Mitigation Action Plans & Scenarios

RESEARCH PAPER

Modelling the Socio-Economic Implications of Mitigation Actions:

A Case Study Of Industrial Energy Efficiency In South Africa

ISSUE 20.

Developing countries exploring pathways to climate compatibility

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The following citation should be used for this document:

Moyo, A & Labintan, C 2013. Modelling the Socio-Economic Implications of Mitigation Actions: A Case Study of Industrial Energy Efficiency in South Africa. MAPS Working/ Research Paper. MAPS

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1. INTRODUCTION

There is a common understanding that anthropogenic activities, mainly the combustion of fossil fuels, are contributing significantly to global warming and its negative impact (IPCC 2007). Everywhere more attention is now being given to low-carbon development policies and their implementation. Such policies aim to reduce the carbon intensity of energy production as well as energy consumption (Urban & Nordensvärd 2013). This means that the carbon intensity of fossil fuel combustion is reduced by decreasing the carbon intensity and energy intensity associated with electricity, heat and fuel production and consumption, as well as reducing demand for energy and transport services associated with fossil fuel burning activities (Dinica 2002). Tackling this goal requires technical and non-technical measures with regard to both energy supply and demand. The first on supply are related to direct emission reduction in heat and electricity production and in fuel burning from transport vehicles, while the second on demand are related to indirect emissions abatement of energy consumption in the industrial, residential and commercial sectors and decrease in demand for energy services, like transport.

A wide range of policy instruments are being developed at national and international level across the world to contribute to emissions reduction. National policy instruments include government designated and implemented projects (direct regulation, standards, licences and bans), economic instruments (tax, subsidies, emission trading and deposit refund systems), information and communication policies as well as voluntary agreements (Dinica 2002). However, the complexity is that there is a trade-off between these different policy instruments and other developmental goals, as their relative social cost constitutes a real constraint and limitation when it comes to implementing them effectively. Among the different policies supporting carbon reduction, energy efficiency is viewed as being the most cost effective (IEA 2012). It has been estimated that implementing energy-efficiency measures in the industrial sector will contribute to savings of 2.5 to 5.5 Gt CO_2 equivalent in 2030, a share of 15% to 30% of projected 2030 emissions compared to the baseline scenario (IPCC 2007). Developing and transitional economy countries could potentially contribute as much as 80% of the energy saving (UN-Energy 2009). This would be mainly in the electricity sector, which accounts for 65% of industrial energy consumption (Yépez-García et al 2011).

While there is significant potential for emissions reduction through the implementation of energy efficiency policies by both developed and developing countries, detailed understanding of the impacts of these polices on economic growth, employment and welfare is limited. This study aims to address this by using a computable general equilibrium (CGE) model to assess the socio-economic implications of increased energy efficiency in South Africa. To do this we start with an overview of energy efficiency measures and policies that are being formulated or are being implemented globally. We then draw from similar studies that have used economy-wide models to analyse the impact of energy efficiency policies and measures. We then proceed to analyse the potential socio-economic implications of improvements in industrial energy efficiency in South Africa.

2. OVERVIEW OF ENERGY EFFICIENCY STRATEGIES AND POLICIES GLOBALLY

A number of countries have adopted energy efficiency polices and strategies, or are in the process of formulating them. The motivation for pursuing these polices varies, with some countries seeking to reduce energy consumption for energy security reasons and others considering energy efficiency as important for climate change mitigation. Various countries within the European Union (EU) agreed to a EU-wide target of 20% savings in energy by 2020, also referred to as the 20/20 target (Pasquier 2012). In addition to the EU target, the German government in its new energy concept added a target of a 50% reduction in primary energy consumption in the country by 2050, relative to levels in 2008 (Lutz 2012). Other countries that have or are developing energy efficiency strategies include Australia and New Zealand. Australia is developing a National strategy on Energy Efficiency (NSEE); a 10-year plan aimed at accelerating energy efficiency improvements (COAG 2009). New Zealand has an energy efficiency and conservation strategy (2011-2016), focusing on the efficient use of energy in homes, the transport system and business (MED 2011).

