE TO EFFICIENCY CHANGES	-0.46%	-0.90%	-5.62%	12.97%	1.99%	5.07%	2.89%

The analysis results show that, between 2003 and 2010, energy efficiency declined very slightly, although a very large fraction of this total decline occurred in a single year. Over the seven-year period, if other factors had remained constant, reductions in efficiency would have led to a 127 GWh increase in electricity consumption, which is 2.9% of the 2003 baseline figure. This is equivalent to a compounded annual increase of about 0.4% in electricity consumption attributable to efficiency reductions. Figure 15 illustrates this fall 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 2010 relative to the 2003 baseline. Total electricity consumption in the commercial & public sector in 2010 had increased by 1,452 GWh relative to 2003. This change is composed of the sum of:

- a 1,569 GWh increase due to greater levels of activity;
- a 244 GWh decrease due to structural changes;
- a 127 GWh increase 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 2003-2010, 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 that the baseline.

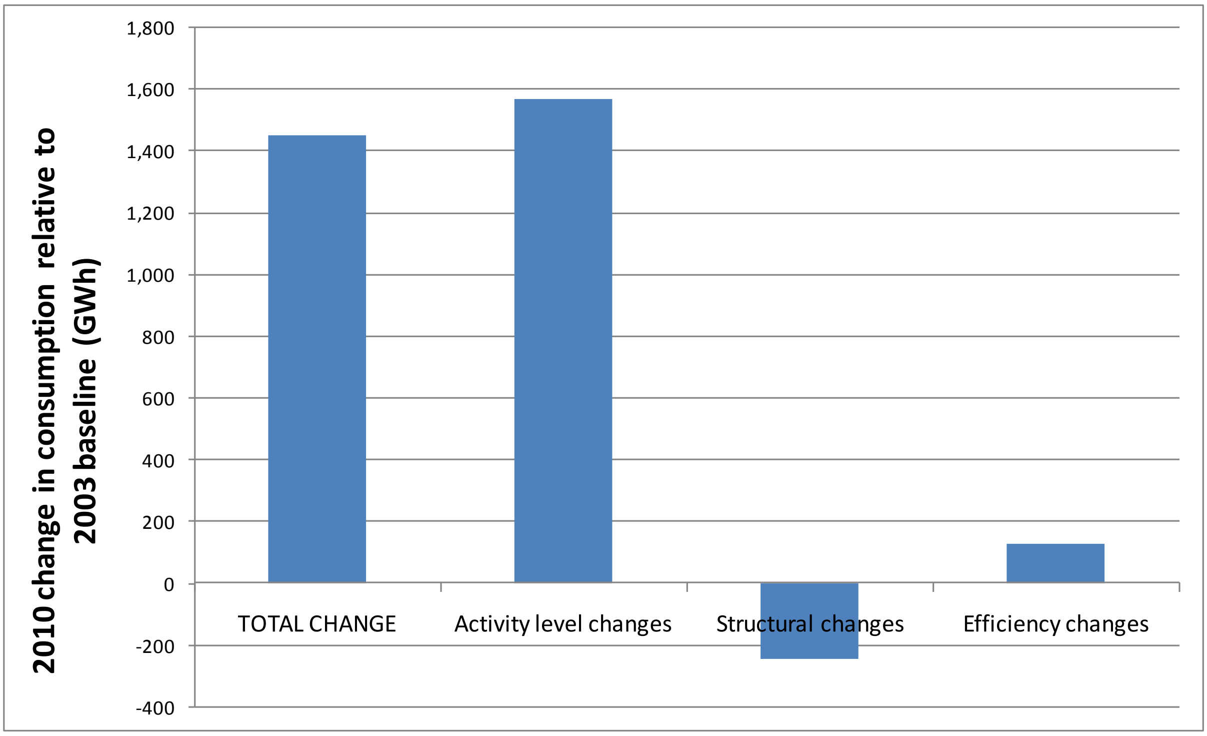

Figure 16 Cumulative change in electricity consumption between 2003-2010 decomposed into three main components

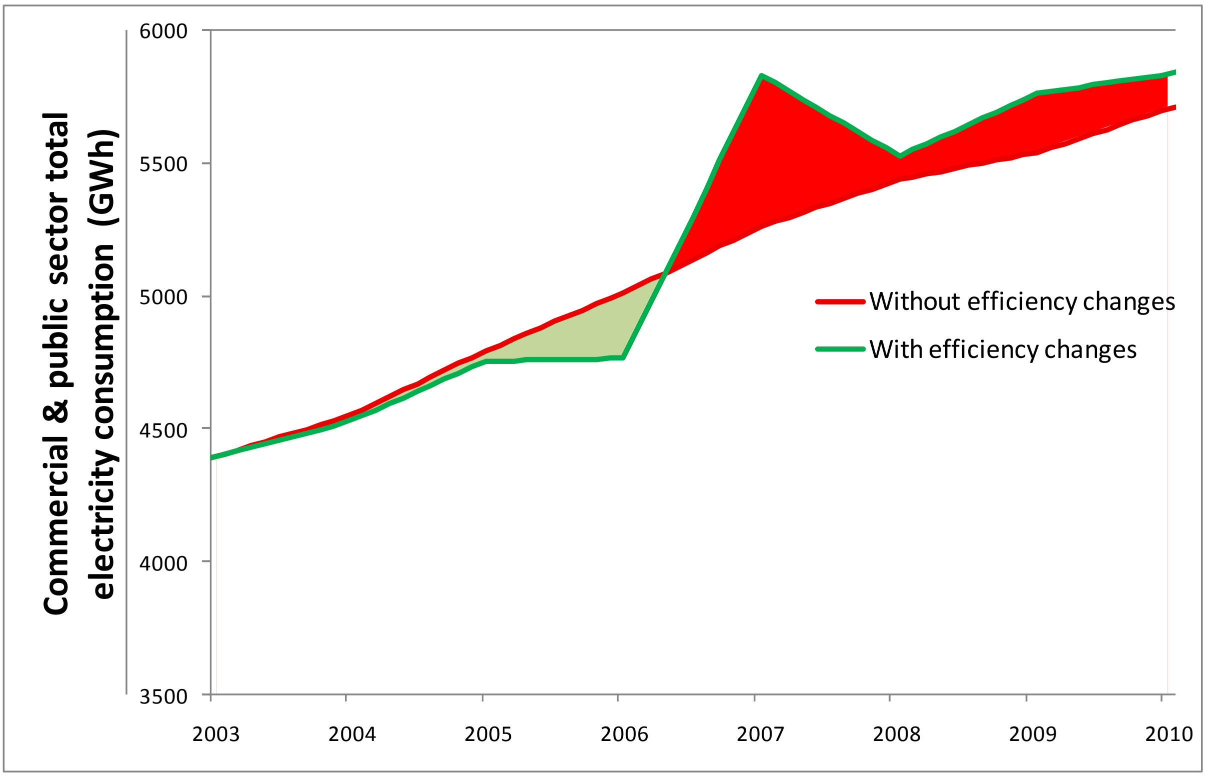

Figure 17 Comparison of actual observed trends in energy consumption of the commercial & public sector (green trace) versus trends that would have occurred with no efficiency change (red trace).

COMMENTS ON RESULTS OF DECOMPOSITION ANALYSIS

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 is only 2.9% higher than it would be 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 at least part of the apparent decline in electricity efficiency from 2003-10 is actually the result of 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.

FUTURE ANALYSIS OF ENERGY EFFICIENCY TRENDS

Two major priorities can be identified to allow improved analysis of energy efficiency trends in the commercial & public sector. The highest priority must be to improve the quality of the historical energy consumption data to permit a more comprehensive and reliable analysis to be conducted of the period from 2000 to the present day. It is believed that the raw data from which the *Energy Balance Tables* are derived is sound, but there are difficulties in converting this raw data into consistent estimates of final consumption for the various sectors and sub-sectors of the economy. There is therefore a strong possibility that more reliable historical data on total energy consumption will become available in the future, allowing more complete estimates of energy efficiency trends to be made.

The next priority should be the building up of data on the penetration rates of auxiliary equipment in offices, to allow the decomposition analysis to provide a more accurate estimate of true efficiency trends. Although the collection of current penetration rates is both feasible and desirable, the likely absence of historical data would make it difficult to create the baseline figure necessary to estimate energy efficiency trends since 2000. One approach to this might be to perform a set of calculations with slightly different assumed penetration rates for 2000, which would provide a spectrum of plausible estimates for the overall efficiency change that has taken place.

In addition to these priorities, other data collection efforts may be identified that would allow the analysis of energy efficiency trends to be improved. The main area of focus should be on the use of surveys to collect data on physical activity levels, based on indicators appropriate to the sub-sector in question. However, unless the energy consumption data itself is reliable, and penetration rates of auxiliary equipment can be assessed, developing more refined indicators for activity level should accorded a lower priority.

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 2000 baseline. 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 proportional[20] – 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

[20] 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 SAARF[21]. 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. These tables are currently being revised to correct for some inconsistencies, and the revised versions of the aggregated energy balances were not available at the time the current analysis was conducted. The figures used in this analysis were therefore derived from the raw disaggregated data on which the Energy Balances are based. This data is itself only available at present for years up to 2011 and, since the analysis requires data on sector-level total energy consumption, it has only been possible to conduct an analysis for the period 2000-11.

