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Linking energy efficiency legislation and the agricultural sector in South Africa

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There are different ways of measuring energy efficiency. Although there is no generally agreed definition of the concept, it should, however, always be approached according to particular circumstances and contexts. As such, technological, operational, performance and equipment efficiencies should be taken into consideration. Generally, energy utilisation in most sectors of the South African economy is inefficient. This requires more energy needs to be generated in order to cater for losses. An increase in generation causes environmental problems at global, regional and local levels. A review of literature on energy efficiency was undertaken and a gap identified between legislation and efficiency in the agricultural sector. This article seeks to suggest ways of implementing an energy legislation in this sector in South Africa. Such implementation will address concerns in terms of harnessing, generating and utilising energy in different sectors in South Africa. Legislation is vital in reducing energy consumption in the agricultural sector. It also ensures efficient use of energy and the maintenance of current levels of production.

Introduction

Energy drives agricultural activities. Apart from direct solar energy used by plants in photosynthesis, gasoline, diesel, electricity and biofuel are used to power equipment used in the processing of produce, storage and transportation of such produce to the market. Efficient use of energy is thus imperative for sustainable production. However, there is no universally accepted definition of energy efficiency. The term 'energy efficiency' generally entails doing more work with less energy while maintaining or increasing the ratio of energy output to energy input. The World Energy Council (2013) defined energy efficiency as a sustainable reduction in energy used for a given service or level of activity. The agriculture sector in South Africa comprises the following: crop and animal husbandry, fisheries and forestry. However, this sector consumes a lower amount of energy compared with the mining and manufacturing sectors.

There is considerable literature on energy efficiency legislation in South Africa. The literature addresses energy efficiency concerns at all levels and sectors of the economy, particularly in agriculture, manufacturing and mining (Deloitte 2012; Department of Energy [DoE] 2012b; Department of Minerals and Energy [DoME] 2004; Inglesi-Lotz & Blignaut 2015; Statistics South Africa 2005). However, the literature does not address the issue of energy efficiency legislation and the extent to which the legislation has resulted in the reduction of energy consumption by different sectors of the economy (Gellings 2000; Winkler 2005).

According to Winkler (2005), coal, electricity, liquid petroleum and natural gas are used for domestic, commercial and industrial purposes. Among these forms of energy, electricity is the most used. The manner in which energy resources are harnessed, generated and utilised by different users in the country raises a lot of concerns. The main challenge is that most sectors of the South African economy are inefficient in terms of using energy. This situation leads to increased global, regional and local environmental problems. The relationship between increasing energy demands and the diversification of energy sources in South Africa is a delicate one. If a balance is not reached, South Africa may experience energy insecurity. According to a report by the DoE (2012b), the bulk of energy generated is consumed by the following sectors: industrial and mining (~41%), transport (~27%), households (~20%), commerce (~8%) and agriculture (~3%).

Research method

This article is a review of literature on energy efficiency legislation in South Africa, commonly known as ISO 50001. An analysis of the extent to which legislation has brought about efficiency in the utilisation of energy in the agricultural sector is done in this study. Information was sourced from the Southern African Development Community (SADC) Protocol on Energy (1996), SADC Energy Corporation Policy and Strategy (1996), SADC Energy Action Plan (1997), SADC Energy Sector Activity Plan (2000) and SADC Regional Infrastructural Master Plan (2012). These pieces of legislation provide guidelines on how energy efficiency could be attained at the level of SADC and within member states. The Draft 2012 Integrated Energy Planning Report (DoE 2012a), the South Report (World Wide Fund 2014), Energy Accounts for South Africa (Statistic South Africa 2005), the Draft Energy Strategy of the Republic of South Africa (DoME 2004), Energy Efficiency in Agricultural Equipment (Gellings 2015), the South Africa Energy Efficiency Report (Deloitte 2012) and many other reports and journal articles were used in the study. ISO 50001 was also considered in the study. This is a voluntary Energy Management Standard for measuring and verifying energy efficiency savings for tax incentives. It is a key basis for the development of energy efficiency policies in South Africa and recognises the role energy efficiency can play in economic growth. It was developed by the SADC as a policy tool. The document outlines policies and strategies to address energy efficiency at both regional and national levels. This has led to the introduction of policies, legislation and voluntary measures to address energy use through energy efficiency in South Africa (a member of SADC).