Energy efficiency strategies and policies have also been adopted in some South American countries. The motivation for pursuing these policies in the past has not necessarily been to reduce the emission of greenhouse gases (GHGs) but has included issues such as enhancing energy security through managing consumption of energy. However, under the MAPS[1] programme taking place in Brazil, Colombia, Chile and Peru, energy efficiency is being considered as one of the most important and cost-effective means of mitigating climate change and achieving emissions reduction targets. The Brazilian government signed the National Climate Change plan (PNMC) in 2008. Although the policy largely focuses on reducing emissions from deforestation, it also includes a national energy efficiency plan, which aims to improve energy efficiency in the industrial, building and transport sectors. Cutting Brazil's electricity consumption by 10% — that is, an equivalent of 106 Twh by 2030 — could result in avoided emissions of 30 million tons of $C0_2$ equivalent and contribute significantly to curbing the country's growing emissions from the energy sector (Enerdata 2011).

In Colombia, the Programme for Rational and Efficient Use of Energy and Other Forms of Non-Conventional Energy (PROURE) aims to increase energy efficiency so that it can drive economic growth, competitiveness and inclusiveness as well as sustainable development in the tourism sector. Energy savings over 10 years are expected to be between 628.67Gwh, equivalent to 139.773 $tC0_2$ eq (IDB 2011).

The Chilean government established the Chilean National Energy Efficiency Programme (PPEE) in 2005, putting energy efficiency on the national agenda. There is also an Energy Efficiency Action Plan that is part of Chile's National Energy Strategy, which was established in 2012. The goal of the action plan is to reduce the projected demand for energy by 12% by 2020 (Ministry of Energy 2012), saving 1122 MW with 1.2 million tons of $C0_2$ eq reduction per year (IEA 2012). The plan would target mainly appliances, buildings and the industry and transport sectors.

In 2009 the government of Peru established the Energy Efficiency Referential plan (2009-2018), which is aimed at reducing the country energy demand by 15% toward 2015 mainly in residential, productive, public services and transport sectors. This would result in an energy saving of 372.71PJ (APEC 2011).

[1] Mitigation Action Plans and Scenarios (MAPS) is collaboration amongst developing countries to establish the evidence base for long-term transition to robust economies that are both carbon efficient and climate resilient. See www.mapsprogramme.org for more information.

As the countries involved in the MAPS programme consider implementing more energy efficiency measures, one of the key concerns for stakeholders and policymakers is the impact that such measures would have on economic growth and development in their countries.

3. POTENTIAL FOR REBOUND EFFECTS

There is considerable debate among scholars and decision-makers on the real benefit of implementing energy efficiency measures and the period of benefit, because of associated feedback effects (Khazzoom 1980; Schipper & Grubb 2000; Brookes 2000; Greening et al 2000; Laitner 2000). The debate is related to the net energy saving and the equivalent cost of saving. Khazzoom (1980) argues that, because energy efficiency investment reduces the cost of energy services, such investment would result in a rebound effect that would tend to offset at least a part of initial energy saved. In other words, the rebound effect is the percentage of final energy saved that is shortly consumed by the rebound in demand due to reduced costs. Gains in the efficiency of energy consumption will result in an effective reduction in the unit price of energy services, but the magnitude of the response may vary across countries and within a country's end-user sectors (Greening et al 2000). Researchers have identified three categories of rebound effects: direct, indirect and economy-wide (Greening et al 2000; Schipper & Grubb 2000; Sorrell 2007). The direct rebound effects are based on partial equilibrium conditions and are the result of pure price effects. While the indirect rebound effects originate from the pure price effects that cause direct rebound effects, economic linkages ensure that these price effects are transmitted throughout the whole economic system. Consequently, these indirect rebound effects belong to a general rather than a partial equilibrium perspective. However, the economy-wide rebound effects track the impact that the decline in the effective price of energy, that stems from energy-efficiency gains, has over the aggregate demand for energy in the economy.

Exploring the intensity of the effects, Schipper and Grubb (2000) argue that the rebound effect between energy efficiency and energy use can be weak, strong or even backfire, such that final energy demand increases. They found that in most cases the effect is not large enough to offset all the energy savings. They also found that the direct effect is correlated to direct reduction in energy consumption and the indirect effect is related to household income (purchasing power) or growth in GDP.

Economy-wide models can be used to estimate the rebound effect. However, a limitation of previous studies that have used CGE models to estimate the rebound effect is that they assume that the imposed change in energy efficiency is equivalent to the potential energy savings. Guerra and Sancho (2010) argue that making this assumption would give us biased results, as the imposed change in efficiency does not take into account the interrelationships within the commodities market. Energy productivity increases would therefore not have an impact on prices and quantities of sectors that provide inputs into the energy sector (Guerra & Sancho 2010). Imposed changes in energy efficiency would resemble potential energy savings in a partial equilibrium context. To address this, Guerra and Sancho (2010) suggest an 'unbiased economy-wide rebound measure' in which the potential energy savings are estimated under general equilibrium, where prices are held constant while controlling for market interdependencies. To estimate potential energy savings, Guerra and Sancho (2010) propose the use of an input-output approach so as to isolate quantity from the price effect and thereby obtain a general equilibrium estimate of these savings. We do not estimate the rebound effect in this paper, because of the continuing debate and the complexities involved in estimating it.