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 surveys conducted in January-March 2013 and May 2014. These surveys are described in detail in the section "Household energy survey" below. The survey results provide snapshots of energy intensity by LSM for the periods in which they were conducted. Figures for energy intensity by LSM for the years extending back to 2000 were imputed using a process described in the section "Determining energy intensity" on page 46.

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HOUSEHOLD ENERGY SURVEY

A household energy survey was conducted during May 2014, which was essentially a repeat of a similar survey conducted during January to March 2013 under the pilot phase of this activity. Because of resource constraints, the sample size and geographical scope of the 2014 survey was more restricted than for the earlier 2013 survey. Responses from a total of 968 households were obtained across four different municipalities[22], whereas the 2013 survey obtained 1,720 responses across eight municipalities.

The survey 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 14.2 million in 2011. This represents an increase of 38%, equivalent to a compounded annual increase of 3.0%. Over the same period, the total energy consumption of the residential sector increased by almost exactly the same ratio, from 307 PJ in 2000 up to 424 PJ in 2011. The change in energy intensity of the residential sector over this period was therefore very small, increasing from 29.7 GJ per household in 2000 to 29.9 GJ per household in 2011.

The same eleven 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 2011, this fraction had

[22] These were: Mantsopa, Beaufort West, Ephraim Mogale and Randfontein.

fallen to 2.6%, with the fraction of households in LSMs 2 & 3 also falling steeply. Meanwhile, the middle and upper range of LSMs grew significantly – in particular LSM 6, which increased from 13% of households in 2000 up to 20% by 2011. Figure 18 below provides a graphical representation of changes in the distribution of households by LSM between 2000 and 2011.

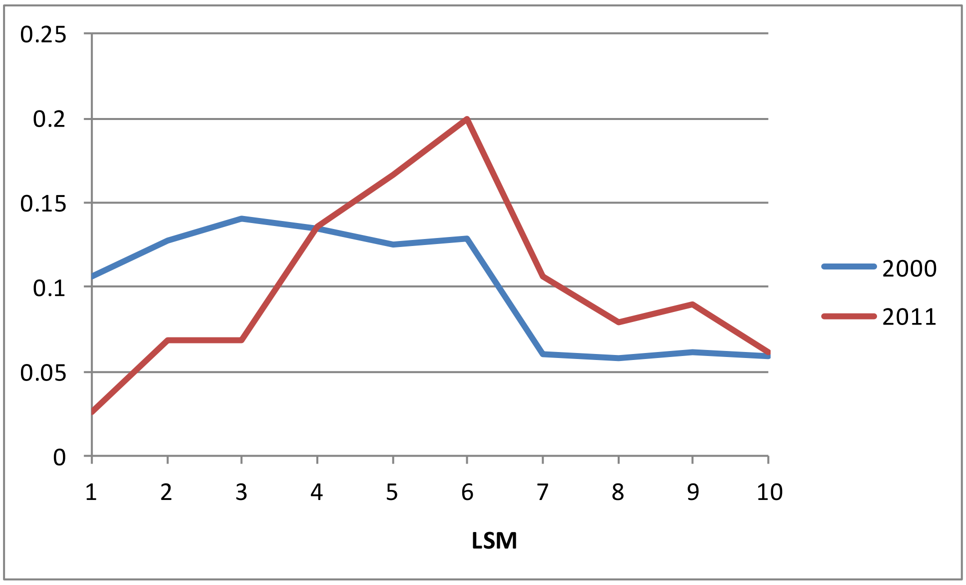

Figure 18 Distribution of households by LSM, 2000 and 2011

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 2014 household energy survey described above. The survey was designed to allow the LSM of each respondent household to be determined, so the results are disaggregated by LSM[23]. Note however that the scope of the survey was relatively limited, and did not extend to detailed questions regarding usage levels of household appliances. Results are therefore given only for each of the main energy-consuming activities in the home – cooking, water heating, space heating and lighting.

Cooking

Figure 19 and Table 8 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 76% of households overall and over 90% of households in LSM 5 and above. However, in LSMs 2 & 3 paraffin still dominates as a cooking fuel, with electricity being the main energy source in less than 10% of these households. A small fraction of households in the lower LSMs rely on wood for cooking, where LPG also plays a minor role. LPG is also the cooking fuel of choice for a very small number of households in all other

[23] Because of limitations on the geographical areas where the survey could be conducted, LSM 1 was not represented in the sample.

LSMs apart from 10[24]. Because cooking is carried out in every household sampled, the totals all add up to exactly 1.00.

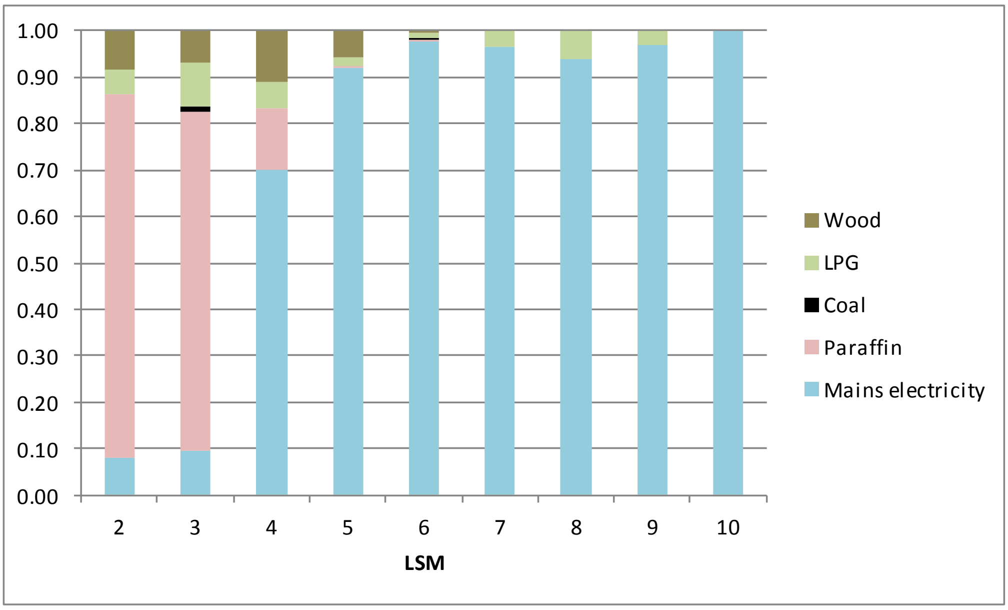

Figure 19 Fraction of households in each LSM using energy source as main cooking fuel

Table 8 Main energy source used for cooking (fraction of households by LSM)

	LSM									
ENERGY SOURCE	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Overall**
Mains electricity	0.08	0.10	0.70	0.92	0.98	0.97	0.94	0.97	1.00	0.76
Paraffin	0.78	0.73	0.13	0.00	0.00	0.00	0.00	0.00	0.00	0.16
Coal	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LPG	0.05	0.10	0.06	0.02	0.01	0.03	0.06	0.03	0.00	0.04
Wood	0.08	0.07	0.11	0.06	0.00	0.00	0.00	0.00	0.00	0.04

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 9 below. Across all households, 44% do not use any secondary energy source (i.e. they always use the main energy source only), a figure which rises to 71% and 70% in LSMs 2 & 3 respectively. For those households where a secondary energy source is used, wood is the most significant among lower LSMs, and plays a small role across all LSMs. LPG dominates in the higher LSMs, while paraffin is also an important secondary cooking fuel among the middle LSMs 4-7. It would seem likely that the use of wood as a secondary cooking fuel among the highest LSMs is a matter of lifestyle choice. Conversely, the 10% of LSM 10

[24] Note that, because of the relatively small sample size and the limited geographical scope of the survey, LSM 10 was somewhat under-represented. It is likely that the absence of LPG as a main cooking fuel in the LSM 10 households sampled was a statistical quirk.

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.

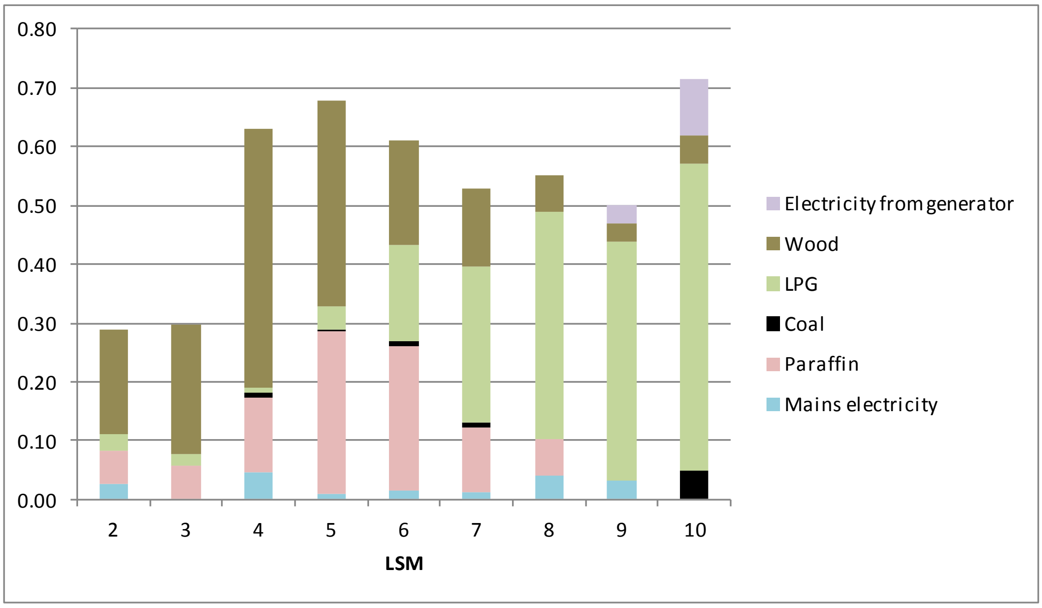

Figure 20 Fraction of households in each LSM using energy source as secondary cooking fuel

Table 9 Secondary energy source used for cooking (fraction of households by LSM)

	LSM									
ENERGY SOURCE	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Overall**
None	0.71	0.70	0.37	0.32	0.39	0.47	0.45	0.50	0.29	0.44
Mains electricity	0.03	0.00	0.05	0.01	0.02	0.01	0.04	0.03	0.00	0.02
Paraffin	0.05	0.06	0.13	0.28	0.25	0.11	0.06	0.00	0.00	0.17
Coal	0.00	0.00	0.01	0.00	0.01	0.01	0.00	0.00	0.05	0.01
LPG	0.03	0.02	0.01	0.04	0.16	0.26	0.39	0.41	0.52	0.13
Wood	0.18	0.22	0.44	0.35	0.18	0.13	0.06	0.03	0.05	0.24
Electricity from generator	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.10	0.00

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

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 10 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 6 upwards are very strongly dependent on electricity for water heating, with solar energy playing a very small role[25].