Energy efficiency policies and the legislative framework in South Africa

According to Camaren and Swilling (2011), the need for an energy-efficient economy is urgent and the current resource and energy-intensive growth path strategies used by policymakers in South Africa is unsustainable. As a result, there is a shift in South Africa towards energy efficiency. The country passed the White Paper on Energy Policy (1998), the White Paper on Renewable Energy (2003), the White Paper on National Climate Change Response (2011), the Integrated Energy Plan (IEP 2003), the National Integrated Resource Plan (2003/2004), and the National Energy Efficiency Strategy (2009). All these pieces of legislation are drivers towards regulating the use of energy by the different sectors of the economy.

Gerrard (2011) argued that there are two main ways in which energy problems could be addressed: energy efficiency and renewable energy. The International Energy Agency (IEA 2006) considers 'energy efficiency' as a way of managing and restraining the growth in energy consumption. Xiaohua Xia and Jianjfeng Zhang (2010) and Zhang et al. (2013) maintained that energy efficiency consists of the following components: technology efficiency, equipment efficiency, operation efficiency and performance efficiency. In a study conducted by Blancard and Martin (2014) on energy efficiency measurements in agriculture, they maintained that efficiency is not a fixed value and should be considered with caution, especially in situations of data uncertainty and availability (such as the case of South Africa). Blancard and Martin defined energy efficiency in agriculture as 'the ratio between outputs in physical units or converted to energy and inputs converted to energy'. It is on this basis that the French Environment and Management Agency, through its Energy Efficiency Plan (EEP), measures the subsidisation of agricultural equipment that confers energy savings.

Perez-Lombard et al. (2009) submitted that these different ways of approaching and defining energy efficiency demonstrate that there is no generally acceptable definition of the concept. In an attempt to ascertain a meaning of the concept, it should be borne in mind that it has to be defined according to a particular context. Energy efficiency is interpreted in this study based on the four components involved at different stages in agricultural production. In agriculture, inefficiency in the use of energy is generally related to the use of equipment that is not technologically advanced, and inadequate skills and training to operate such machines at the optimum level. Following the inception of the SADC protocol on energy efficiency, South Africa introduced the White Paper on Energy Policy (WEP 1998). It stipulates that energy efficiency would be attained through the introduction of energy efficiency incentives in the industrial sector, households as well as commercial energy consumers. Such a strategy would be realised with the introduction of energy efficiency norms and standards for commercial buildings, industrial equipment, domestic appliances, labelling programmes and programmes to reduce consumption in energy installations.

However, Mthombeni (2011) argued that since the introduction of new requirements by the European Union permitting the use of IE3 motors in agriculture from 2015, while IE2 motors may only be used in case the machine is equipped with variable speed drives (VSDs) to ensure energy efficiency, the South African market has been flooded with cheap imports of IE1s, EFF2s and EFF3s motors (which are energy inefficient). These motors have been found to be energy inefficient and consume 63% of electricity used by industries (representing 25% of the total electricity consumption in the United States) (Janicijevic & Hauptfleisch 2015). Furthermore, the White Paper on Renewable Energy (2003) empowers the government to intervene in industrial and household sectors while the IEP (2003) stresses that energy efficiency would be achieved through the introduction of energy efficiency policies, legislation and regulation programmes. In South Africa, these pieces of legislation are mostly voluntary and there are no mechanisms in place to enforce such legislation, thus allowing the continuous usage of energy-inefficient motors in the agricultural sector, leading to dumping from European Union member countries (given the low prices farmers pay for these motors). The National Integrated Resource Plan (2003/2004) emphasised that energy efficiency would be attained through energy-efficient lighting and best practices in the five demand-side management (DSM) programmes (residential energy efficiency, commercial energy efficiency, industrial and mining energy efficiency, residential load management, and industrial and mining load management). Furthermore, the National Energy Efficiency Strategy (2009) underlined, among others, energy labels, energy performance standards, energy audits, energy management and the promotion of efficient technologies as measures aimed at improving energy efficiency. It sets a national target for energy savings (at least 12% to be achieved by 2015).