4. INDUSTRIAL ENERGY EFFICIENCY IN SOUTH AFRICA

South Africa is one of the most energy-intensive countries in the world. This results from the cheap electricity of the past, which led to industries using it inefficiently (DME 2005). South African electricity is largely produced by coal-fired power stations, resulting in high carbon emissions. To address this, an Energy Efficiency Strategy was adopted in 2005 with a vision "[t]o encourage sustainable energy sector development and energy use through efficient practices thereby minimising the undesirable impacts of energy usage upon health and the environment and contributing towards secure and affordable energy for all." (DME 2005:4) Amongst the eight goals of the strategy are those of job creation, alleviation of energy poverty and the reduction of carbon dioxide emissions.

According to the strategy, South Africa would aim to achieve a national target of 12% reduction in final energy demand by 2015 (DME 2005). This reduction would be relative to projections of national energy usage in 2014 with no additional efficiency interventions included. Key assumptions used to make the projections were that South Africa's population would have grown from 44 million in 2000 to 53.3 million in 2015 and that the average annual GDP growth rate over the period would be 2.8% (DME 2005). Targets for the different sectors in the South African economy, such as transport, commercial and public as well as residential, were also proposed in the strategy. In this paper, however, we focus on the mining and industrial sectors as well as electricity generation. In South Africa the mining and industrial sectors account for about two thirds of the electricity used (DME 2005). A target of 15% reduction in final energy demand by 2015 was set for the mining and industrial sector; a 'realistic and achievable' one, as previous research had indicated that at least 11% savings could be achieved through the use of low-to-medium-cost technical interventions and an additional 5% to 15% through low- and no-cost inventions such as improvements in energy management (DME 2005). There was a lot of consultation between the Department of Minerals and Energy (DME) and Eskom, the national power utility, in the development of targets for the electricity generation sector. An interim target of 15% based on measures to reduce parasitic losses only was agreed on (DME 2005).

During the Long-Term Mitigation Scenarios (LTMS) for South Africa study, energy efficiency measures were found to be the most cost-effective way of reducing carbon emissions (Winkler 2007). Energy use could decrease with increased energy efficiency and this would lead to decreases in the production of energy in the economy. Since the production of energy (electricity in particular) is carbon-intensive, reduced production would result in lower carbon emissions. In the Government's white paper on climate change, up-scaling of industrial energy efficiency, together with increased energy efficiency in the other sectors — such as public, commercial and residential — was identified as one of the mitigation options with the biggest emissions reduction potential in the medium term (DEA 2011).

5. METHODOLOGY

In this section we begin by providing a brief overview of previous research evaluating the impact of increases in energy efficiency. We then give a detailed description of a CGE model for South Africa used to conduct our analysis.

5.1 Background on Previous Research

Energy efficiency has emerged as a key solution for addressing climate change and the rising cost of energy. This has resulted in considerable interest in energy efficiency programmes by governments across the world. Energy efficiency is one of the most cost-effective ways of reducing energy use. It can be achieved through no cost measures such as switching lights and machines off when there are not in use, energy management and technological progress. There is however debate among scholars and policymakers on the interaction between energy efficiency, energy consumption and climate change mitigation. These interactions make it difficult to generalise the potential impact of energy efficiency policies and hence these have to be assessed on a country-by-country basis. A number of researchers have carried out studies to explore the impact of energy efficiency policies and programmes. Two approaches have been widely adopted to analyse the impact of energy efficiency improvements. These are the bottom-up engineering approach and the top-down economy-wide approach.

The engineering bottom-up approach is characterised by simulation, optimisation, accounting and hybrid models (Bruce et al 1995; Hourcade et al 1996; Worrell 2004). However, the complexity of energy end-user behaviour, uncertainties and iterative learning processes related to the adoption of efficient technologies challenges the use of bottom-up models for assessing the impact of energy efficiency policy (Mundaca et al 2010). In addition, it is not possible to use the bottom-up approach to capture the indirect impact of energy efficiency policies, as these are partial equilibrium models. Davis et al (2010) carried out research to quantify the rebound effect of energy efficiency in the residential sector in South Africa. The study used a systems dynamics approach to model energy consumption behaviour of households. The national impacts of the rebound were evaluated using LEAP. A criticism of the study is that indirect effects that come about due to interrelations between commodities in the market were not considered as they had used a partial equilibrium approach for their analysis.