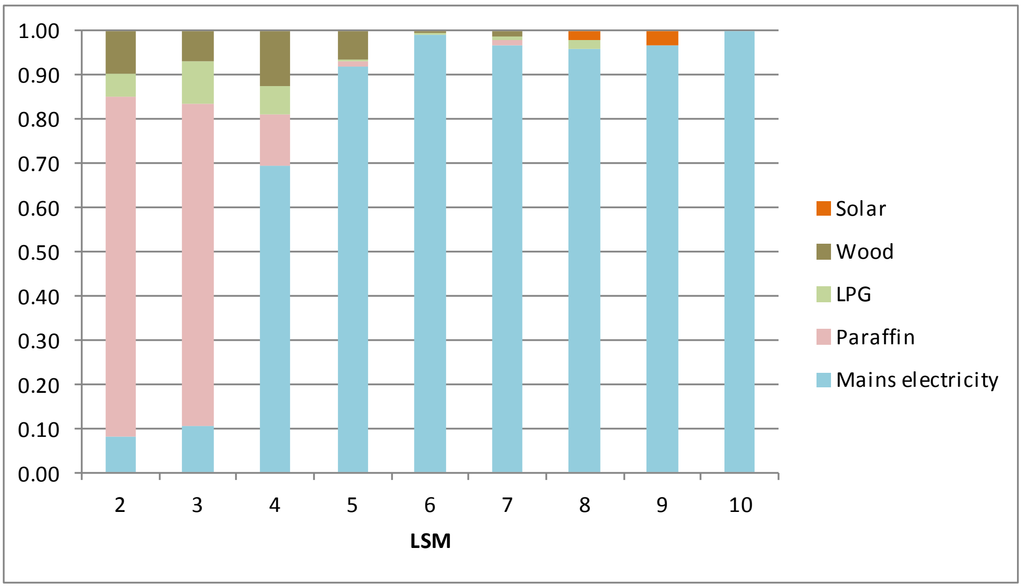

Figure 21 Fraction of households in each LSM using energy source as main fuel for water heating

Table 10 Main energy source used for water heating (fraction of households by LSM)

	LSM									
ENERGY SOURCE	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**TOTAL**
Mains electricity	0.08	0.11	0.69	0.92	0.99	0.97	0.96	0.97	1.00	0.77
Paraffin	0.77	0.73	0.12	0.01	0.00	0.01	0.00	0.00	0.00	0.15
LPG	0.05	0.10	0.06	0.00	0.00	0.01	0.02	0.00	0.00	0.03
Wood	0.10	0.07	0.13	0.07	0.00	0.01	0.00	0.00	0.00	0.05
Solar	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.03	0.00	0.00

Figure 22 and Table 11 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.

25 It is interesting to note that the fraction of households citing solar as their main energy source for water heating is considerably lower than the fraction that own 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.

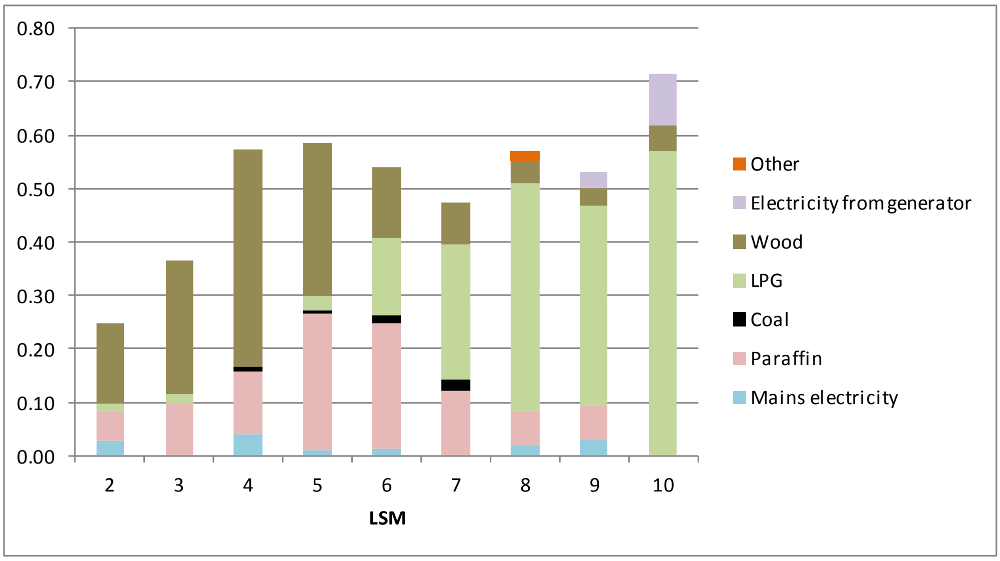

Figure 22 Fraction of households in each LSM using energy source as secondary fuel for water heating

Table 11 Secondary energy source used for water heating (fraction of households by LSM)

	LSM									
ENERGY SOURCE	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**TOTAL**
None	0.75	0.63	0.43	0.42	0.46	0.53	0.43	0.47	0.29	0.49
Mains electricity	0.03	0.00	0.04	0.01	0.01	0.00	0.02	0.03	0.00	0.01
Paraffin	0.05	0.10	0.12	0.26	0.24	0.12	0.06	0.06	0.00	0.17
Coal	0.00	0.00	0.01	0.00	0.02	0.02	0.00	0.00	0.00	0.01
LPG	0.01	0.02	0.00	0.03	0.14	0.25	0.43	0.38	0.57	0.12
Wood	0.15	0.25	0.41	0.29	0.13	0.08	0.04	0.03	0.05	0.20
Electricity from generator	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.10	0.00
Other	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00

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

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 12 below. Overall, only 55% of the households surveyed have any space heating, a figure that falls to 25% in LSM 2. Electricity dominates in LSMs 7-10, with LPG also significant, but both are little used in the lower LSMs. Paraffin is significant in LSMs 3-6, while wood is used as the main space heating fuel in a small but not insignificant number of households across most LSMs.

Note that, as well as asking directly about energy sources used for space heating, the survey also asked respondents whether they operate their cooking appliance to keep warm even when they are not cooking. For these respondents, the main cooking fuel was also recorded as the main space heating fuel, providing the respondent did not indicate any other energy source for space heating. Although almost 9% of households reported using their cooking appliance for space heating, only 12 households in the whole survey relied on this as their only source of space heat.

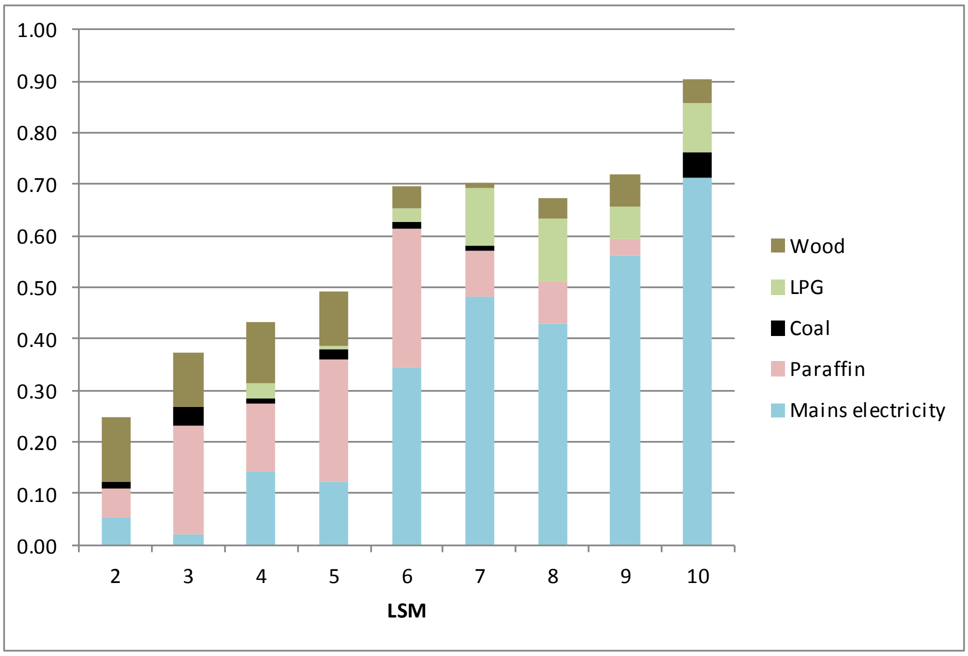

Figure 23 Fraction of households in each LSM using energy source for space heating

Of all the energy-using household activities covered in this analysis, space heating is the most strongly affected by geographical location. Three of the four areas where the household energy survey was conducted are located in the Highveld, while the fourth is in the Karoo. All of these areas suffer very low evening temperatures during the winter, so the demand for space heating is expected to be slightly higher than the national average, and significantly higher than at locations in the coastal regions of Kwa-Zulu Natal and Eastern Cape.