Blancard and Martins (2014) maintained that measuring energy efficiency is an important aspect in the planning of energy-reduction policies. Decision-makers are normally reluctant to act in the absence of policy data and results supporting a policy position. The notion of energy efficiency is driven by factors such as climate change, the finite nature of fossil fuel, increase in energy demands, securing the supply of energy and a reduction in energy-related public expenditure as well as developmental goals and job creation (Ryan & Campbell 2012). The Integrated Resource Plan for Electricity 2010 to 2030 (IRP 2011) stresses that energy efficiency would be achieved through changes in the structure of the economy, higher electricity prices, improvements in technology, financial support, access to capital, appliances labelling and building standards. This assertion is affirmed by Camaren and Swilling (2011), posited that:

> the global policy context related to energy usage in developed and developing countries is heavily informed by changes in the global economy and global climate due to increased uncertainty, short-term unpredictability, non-linearity and vulnerability to resource scarcity. (p 3).

Although energy efficiency is an important tool in addressing issues such as climate change, the finite nature of fossil fuel and secure energy supply and the increased demand for energy penetration into society remains somewhat slow. In addition, the National Climate Change Response White Paper (NCCRP 2011) affirms that, as part of the Energy Efficiency and Energy Demand Management Flagship Programme, the DoE should continue to develop and facilitate an aggressive energy efficiency programme in industry (Musango & Brent 2011).

In South Africa, there are only two Acts that specifically refer to energy efficiency.

They are the National Energy Act 34 of 2008 (NE Act) and the Electricity Regulation Act 4 of 2006 (ER Act). The ER Act regulates electricity as a way of promoting energy efficiency (Mnguni & Tucker 2012) while the NE Act regulates electrical products as a way of enhancing energy efficiency. The Act stipulates that the Ministry of Energy may issue regulations that lay out steps and procedures for the application of energy efficiency technologies and procedures; labelling for energy efficiency; prohibiting the manufacturing, importing and selling of electric products and fuel burning appliances for the purpose of countering poor energy efficiency; standards and specifications for energy carriers; and energy efficiency standards for specific technologies. There is no Act in South Africa that deals with energy efficiency specifically. The Act is regulated by different departments and pieces of legislation. It is not clear whether the South African legislation that promotes energy efficiency corresponds with SADC frameworks.

Definition of energy efficiency

Blancard and Martin (2014) argued that in the agricultural sector, one can measure energy efficiency as the amount of energy required per quintal of product. It is necessary to define 'energy efficiency', as the notion of 'energy efficiency' remains contested as a consequence of its many possible multi-layered and context-dependent meanings. Economists describe 'energy efficiency' from an economic perspective as the use of energy at a level set by consumers in a market where the price reflects the true social cost in the absence of information and transaction costs. Economists link energy efficiency to the cost of energy used in the market. Furthermore, a tool is more energy efficient if it supplies more service for the same energy input, or the same service for less energy input. For example, when a tractor uses less energy (gasoline) to produce the same amount of work, the tractor is regarded as being energy efficient. Notably, the definitions place emphasis on the reduction of energy usage while maintaining production level and quality of output. According to the United States (US) Department of Energy, 'energy efficiency' is perceived as simply doing more with less as 'efficiency' is naturally linked to the manner in which energy is consumed at the point of end use, production as well as distribution. This definition accentuates efficient energy use and consumption as a means through which energy efficiency could be achieved.

It could be argued that generally, a reduction in energy consumption is normally associated with technological advancement. This is not always the case since it can also be achieved through better organisation and management or improved economic conditions in the sector (non-technical factors). This argument draws attention to technological change, better organisation and management as means through which energy efficiency may be achieved. Similarly, the European Union's Action Plan for Energy Efficiency considers 'energy efficiency' as reducing energy consumption without reducing the use of energy-consuming plants and equipment. The aim is to make better use of energy. Energy efficiency, therefore, implies promotion of behaviour, working methods and manufacturing techniques that are less energy intensive. Similar to the World Energy Council's (2013) definition, behaviour and management serve as measures through which energy efficiency could be attained.

According to Barton (2008), 'energy efficiency' is the ratio of function, service or value provided in relation to the energy converted to provide a service or the amount of work done in relation to the energy used. The wide discrepancy of views on energy efficiency described above suggests that it is an extremely flexible concept consisting of different facets. Nonetheless, aspects pervade the different definitions and could, therefore, be used collectively in an attempt to come up with a definition for the purpose of this study. The following notions pervade the above definitions: measures of energy input and output, the cost of energy in the market, energy use or consumption, alternative equipment and technology (moving from more energy-intensive equipment or technology to less energy-intensive ones), change of behaviour and introduction of energy-efficient management, among others.