On the other hand, some researchers have used CGE models to evaluate the economy-wide implications of mitigation actions such as increased energy efficiency as well as the associated rebound effects. Allan et al (2007) used a recursive dynamic CGE model (UKENVI) to analyse the impact of increased efficiency in the industrial use of energy in the UK. They estimated the impact of a 5% across-the-board energy efficiency improvement in all production sectors and results indicated positive impacts on economic growth and employment with percentage changes of 0.17 and 0.21 from the base, respectively. Other researchers such as Pauw (2007) and Hanley et al (2009) have also used CGE models to study the implications of energy efficiency measures and their associated rebound effects. Hanley et al (2009) in a study of energy efficiency in Scotland found that the rebound effect was high and was moving towards becoming backfire. During the LTMS for South Africa study, Pauw (2007) used a recursive dynamic CGE model (STAGE) to analyse, among other mitigation actions, the implications of industrial energy efficiency measures on the South African economy. A distinction was made between electricity and thermal industrial energy efficiency. A bottom-up model MARKAL was used to provide energy efficiency data used in the simulations. Results indicated that the demand for electricity per unit of output went down by 29% by 2050 and thermal/coal demand by 45% over the same time interval. GDP increased by 0.4% and 0.95% for the electricity and thermal industrial energy efficiency scenarios respectively. Minimal changes in wages meant that, for both scenarios, the re-distributional effect was not significant. Marginal increases in household expenditure were found. While we also consider the impact of energy efficiency on the industrial sector of South Africa, in this paper we link energy efficiency to the targets set by government and use a static model for our analysis. The CGE model we use is described in the next section.

5.2 The static CGE Model for South Africa

For our analysis we adapt a comparative-static CGE model for South Africa developed by Thurlow and Seventer (2002) based on the standard International Food Policy Research Institute (IFPRI) model by Lofgren et al (2001). Arndt et al (2011) disaggregated the energy sector in the model in order to make it more detailed. The model uses South Africa's 2005 Social

Accounting Matrix (SAM) made up of 53 industries, 46 commodities, seven production factors (capital, four labour categories, farm land), three institutions (government, private sector and rest of the world) and 14 households income groups. Households are disaggregated into income deciles, with the ninth decile further divided into five groups. The CGE model mimics the behaviour of agents such as households, firms and government within the South African economy. A more detailed description of the production in the model is provided, as it is relevant for the implementation of industrial energy efficiency. Figure 1 illustrates the structure of production in South Africa.

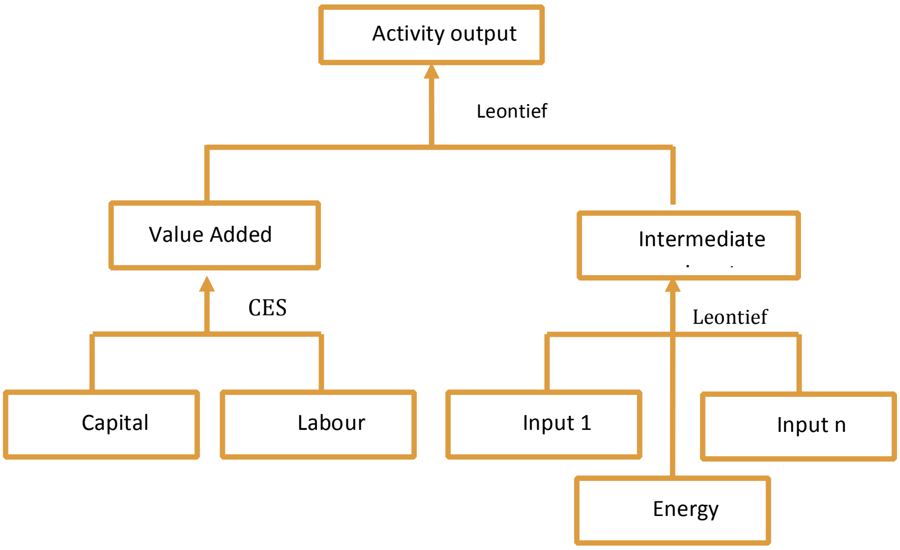

Figure 1: Structure of production in South Africa, with energy as an intermediate input

Source: Thurlow 2008, Adapted

In the model, producers maximise their profits. The choice of factors of production is governed by the constant elasticity of substitution (CES) function shown in Equation 1 (Thurlow 2008).