Table 12 Main energy source used for space heating (fraction of households by LSM)

	LSM									
ENERGY SOURCE	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**TOTAL**
None	0.75	0.63	0.57	0.51	0.30	0.30	0.33	0.28	0.10	0.45
Mains electricity	0.05	0.02	0.14	0.12	0.34	0.48	0.43	0.56	0.71	0.24
Paraffin	0.05	0.21	0.13	0.24	0.27	0.09	0.08	0.03	0.00	0.18
Coal	0.01	0.04	0.01	0.02	0.01	0.01	0.00	0.00	0.05	0.02
LPG	0.00	0.00	0.03	0.01	0.03	0.11	0.12	0.06	0.10	0.03
Wood	0.12	0.11	0.12	0.10	0.04	0.01	0.04	0.06	0.05	0.08

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

Lighting

As shown in Figure 24 and Table 13 below, only 18% of all surveyed households use a main energy source other than electricity for lighting. In LSMs 2 & 3, the majority of households rely on candles for lighting, with paraffin lighting also playing a minor role. Although candles and paraffin are also used as the main source of lighting in some LSM 4 households, mains electricity is already strongly dominant, while for LSMs 5 and above it is universal.

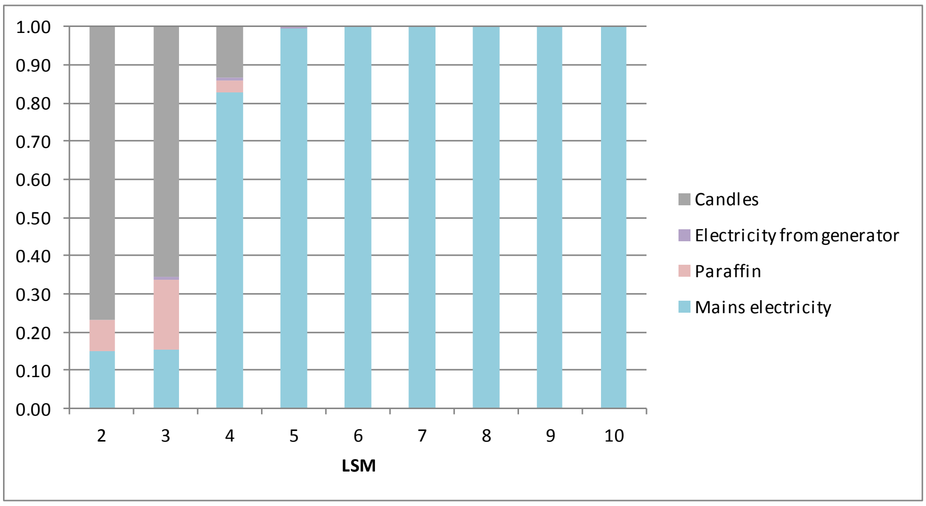

Figure 24 Fraction of households in each LSM using energy source for lighting

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

	LSM									
ENERGY SOURCE	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**TOTAL**
Mains electricity	0.15	0.15	0.83	1.00	1.00	1.00	1.00	1.00	1.00	0.82
Paraffin	0.08	0.18	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.03
Electricity from generator	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Candles	0.77	0.65	0.13	0.00	0.00	0.00	0.00	0.00	0.00	0.15

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

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 bracket 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. Deriving the second set of data is discussed in more detail in the following section.

Determining energy intensity by LSM

The nature of the relationship between energy intensity and LSM was determined using household survey data – specifically, the respondents' estimates of their household's annual energy consumption. Although two household surveys were conducted (early 2013 and May 2014) separated by more than one year, resource constraints meant both surveys were limited in terms of sample size and geographical scope. Hence neither survey can be considered statistically representative of the whole country and, because the surveys covered different geographical areas, the results of the two surveys cannot be used to determine trends through time. For the purposes of this analysis, the results of the two surveys have been combined into a single data set containing 2,688 responses and covering twelve municipalities.

Figure 25 below shows the data on household energy intensity versus LSM obtained from the combined household surveys. Also shown are the best-fit second order polynomial and the corresponding equation. This equation was then used to model the relationship between energy intensity and LSM for previous years back to 2000. Based on data on total sectoral energy consumption, and on the number of households in each LSM, the polynomial curve was scaled accordingly, to provide a complete set of figures for energy intensity versus LSM for each year. These figures were the basis for the decomposition analysis.

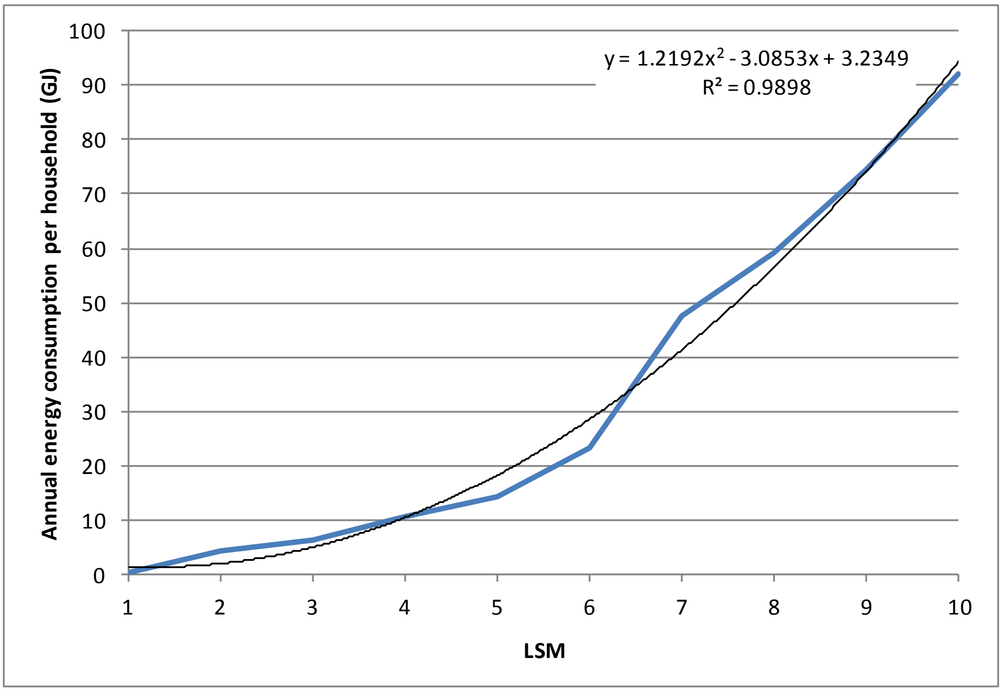

Figure 25 Survey data showing the relationship between household energy intensity and LSM. The best-fit second order polynomial curve is superimposed on the data.

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 14 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 2011, energy efficiency improved significantly, but with the entire improvement occurring in the years after 2005. Over the whole eleven-year period, if other factors had remained constant, improvements in efficiency would have led to a 119 PJ fall in energy consumption, which is 29.5% of the 2000 baseline figure. This is equivalent to a compounded annual fall of about 3.1% 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. However, it can also be seen from Figure 26 that the cumulative improvement in efficiency only exceeded the target level from 2009 onwards.