Based on the common features inherent in the different definitions of energy efficiency discussed above, the concept could be defined as: (1) an improvement in energy equipment, technology, practices, products and services (such as lighting, cooling, heating, manufacturing, cooking and transport); (2) a change in behaviour; or (3) the introduction of energy management systems in order to reduce the amount or quality of energy used. The drivers and measurements of energy efficiency are discussed later in order to justify the need for policy measures in this regard.

Drivers of energy efficiency and measurement approaches in agriculture

It is important to understand the drivers of energy efficiency as they influence the development and introduction of policy measures pertaining to energy efficiency in the agricultural sector. These drivers include climate change, the finite nature of fossil fuel, increase in energy demand, energy security, the reduction in energy-related public expenditures, developmental goals and job creation (Du Plessis 2014).

Climate change, primarily caused by the use of fossil fuels, is regarded as one of the primary drivers of energy inefficiencies in the agricultural sector. In 2012, the IEA (2006) also stated that the direct combustion of fossil fuels represents, by far, the largest source of energy-related carbon dioxide (CO_2). Inglesi-Lotz and Blignaut (2015) maintained that energy consumption in both developed and developing countries is explained by three main factors as follows: production changes, changes in the structure of the economy and efficiency improvements. Since agriculture is highly dependent on climate, increase in temperature leads to an increase in the number of hectares under irrigation farming and more boreholes to access underground water (all of these depend on energy to function). Inglesi-Lotz and Blignaut used sectoral decomposition analysis of electricity consumption from 1983 to 2006 in South Africa and found that increase in consumption over this period was mainly owing to output or production-related factors, with structural changes playing a secondary role. Their study revealed evidence of efficiency improvements; however, such efficiency was not enough to offset the combined production and structural effects that propelled electricity consumption higher in different sectors (Inglesi-Lotz & Blignaut 2015). South Africa is highly energy-intensive and this makes the country one of the highest emitters of greenhouse gases (GHGs) in Africa (Barnard 2014). In its 2010 report on South Africa, the IEA identified energy efficiency as a cost-effective strategy to boost productivity if energy efficiency measures are introduced in all sectors of the economy (DoE 2012b). A 57% carbon emission reduction is possible by 2050.

Blancard and Martin (2014) used the Data Envelop Analysis (DEA) similar to the costs framework and decomposed energy efficiency measurements into technical and allocative efficiencies in energy contents of inputs in agriculture. They replaced input prices used in traditional economic efficiency measurements by their energy content and used the energy efficiency model to explore the optimal input mix that can produce current outputs at minimum energy consumption. Lekunze and Luvhengo (2016) further used the stochastic frontier model to measure technical efficiency in small stock production. Findings from these studies revealed that such decomposition of factors can help policymakers find the accurate energy policy when dealing with agriculture. However, the authors recommend that energy efficiency is not a fixed value and policymakers should consider it with caution. The generation of energy in South Africa is over-dependent on fossil fuels. The finite nature of fossil fuel is an important driver for energy efficiency. Serious doubts have been expressed over the certainty and accuracy of reserve projections on some of South Africa's coal reserves (Hartnady 2010; Simmons 2005). The economic situation appears to be heading towards a state of severe energy crisis, which is exacerbated by the anticipated finite nature of fossil fuel (Hartnady 2010). If energy efficiency legislation and strategies are not enforced, agricultural productivity will decline. This is because an increase in the effects of climate change has resulted in a shift from less energy-intensive farming methods to high energy-intensive production methods within the agricultural sector. However, the introduction of energy-efficient measures in the utilisation of fossil fuels stands a chance to significantly boost the finite nature of fossil fuel and also reduce the increased demand for energy (Simmons 2005).