$$QVA_a = \alpha_a^{va} \cdot \left(\sum_{f \in F} \delta_{fa}^{va} \cdot QF_{fa}^{-\rho_a^{va}} \right)^{-\frac{1}{\rho_a^{va}}} \qquad (1)$$

where QVA_a is the aggregate quantity of value-added. QF_{fa} is the quantity of factor of production (f) demanded by activity a (Lofgren et al 2001). These factors of production (f) include land, capital and labour. α_a^{va} is the shift parameter of the CES activity production function and δ_{fa}^{va} is the share parameter for factor f in activity a for the value added function. ρ_a^{va} is the elasticity of substitution between the factors of production (Lofgren et al 2001). As explained in Arndt et al (2011), there are no reliable estimates of these elasticities in South Africa, but there are assumed to be less than one for most activities. These estimates were found to be consistent with findings in other countries.

In the South African CGE model, the ratio of intermediates to value added is determined by technology rather than a decision by producers (Thurlow 2008). This is shown in Equation 2 below.

$$QINT_{ca} = ica_{ca} \cdot QINTA_a \quad (2)$$

where $QINT_{ca}$ is the disaggregated intermediate production input. ica_{ca} is the quantity of commodity c per unit of aggregate intermediate input a (Lofgren et al 2001). $QINTA_a$ represents the quantity of aggregate intermediate input. Energy is included as an intermediate input in the CGE model.

The price of the aggregate intermediate $PINTA_a$ is given by Equation 3 below

$$PINTA_a = \sum_{c \in C} PQ_c \cdot ica_{ca} \quad (3)$$

where PQ_c price of the composite good (Lofgren et al 2001).

Intermediate inputs are combined in fixed proportions in the production of output, hence there are governed by a Leontief function as shown by Equation 4 and 5 (Thurlow 2008). The ratio of intermediates to value added is therefore determined by technology (Thurlow 2008).

$$QVA_a = iva_a \cdot QA_a \quad (4)$$

where iva_a is the quantity of value-added per activity unit and QA_a quantity (level) of activity (Lofgren et al 2001).

$$QINTA_a = \text{int}\, a_a \cdot QA_a \quad (5)$$

where $\text{int}\, a_a$ quantity of aggregate intermediate input per activity unit (Lofgren et al 2001).

The activity price PA_a is a summation of the value added price PVA_a and the price of the intermediate inputs $PINTA_a$ as shown in Equation 6.

$$PA_a = PVA_a + PINTA_a \quad (6)$$

In the CGE model, one activity can produce more than one commodity. The production of by-products is determined by technology and is hence governed by a Leontief function (Thurlow 2008). Commodities can also be produced by more than one activity and are aggregated through a CES function in order to allow for substitution between commodities by demanders (Thurlow 2008).

There are two markets for the commodities produced in the economy, namely the domestic and export markets. Producers will sell their commodities in markets where they will maximise their profits. This substitutability is shown in the constant elasticity of transformation (CET) function in Equation 7 below.

$$QX_c = \alpha_c^t \cdot \left(\delta_c^t \cdot QE_c^{\rho_c^t} + (1-\delta_c^t) \cdot QD_c^{\rho_c^t}\right)^{1/\rho_c^t}$$

(7)

where QX_c is aggregate marketed quantity of domestic output of commodity, QE_c is the quantity of export and QD_c is quantity sold domestically of domestic output (Lofgren et al 2001). The share parameter is given by δ_c^t, while α_c^t represents the efficiency parameter. ρ_c^t is the elasticity of transformation between the domestic and export goods.

The value of the marketed output is given by Equation 8 below

$$PX_c \cdot QX_c = PDS_c \cdot QD_c + PE_c \cdot QE_c \quad (8)$$

where PX_c is the average output price, PDS_c is the supply price of commodity c produced and sold domestically, and PE_c is the price of exports (Lofgren et al 2001).

The export-domestic supply ratio shown in Equation 9 gives the relationship between prices and quantities of export and domestic goods (Lofgren et al 2001).

$$\frac{QE_c}{QD_c} = \left(\frac{PE_c}{PDS_c} \cdot \frac{1-\delta_c^t}{\delta_c^t}\right)^{\frac{1}{\rho_c^t - 1}}$$

(9)

The domestic market is not only supplied by domestic production, but by imports as well. Demanders in the domestic market can choose between domestic and imported products/goods and the substitutability in the model is governed by the Armington CES function in Equation 10 (Thurlow 2008).

$$QQ_c = \alpha_c^q \cdot \left(\delta_c^q \cdot QM_c^{-\rho_c^q} + (1-\delta_c^q) \cdot QD_c^{-\rho_c^q}\right)^{-1/\rho_c^q}$$

(10)

where QQ_c is the quantity of goods supplied to domestic market (composite supply), QM_c is the quantity of imports. α_c^q is the efficiency parameter and δ_c^q is the share parameter (Lofgren et al 2001). ρ_c^q is the elasticity of substitution between the domestic goods and imports. The cost-minimising behaviour of domestic demanders determines the ratio of domestically produced goods to imported (Thurlow 2008).