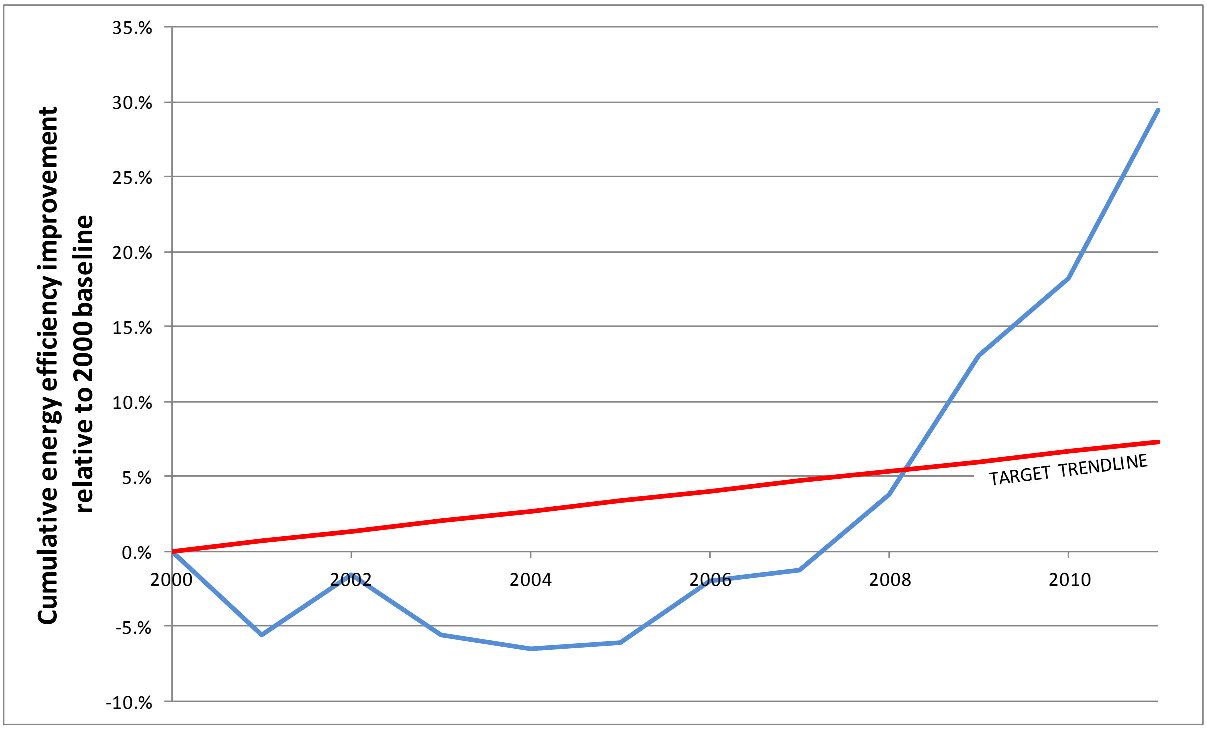

Figure 26 Cumulative change in residential sector energy consumption attributable to efficiency changes, expressed as a percentage of the total sectoral electricity consumption in 2000

Figure 27 provides a graphical representation of the full decomposition results for 2011 relative to the 2000 baseline. Total energy consumption in the residential sector in 2011 had increased by 117 PJ relative to 2000. This change is composed of the sum of:

- a 129 PJ increase due to greater levels of activity (i.e. increased number of households);
- a 107 PJ increase due to structural changes (i.e. increases in living standards);
- a 119 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 2000-2011, 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 that the baseline.

Table 14 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
CHANGE IN FINAL ENERGY CONSUMPTION (TJ)	28,616	-2,889	26,753	23,804	19,879	18,531	48,297	7,470	-35,340	-5,982	-11,661
ACTIVITY LEVEL EFFECT	7,269	8,075	9,429	10,268	11,156	12,191	13,677	14,967	14,627	13,898	13,616
STRUCTURAL EFFECT	-1,346	5,272	1,356	9,862	9,981	23,147	37,637	12,732	-12,519	1,060	20,054
EFFICIENCY EFFECT	22,693	-16,236	15,968	3,674	-1,258	-16,806	-3,017	-20,229	-37,447	-20,940	-45,331
% CHANGE IN ENERGY CONSUMPTION DUE TO EFFICIENCY CHANGES	7.4%	-4.8%	4.8%	1.0%	-0.3%	-4.2%	-0.7%	-4.3%	-7.8%	-4.7%	-10.4%

CUMULATIVE CHANGES (2000 base year)

	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
CHANGE IN FINAL ENERGY CONSUMPTION (TJ)	28,616	25,727	52,480	76,284	96,163	114,694	162,991	170,461	135,121	129,139	117,478
ACTIVITY LEVEL EFFECT	7,269	15,344	24,773	35,041	46,197	58,388	72,064	87,031	101,658	115,555	129,171
STRUCTURAL EFFECT	-1,346	3,926	5,282	15,144	25,125	48,271	85,909	98,641	86,121	87,181	107,235
EFFICIENCY EFFECT	22,693	6,457	22,425	26,099	24,841	8,035	5,018	-15,211	-52,658	-73,598	-118,928
% CHANGE IN ENERGY CONSUMPTION DUE TO EFFICIENCY CHANGES	5.6%	1.6%	5.6%	6.5%	6.2%	2.0%	1.2%	-3.8%	-13.1%	-18.3%	-29.5%

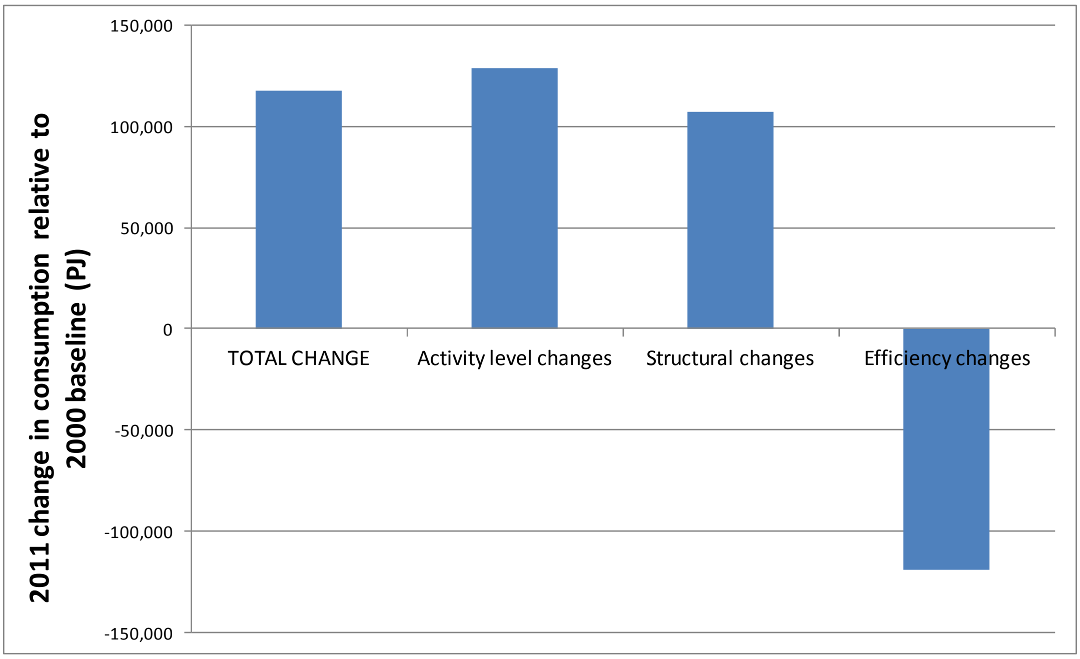

Figure 27 Cumulative change in residential sector energy consumption between 2000-2010 decomposed into three main components

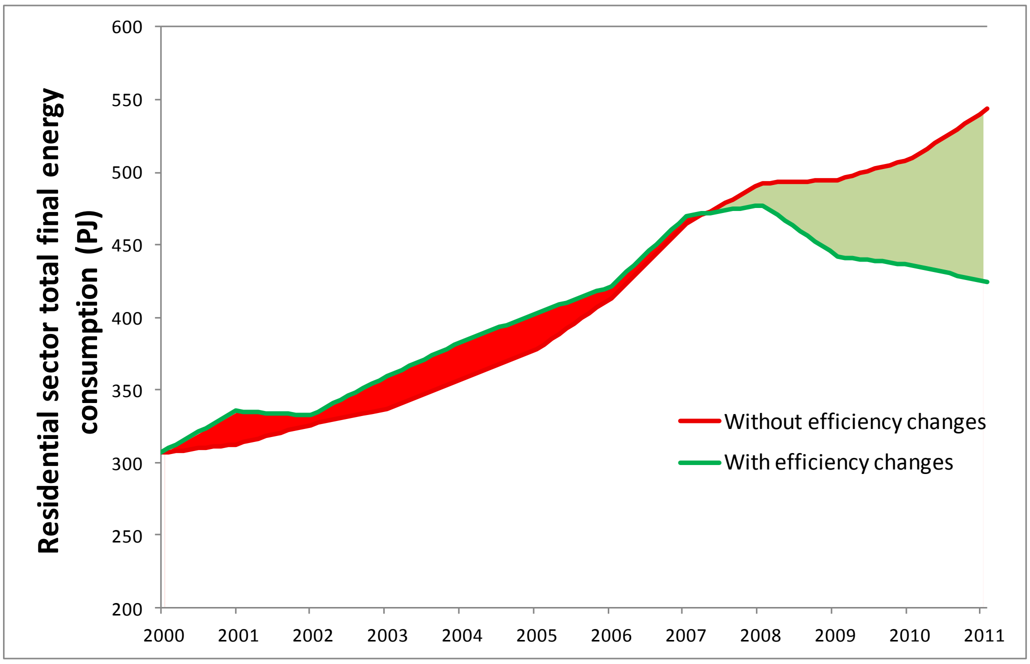

Figure 28 Comparison of actual observed trends in energy consumption of the residential sector (green trace) versus trends that would have occurred with no efficiency change (red trace).

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 this survey and in the similar survey conducted in 2013 can provide only snapshots. Furthermore, the current survey and the 2013 survey covered distinct geographical areas, with relatively small sample sizes, and cannot be considered statistically representative of the whole country. It would therefore be incorrect to interpret any differences between the results of the two surveys as being indicative of trends through time. Because of this, the results of the 2013 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 agreement[26] with the statement:

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

All 968 households surveyed provided a response to this question, the results of which are shown in Figure 29 below. About 38% of households agree strongly with the statement, and a further 22% agree, making a total of 60% of households that struggle to some extent with energy costs. This contrasts with a total of only 16% of households for whom energy is comfortably affordable. The breakdown of average responses by LSM shown in Figure 30 suggests that there is very little variation in the perception of affordability across the LSM groups.