The living standards of citizens in a number of economies today are improving and, by implication, increasing their energy and food consumption. In South Africa, the ever-increasing modernisation of agriculture and the intensification of production entail utilisation of machines that depend on energy. In a study by Camaren and Swilling (2011), it was revealed that local development is vulnerable to changes in the global economy and climate, as well as to regional pressures, and has prompted significant growth in the renewable energy sector in South Africa. In 2011, the IEA (2006) stressed that the introduction of energy efficiency measures would result in a reduction in the demand for absolute electricity. Energy savings from energy efficiency may greatly assist countries to meet the electricity demand of countries, avoid blackouts and other costly results of power shortfalls. Being energy efficient could, perhaps, be the most important means of reducing such consequences.

Energy security entails an assurance of sufficient energy supply to allow an economy to function in a political and acceptable manner (Ciuta 2010). Gunningham (2012) considered 'energy security' as having a reliable and adequate supply of energy at reasonable prices which, by implication, also means addressing short- and long-term energy insecurity. In the past two decades, South Africa has witnessed steady economic growth, resulting in an increasing focus on industrialisation, together with mass electrification programmes to take power into deep rural areas (Kiratu 2010). South Africa's energy demand is expected to be twice the current level by 2030. Electricity generation is a high consumer of fossil fuels, especially in the form of coal (Kiratu 2010; Strydom & Surridge 2009). The advent of new coal-fired electricity generation stations and new gas to liquid fuel plants is likely to increase South Africa's dependence on fossil fuels. To reduce the increased dependence on fossil fuels, more efforts and financial support may be put into energy efficiency, for it is likely to enhance energy security as well as energy-related public expenditures.

The public budgetary position of South Africa may be improved through lower expenditure on energy, based on benefits accruing from the introduction of energy efficiency measures (Ryan & Campbell 2012). In countries where fuel is imported, there is a positive impact on current reserves and in energy exporting countries, energy efficiency can free up more fuel for export. In addition, for countries with energy consumption subsidies, reduced consumption means lowered government budgetary outlays to finance these subsidies. According to Ryan and Campbell (2012), reducing expenditure on energy may improve the public budgetary position in several ways. In countries with state-owned enterprises, reducing energy demand means less public expenditure on fuel. This can be particularly important in fuel importing countries where foreign currency reserves may be depleted through high fuel imports.

In contrast, in countries with fuel exports, domestic energy efficiency remains important, as reduced energy demands domestically free up more fuel for export. Sustainable development is an international concern and access to modern energy services is an important issue in serving the basic needs for living and the conditions for social and economic development (Ryan & Campbell 2012). In designating 2012 as the International Year of Sustainable Energy for All, the United Nations called on governments to support its Millennium Development Goals (MDGs) through energy policies with a specific call to double the rate of improvement in energy efficiency. The MDGs form the bedrock of South Africa's National Development Plan (2010 to 2030). This plan, in its fourth chapter, stresses that between 2021 and 2025, energy efficiency will have to increase as well as the resilience of the transport network through the introduction of energy efficiency measures.

Furthermore, the development of energy efficiency programmes has the potential to create jobs within a short period of time. Improvement in employment rates can be attributed to energy efficiency programmes directly through job creation and indirectly through consumer surplus spending (Janssen & Staiaszek 2012). Direct jobs created in the delivery of energy efficiency measures are easiest to measure and are likely to be abundant. In measuring the sectoral consumption of energy in an economy, the gross production value (GPV), as a primary indicator of a country's economic performance, is widely used to estimate its energy consumption. In South Africa, the GDP contribution of the primary and secondary sectors (agriculture, mining and manufacturing) is declining while that of the tertiary sector (tourism and service industry) is on the rise. However, energy consumption (electricity) in the primary and secondary sectors is higher compared with their GDP contribution. The decreasing contribution to GDP and the growing consumption in terms of energy within these sectors is a direct indication of energy inefficiency in these sectors. This is consistent with the definition of energy efficiency by economists that energy efficiency is a measure of input and output. If this method of measurement is accurate, historical values for gross value added for the agricultural sector from Statistics South Africa (2005) during the period 1980 to 2010, and projected value estimates based on this historical contribution of the agricultural sector to the country's GDP from 2010 to 2050, were used to compute the final fossil fuel demand for the agricultural sector. The results revealed inefficiency in energy consumption in the agricultural sector as the increase in demand is higher than the sectors' contribution to the country's gross domestic production (Deloitte 2012).