Absorption, which is all domestic spending on goods and services in the economy is given by Equation 11.

$$PQ_c \cdot (1 - tq_c) \cdot QX_c = PDD_c \cdot QD_c + PM_c \cdot QM_c \quad (11)$$

where PDD_c js the demand price of commodity c produced and sold domestically, PM_c is the price of imports, and tq_c is the rate of sales tax (Lofgren et al 2001).

The import–domestic supply ratio in Equation 12 below shows the relationship between prices and quantities of imports and domestic goods (Lofgren et al 2001).

$$\frac{QM_c}{QD_c} = \left(\frac{PDD_c}{PM_c} \cdot \frac{\delta_c^q}{1 - \delta_c^q} \right)^{\frac{1}{1+\rho_c^q}}$$

(12)

These goods make up the composite goods that are consumed as final demand by household, governments and investment. Some of the goods are used as intermediate inputs by activities. The commodity market equilibrium is therefore given by Equation 13 below where the total quantity of goods supplied to the domestic market is equivalent to total demand.

$$QQ_c = \sum_{a \in A} QINT_{ca} + \sum_{h \in H} QH_{ch} + QG_c + QINV_c + qdst_c + QT_c$$

(13)

where QH_{ch} is the quantity of consumption of marketed commodity c for household h. Households maximise their utility subject to a budget constraint. QG_c represents government consumption demand for commodity c, $QINV_c$ is the quantity of fixed investment demand for commodity c, $qdst_c$ is the change in quantity of stock and QT_c is the quantity of commodity demanded as transactions service input (Lofgren et al 2001).

In the model, factor incomes and their payment into domestic institutions provide the link between production and demand. It is necessary to have a balance between demand and supply in order for equilibrium to be reached (Thurlow 2008). To achieve this balance, decisions on the system constraints and macro-economic closures are made based on the functioning of a particular economy and these are imposed on the model. Factors of production in the model — that is labour, capital and land — can either be fully employed or unemployed and mobile across sectors, fully employed and activity-specific. It is also possible to have a forward-sloping labour supply curve. There are three macro-economic closures in the model, that is the savings-investment (S-I) closure, the government closure and the current account or 'rest of the world' (ROW) closure (Thurlow 2008). The S-1 closure can be investment-driven savings or, alternatively, savings driven investment. With the government closure, government savings can be flexible and the direct tax rate fixed or alternatively, government savings can be fixed and direct tax rates made flexible. The exchange rate can be flexible with fixed foreign savings for the 'rest of the world' closure, or the exchange rate can be fixed and foreign savings made flexible (Thurlow 2008). The closures that we use in our simulations in this study are described in section 6.1.

6. ANALYSIS

This study models the impact of mining and industrial energy efficiency on emissions, economic growth and employment and household consumption. In this section we describe how the energy efficiency simulations were set up before proceeding to present and discuss our findings.

6.1 Simulation set-up in the CGE model

For our analysis we model the impact of energy efficiency in the industrial sector of South Africa, including mining. For simplicity we restrict energy efficiency to electricity and do not include other energy commodities such as coal and petroleum. Energy or electricity efficiency in the industrial sector for this study therefore is mostly about having the right size of motors and pumps, switching off conveyor belts when they are not being used and energy management to ensure that electricity is not consumed unnecessarily. It is not about fundamental changes in technology and production processes. We therefore assume that there are no costs associated with improved energy efficiency in our simulations. We analyse three scenarios with industrial energy efficiency improvements of respectively, 10%, 15% and 25%. The 15% energy efficiency scenario is meant to match the target set by Government in South Africa's energy efficiency strategy. The 10% scenario represents the implications if government did not meet its target. The 25% scenario represents what could be achieved with more ambitious targets. We simulate energy efficiency in the CGE model by reducing the value of the input co-efficient of electricity in the industrial sector by the percentage improvement in energy efficiency applicable for each scenario. This means less energy input will be required per unit of output produced by the industrial sector. The other input coefficients in the model remain constant in all the simulations.