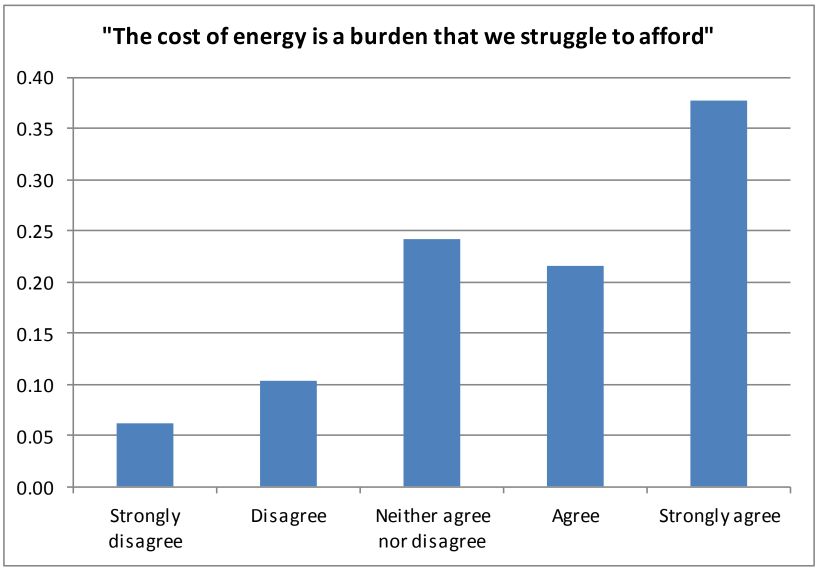

Figure 29 Responses to question on affordability of energy

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

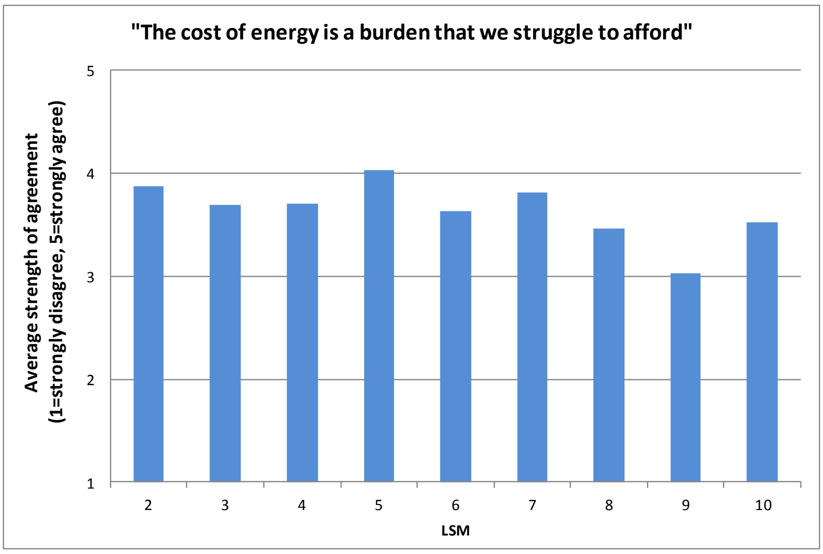

Figure 30 Breakdown by LSM of the responses to survey question on the affordability of energy

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 70% 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 62% and 65% respectively. Fewer than 15% of households profess a lack of awareness in respect of any of the three questions.

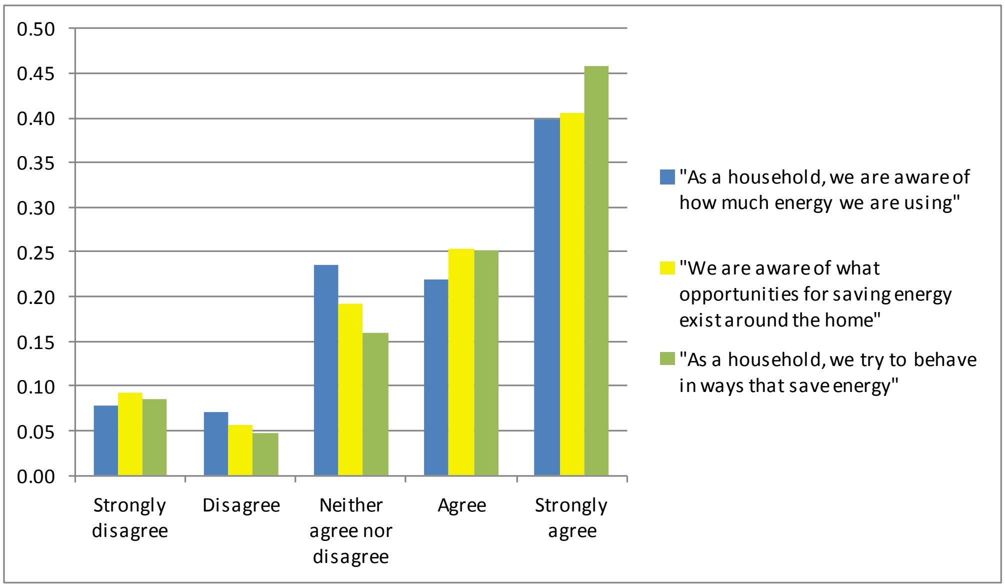

Figure 31 Survey responses relating to awareness of energy consumption

Figure 32 illustrates the variation in householders' perception of their awareness of energy across the LSM bands. The level of awareness appears to show a slight peak among the upper-mid LSM brackets, with LSMs 2 & 3 showing the lowest levels.

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 response[27], 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, geyser blankets, solar geysers, solar PV and low-flow shower heads also achieving somewhat higher levels of awareness than the other technologies, particularly among upper-mid range of LSMs.

[27] In fact, the same questions were used to determine both awareness levels and ownership levels of the technologies (see next section).

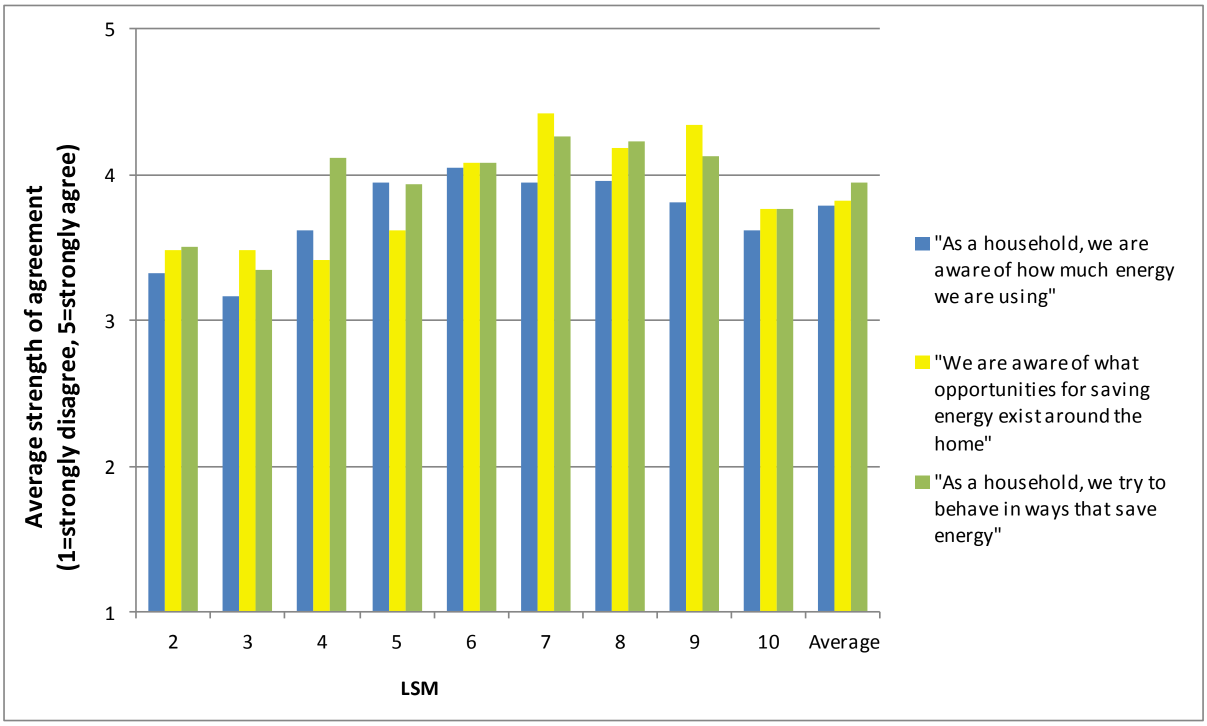

Figure 32 Breakdown by LSM of survey responses relating to awareness of energy consumption

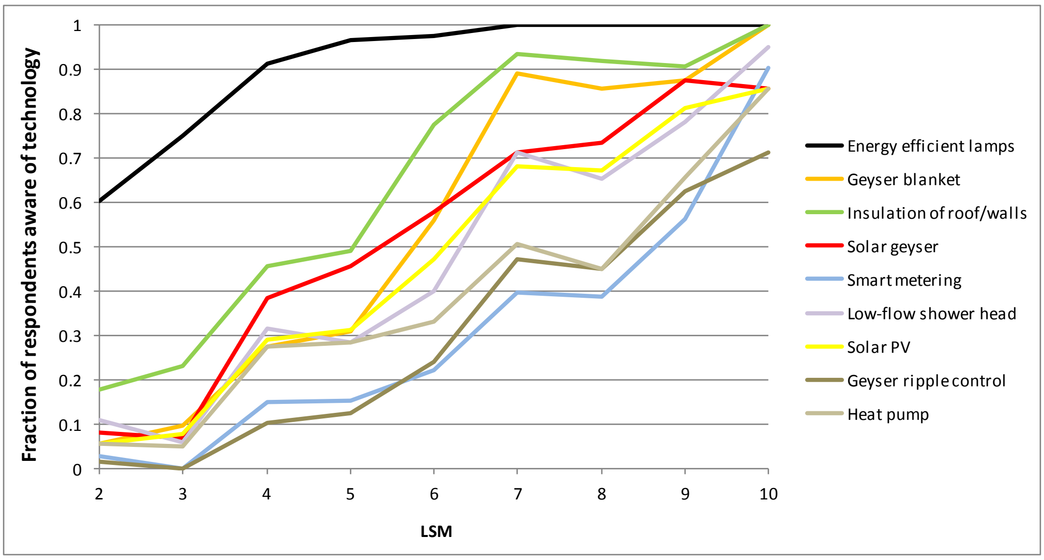

Figure 33 Level of awareness of a range of energy efficiency technologies

Behaviour

Survey questions aimed at discovering whether households are actually behaving in ways that are likely to result in improved energy efficiency included a question on the level of adoption of energy efficiency technologies. The results of this question are presented in Figure 34 below. Adoption levels of energy efficient lamps are above 90% for LSMs 8-10, and are above 50% for LSMs 5 and above. Roof / wall insulation also has high adoption rates in the higher LSMs, with levels reaching around 50% for LSMs 7 & 8.