The DoE (2012a) maintains that there are basically two traditional approaches generally used in projecting the demand for energy, namely energy-econometric and end-use accounting. While energy demand can be closely linked to economic activity, this approach is most effective in quantifying energy demand in sectors such as agriculture whose productivity may not always have a high level of correlation with energy demand. In South Africa, the energy efficiency market is growing as the private sector comes to grips with increasing energy prices and customer demand for sustainable business practices (Rutovitz 2010). Various companies offer a variety of services across the board from energy efficiency assessments to the implementation of energy efficiency measures to reduce energy demand. In turn, this may provide opportunities for work and jobs for a multitude of individuals in different disciplines, such as civil, mechanical and electrical engineering at various technical levels. Greenpeace estimated that energy efficiency can create 27 000 jobs in South Africa by 2030. These figures, however, illustrate that energy efficiency could contribute to a green economy. The present increased demand for energy, climate change, threat to energy security and finite nature of fossil fuel have driven the world (South Africa inclusive) into realising the need for energy efficiency. These drivers have led to efforts to develop methods to utilise energy efficiently.

The common forms of energy used in agriculture are diesel, coal and electricity. Although the agricultural sector contributes immensely to the economic activities and job creation in the economy, the proportion of energy consumption is relatively small compared with the industrial and manufacturing sectors. According to the Food and Agricultural Organisation (FAO 2013), the energy intensity usage in the agricultural sector follows three stages: basic human work for tillage, harvesting and processing, together with rain-fed irrigation which does not need external energy. Furthermore, the use of animals to provide various energy inputs and the application of renewable energy technologies, such as wind pumps, solar driers, water wheels, modern renewables and fossil fuel technologies for movables, stationary power appliances and machines for processing agricultural products, have reduced the amount of energy consumed by the agricultural sector. In agriculture, energy usage increases as production intensity also increases. Since energy is provided using traditional methods in the first two stages, productivity is low at these stages. However, with modernisation of the agricultural sector, energy intensity increases owing to the increase in investments in order to develop infrastructure, increased usage of chemical fertilisers as well as machines. The initial phase may see the use of energy-inefficient technologies. As the need for efficiency within the sector increases, there is a reduction in the use of energy owing to investments in energy-efficient technologies while still maintaining the level of output.

Ogunlade et al. (2006: 35) argued that:

> of the 122.3 million hectares of land in South Africa, 16.7 million hectares are potentially arable, 83.9 million hectares are suitable for grazing, 11.8 million hectares are protected by nature conservation, 1.4 million hectare is under forestry while 6.9 million hectares are used for other purposes. Of the 16.7 million hectares of arable land, 14.2 million hectares are under commercial farming while 2.5 million hectares are under emerging or small-scale agriculture. (p. 35)

Most of the energy used in agriculture is consumed by commercial farms as they tend to increase in size and decrease in number. In an attempt to model energy usage in the agricultural sector in South Africa, Winkler (2005) focused on the end-users of energy in the agricultural sector. Winkler aggregated agricultural activities into sub-sectors and later into groups, and used value added as an indicator to measure energy consumption by sub-sectors.

The study revealed that an estimated 73 PJ of energy was consumed in the agricultural sub-sector by 2001 (with approximately 58% diesel, 10% liquid fuel, 30% electricity and 2% coal). The study also revealed that energy usage in agriculture is primarily for the purposes of preparing the land; irrigating the land; applying nutrients, pesticides and herbicides; harvesting; and primary processing. Based on the above, the authors identified the following set of end-use demands: traction (tractors, harvesters and on-site transport); irrigation (electricity-, diesel- and petrol-driven pumps); primary processing (electrical equipment), heat (hot water for dairies, incubators and drying crops) and other (electricity demands for lighting and cooling). They derived a set of end-user energy intensities based on the above allocation, assuming that the allocation of fuel to various activities is based on the IEP of South Africa. Using value added as the driver for energy demand in the agricultural sector, the results revealed that demand projections for energy use intensity by 2025 in the agricultural sector for traction, irrigation, processing, heat and others will be 0.564GJ/R, 0.401GJ/R, 0.344GJ/R, 0.211GJ/R, 0.596GJ/R, respectively, from a base of energy use intensity in the year 2000 which stood at 0.564GJ/R, 0.314GJ/R, 0.214GJ/R, 0.211GJ/R, 0.371GJ/R, respectively. The forecast for the value added in millions by agriculture over this period were R26588, R27510, R28098, R28538, R28912 and R29200 in 2001, 2005, 2010, 2015, 2020 and 2025, respectively.