Next, we define the closures that we use in our simulations. For the factor market we assume that skilled labour is fully employed and mobile, whilst unskilled labour has forward-sloping labour supply curves. All capital is assumed to be factor specific and mobile. Land is fully employed and mobile. In relation to the macro-economic closures, Nell (2003) found that for South Africa savings are investment-driven, hence we adopt this closure. Government savings are assumed to be flexible and the tax rate is fixed. The exchange rate is flexible and foreign savings are fixed in our simulations, as is the case in the South African economy.

6.2 Results and discussion

In this study we model the impact of mining and industrial energy efficiency on emissions, economic growth and employment and household consumption. We calculated emissions using the reference approach, which is based on the quantity of fossil fuels supplied to the electricity sector and their assumed carbon content (Alton et al 2012). Standard carbon emissions factors of 1.93 tons of CO_2 per metric ton of coal, 2.33 per metric ton of crude oil and 0.056 per gigajoule of natural gas were used to calculate emissions. Figure 2 below presents emissions results of the reference scenario and the three energy efficiency scenarios modelled.

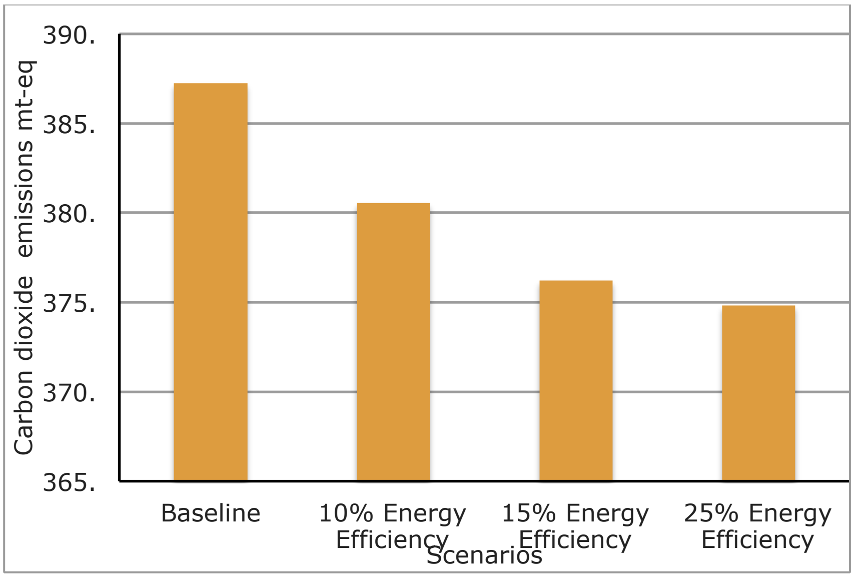

Figure 2: Total carbon dioxide emissions using Reference Approach

As expected the results show that energy efficiency in the industrial and mining sectors results in decreased emissions and that emissions reductions achieved rose with increased energy efficiency levels. Emissions are estimated to decrease by 1.14%, 2.84% and 3.20% with electrical energy efficiency improvements by industry of 10%, 15% and 25% respectively. These emissions reductions are relatively low, but this could be due to our focus on electricity efficiency. According to the Department of Energy's 2006 Energy Balances, electricity accounts for 39.15% of total energy inputs consumed by the industrial sector (ERC 2013). Emissions reductions would have been higher if we had also considered the efficient use of coal and petroleum in addition to electricity efficiency.

The implementation of energy efficiency measures could also be expected to have an impact on South Africa's economy. Table 1 below presents the implications of the energy efficiency on the macro-economic indicators.

Table 1 Macro-economic results

		Deviation from baseline (%)		
	Baseline Scenario (000 Rands)	10% Energy efficiency	15% Energy efficiency	25% Energy efficiency
Overall GDP at market prices	1571.08	0.23	0.33	0.42
Absorption	1598.50	0.22	0.33	0.42
Exports	384.46	0.04	0.07	0.07
Imports	-411.88	0.04	0.07	0.07