Adoption of all the other energy saving technologies is seen only at LSM 7 and above. Geyser blankets and low-flow shower heads are the next most popular technologies, reaching adoption levels in LSM 10 of almost 50% and slightly over 60% respectively. Two other technologies show significant adoption rates in the higher LSMs – geyser ripple control and solar geysers, which are in use in 30% and 20% of LSM 10 households respectively.

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 geyser ripple control, for every technology over one-third of current users are new adopters. In the case of solar geysers, over three-quarters of the surveyed households that use the technology have acquired in within the last year.

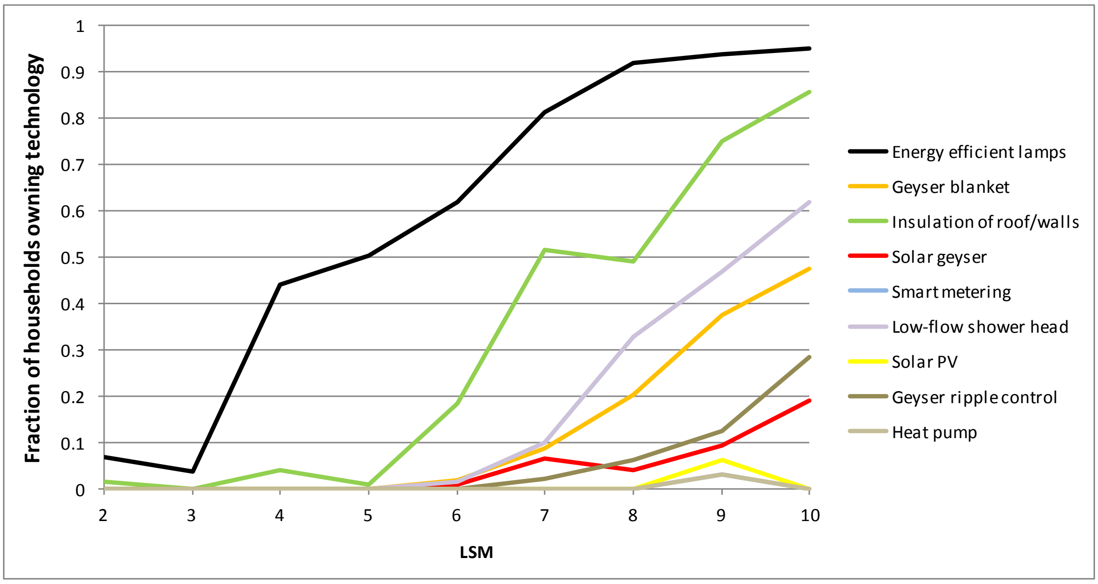

Figure 34 Adoption levels of a range of energy efficiency technologies

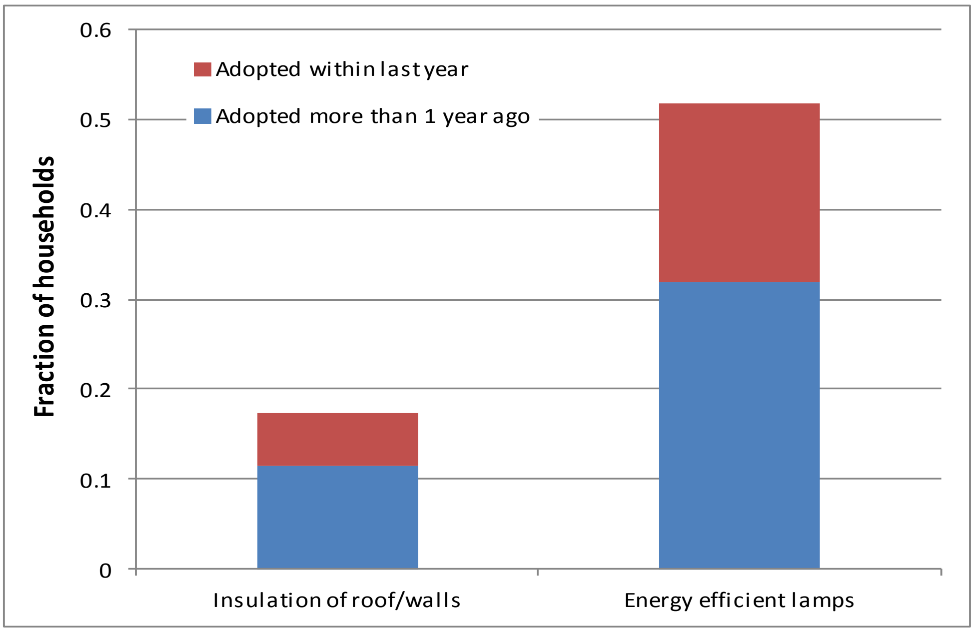

Figure 35 Overall adoption rates for the two most popular energy efficiency technologies

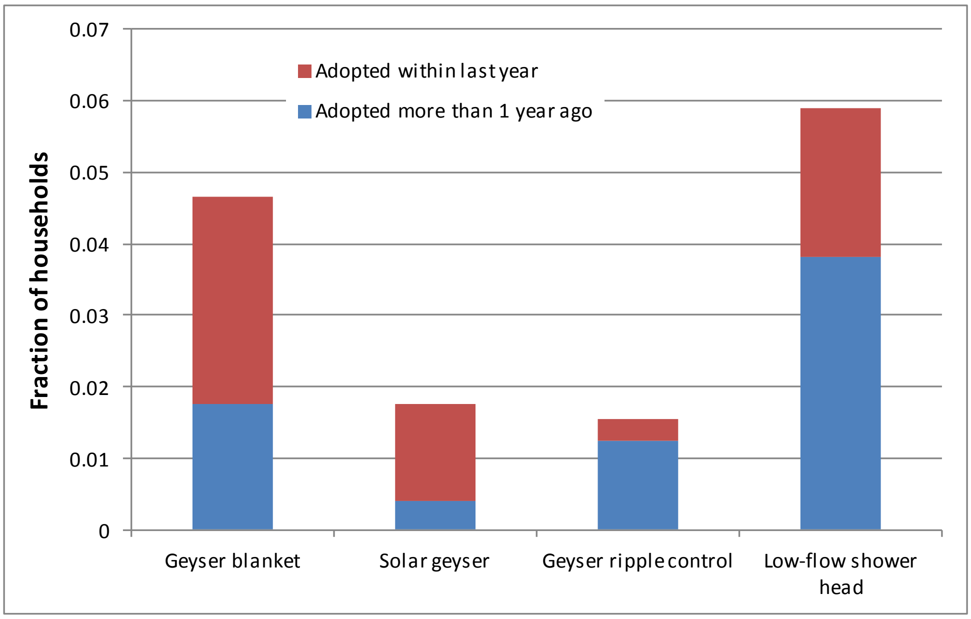

Figure 36 Overall adoption rates for other energy efficiency technologies

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 slightly under one-third of households overall either agree or strongly agree that energy efficiency is a consideration. Somewhat more than one-third of households in the survey do not consider the energy efficiency of appliances they are buying, while the remaining 30% are neutral.

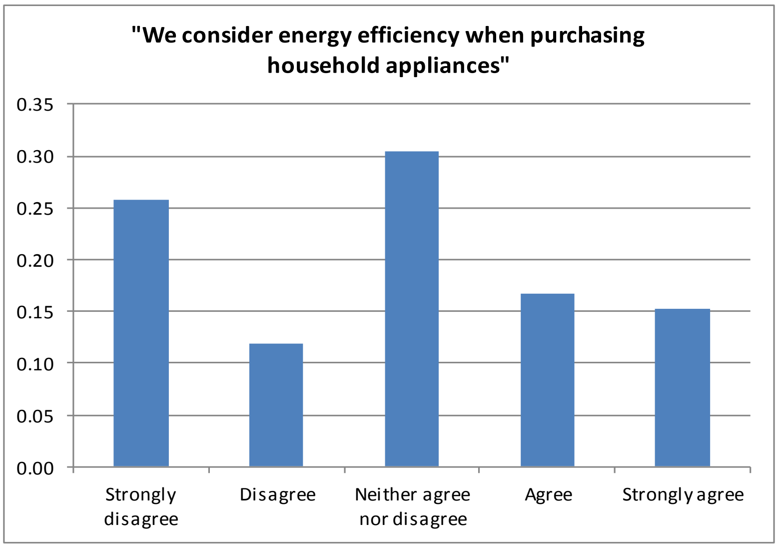

Figure 37 Extent to which energy efficiency influences appliance purchasing decisions

Figure 38 shows the responses to this question broken down by LSM, where it can be seen that only in the highest LSMs does the average response exceed the neutral level. These results are understandable in the context where many appliance purchases in LSMs 5 and below 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.

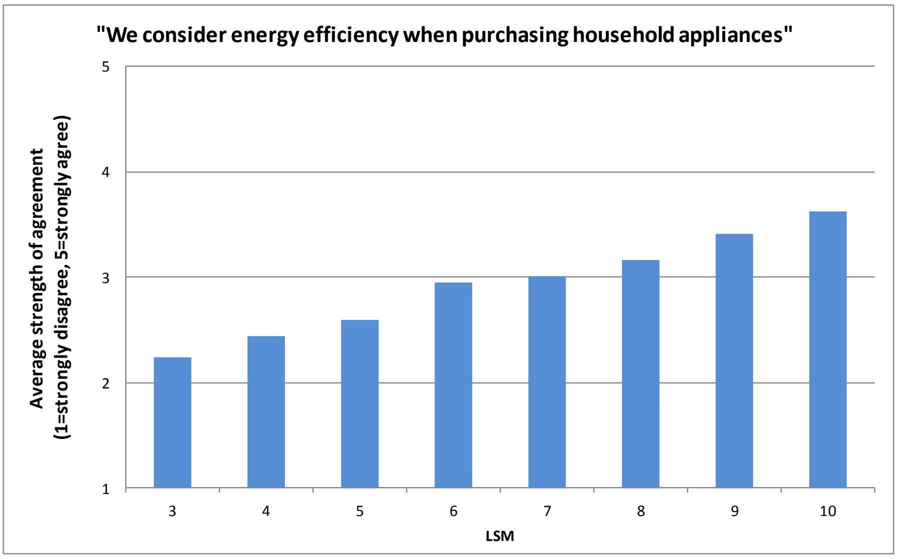

Figure 38 Breakdown by LSM of the extent to which energy efficiency influences appliance purchasing decisions

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.

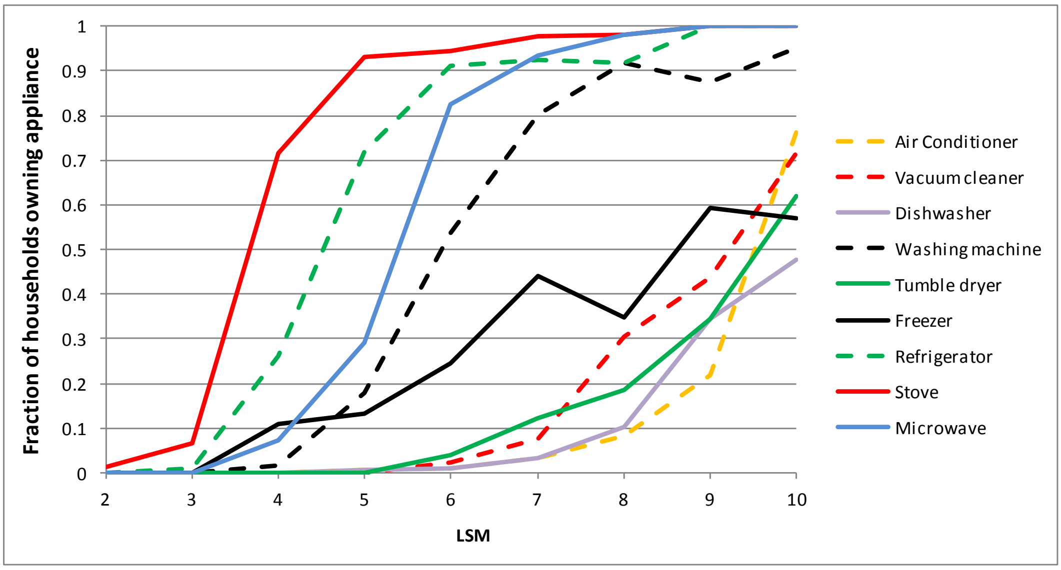

Figure 39 Ownership rates of a range of household appliances

Figure 39 indicates that there is a distinct group of early-adopted appliances (stove, refrigerator, microwave oven and washing machine) that reach significant levels of adoption between LSMs 4-6.

Conversely, the group of late-adopted appliances (tumble dryer, vacuum cleaner, dishwasher and air-conditioner) start to show significant adoption only in LSMs 7- 8, and even in LSM 10 are owned only by half to three-quarters of households. Adoption patterns of freezers appear to follow a different pattern, with ownership already significant in LSMs 4-5, but not rising above about 60% even in the highest LSMs.

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 the five appliance types 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 shown in Table 15 below, aggregated across all surveyed households.

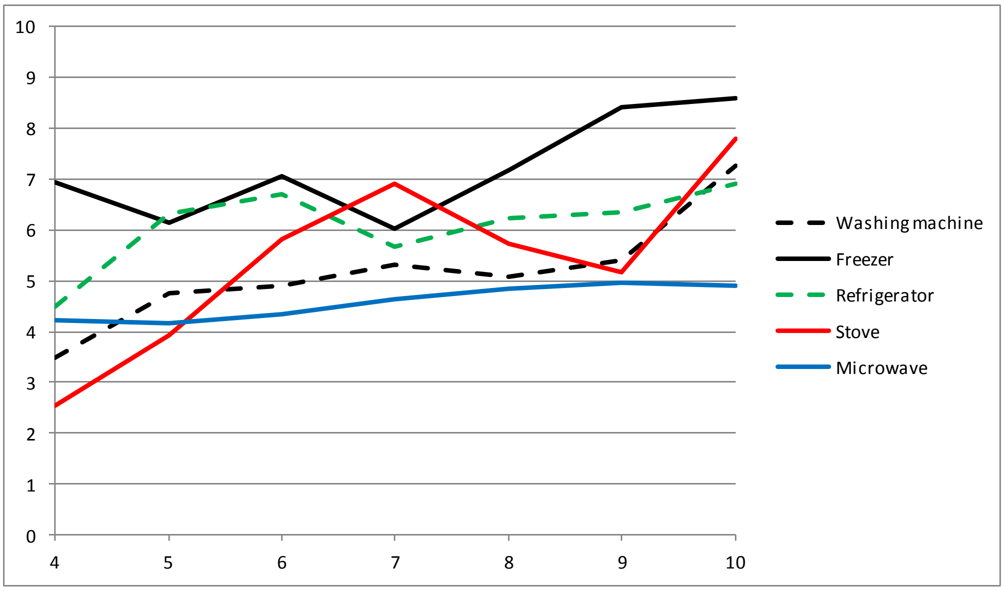

Figure 40 Average age of selected appliance types by LSM

For some of the early-adopted appliances shown in Figure 40, there appears to be a weak trend towards an increase of appliance age with LSM, reflecting the fact that a certain fraction of owners in lower LSMs have only recently acquired that type appliance for the first time. The average age of microwave ovens appears to be remarkably constant across all LSMs, indicating that the age range of 4-5 years represents the natural rate of turnover for this appliance. The results in Table 15 indicate that the average age of the late-adopted group of appliances does appear to be somewhat lower than that of the early-adopted group, suggesting that the influence of first-time purchases is strong. For refrigerators and stoves, ownership levels are already close to saturation by LSM 5, so the average age of these appliances is a reasonably good representation of the rate at which they tend to be replaced.

Table 15 Average age of appliances owned by survey respondents

Appliance	Average age (years)
Air Conditioner	3.8
Vacuum cleaner	4.6
Dishwasher	4.0
Tumble dryer	4.5
Washing machine	5.2
Freezer	6.9
Refrigerator	6.3
Stove	5.0
Microwave oven	4.5

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 2000-2011 has been about 29.5%. 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 is the rapid rate at which households' living standards are improving, which is associated with the acquisition of increasing numbers of energy-using household appliances. Ownership of refrigerators increases from virtually zero 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 (remembering however that the sample on which the analysis was conducted was small and geographically limited). 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 4-7 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.

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 Lermit and N Jollands (2001).

Substituting the figures from Table 1 into these equations gives:

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

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

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

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	
	[T_2_1] Name of respondent	
	[T_2_2] Surname of respondent	
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)	
	[T_6_1] House number or street number	
	[T_6_2] Street name	
	[T_6_3] Suburb/township extension	
	[T_6_4] Stand/erf number	
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)	
	[T_10_1] Number of toddlers/infants	

	aged under 5	
	[T_10_2] Number of children aged between 5 - 17	
	[T_10_3] Number of adults aged 18 and over	
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*

		<3> Not present, but IS aware of it *<4> Not present and NOT aware of it*
	[T_184_7] Ripple control on other appliances (pool, air conditioner)	*<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_8] Smart metering	*<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_9] Heat pumps	*<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_10] Low-flow shower head	*<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_11] Other	*<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*
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?	<1> All of them <2> Most of them <3> Some of them
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?	<1> House is warmer in winter/cooler in summer <2> Reduced use of heater/fan/aircon/fire for heat <3> High (initial) cost of insulation

		<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! :)	