Results show that improved energy efficiency in the industrial sector would result in increases in GDP and absorption relative to the base, across all the three scenarios. GDP increases by 0.23%, 0.33% and 0.42% respectively for the 10%, 15% and 25% electrical energy efficiency scenarios. This could be as a result of improved energy efficiency lowering the costs of production for firms, as industries will be using less energy and therefore spending less on energy inputs. These industries will be able to produce the same amount of goods as before with less energy. With lower cost of production, these industries will be able to lower the prices of their goods. The lower prices could mean that consumers would spend less on these goods than before to get the same level of satisfaction. Lower prices of goods could increase demand and consumption in the economy. Increases in demand will stimulate firms to increase their production in order to meet this demand and increase their revenues and profits. Increased productivity in the economy will have positive effects on economic growth. Lower input costs and increased demand would lead to increases in production in the economy, resulting in higher levels of output and GDP. Absorption increased by similar margins as GDP for the three scenarios, relative to the base, signalling improvements in aggregate welfare in the economy. Trade would also increase as the higher production could mean increase in some of the inputs used in the production processes of some of the industries and mines. Lower prices of locally produced goods due to decreased energy input costs could make those goods more competitive domestically and internationally. Increased output from industries and mines could also result in increases in exports.

The improved performance of the South African economy would also have a positive impact on employment and household welfare. As can be seen in Table 2 below, employment of unskilled labour in the economy would be expected to increase for all the energy efficiency scenarios.

Table 2 Quantity of labour supply by education-based skills levels

		Deviation from baseline (%)		
	Baseline Scenario (thousands)	**10% Energy efficiency**	**15% Energy efficiency**	**25% Energy efficiency**
Unskilled-primary	3.18	0.06	0.08	0.08
Unskilled-middle	3.45	0.06	0.09	0.12
Skilled-secondary	3.09	0	0	0
Skilled-tertiary	1.62	0	0	0

Increased productivity in the economy would have positive effects on economic growth and employment as more labour could be required to increase production. No changes would be expected as for skilled labour as the model assumed full employment in the economy.

We also considered the impact of the energy efficiency scenarios on household per capita incomes. The results from the simulations are presented in Figure 3.

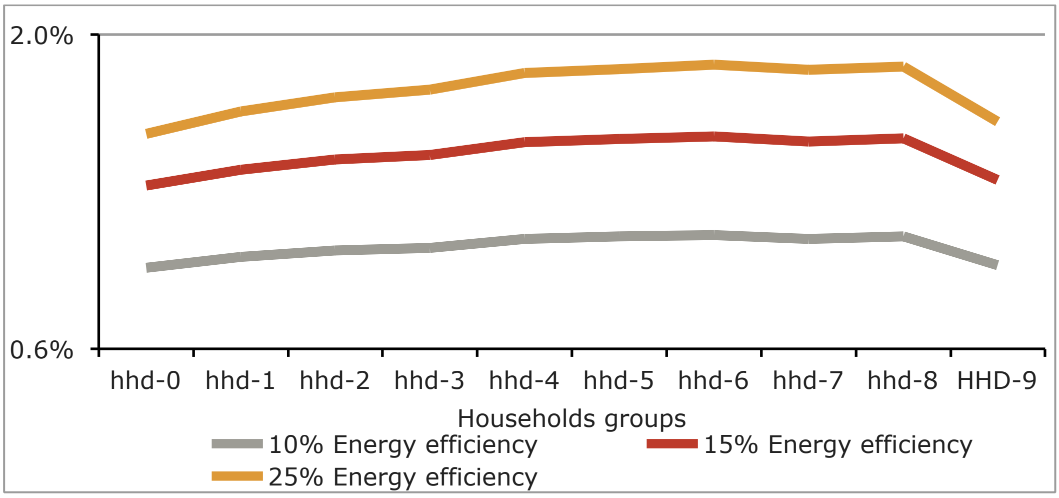

Figure 3: Percentage deviation of average per capita households consumption growth rate of industrial energy efficiency scenarios from Reference Scenario (%)

Energy efficiency improvements could also improve household welfare as evidenced by the higher per capita consumption of all the household groups for the energy efficiency scenarios, relative to the baseline scenario. Results from our analysis also indicate that energy efficiency improvements would not have any distributional effects, confirming earlier findings by Pauw (2007).

7. CONCLUSION

From our analysis it is clear that improvements in industrial electrical energy efficiency will make a positive contribution to emissions reduction, economic growth, employment and household welfare. Similarly to Pauw (2007), we did not find any distributional effects of increased energy efficiency. Our simulations indicate that the benefits of energy efficiency improvements will increase the higher the level of improvement in energy efficiency achieved. Our analysis in this paper focuses on costless improvements in electricity efficiency. Further work could involve the inclusion of all the other energy commodities used by the industrial sector such as coal, gas and petroleum. Costs in energy efficiency improvements such as the adoption of more efficient technologies in production processes could also be factored into the analysis. The rebound effect from industrial energy improvements could also be evaluated.

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