In another study that assessed energy-related behaviour and perceptions by households in South Africa, the DoE (2012b) utilised the expenditure-based and subjective approaches relating to the share of total household income or expenditure devoted to energy. It was assumed in the study that the threshold for determining energy poverty is between 10% and 15% of income spent on energy with 10% being the norm. Households with energy expenditure exceeding this threshold are considered energy poor and are likely to be confronted with difficult choices between meeting energy requirements on the one hand and sacrificing other important competing spending priorities on the other.

Energy efficiency methods and policy challenges in agriculture

In order to improve energy efficiency, a number of options may be considered across all sectors. Options or methods of energy efficiency, among others, include appliance labelling; energy-efficient lighting, buildings, transport and industries; the introduction of energy audits, market-based instruments (MBIs) and machines with energy-efficient motors; and education and awareness as well as voluntary instruments (Davis et al. 2011).

Gellings (2015) maintained that the implementation of energy efficiency in agricultural equipment will help reduce the costs of food production. He argued that when considering the area to be cultivated alone, fertilisers and pesticides consume the largest amount of energy followed by agricultural equipment. This equipment makes use of motors and drivers and some of them are more efficient than others. In terms of crop and animal production, energy use can be direct or indirect. Indirect use refers to energy consumed for producing materials and equipment, transportation of manufacturing machineries and fuel to end-users. However, the direct consumption of energy relates to the use of fuel to operate machineries. The energy efficiency level of such machines is dependent on the following: the type of fuel and the engine (diesel or petrol), matching equipment to task, timely maintenance of equipment, proper operation of equipment, balancing yield with energy consumption, using efficient machines and reducing tillage operations. Policymakers should balance the benefit of reducing energy in farm operations with the costs of increasing energy consumption in the form of chemicals. Energy-efficient appliances are important sources of energy savings (Amann et al. 2010). Considerable reduction in monthly electricity can be achieved by switching to energy-efficient appliances (Govender, Okoro & Chikuni 2014). Even though these appliances may be more costly to purchase than average energy-efficient ones, reduced energy bills may compensate for the cost of the product long before it wears out.

Lighting is one of the major causes of high energy usage in large buildings. Advanced lighting systems such as high efficiency lamps in farms, lighting controls and light reflectors through lighting standards may greatly reduce electricity consumption (Davis et al. 2011). Studies by Deloitte (2015) have revealed that agriculture consumes 2% of South Africa's total electricity and have identified income, price and technology as the key drivers of electricity consumption in the country. The implication is that an increase in the level of GDP results in an increase in the demand for electricity although increasing electricity prices may result in decreasing demand. However, research has shown that energy consumption is more responsive to changes in income than changes in price. Across many countries, the demand elasticity for the price of electricity, in particular, ranges from -0.2 to 0.4, an indication that a 1% price increase may result in a 0.2% to 0.4% reduction in electricity consumption compared with the 0.8% to 1.1% increase in electricity consumption, if there is a 1% change in income or GDP. This is an indication that as long as the income and GDP of South Africa are increasing, an increase in electricity consumption will outpace the decrease in consumption if price is used as the only policy to control consumption and achieve efficiency.

Buildings offer great potential for saving energy through efficiency gains (US National Research Council 2010). Large amounts of energy are wasted in the heating and cooling of unnecessary space in buildings owing to inefficient energy designs and construction of buildings. However, it could be argued that increasing energy consumption in the South African economy is a direct effect of the changing structure of the economy (structural effects) and the influence of new technology. It could also be argued that new technology is expected to be more energy efficient and a shift in the structure of the economy from high energy users and GDP contributors in the 1970s and 1980s such as mining (from 21% in 1970 to 6% in 2010) to non-traditional sectors (service sector in 2010) should be accompanied by a shift in energy consumption pattern as well. If the above argument is factored into the idea of structural change and new technology transfer into the South African economy as the fundamental cause of the burgeoning energy consumption, the idea of energy inefficiency in these industries cannot be ruled out. Efficient energy utilisation, coupled with contracting traditional sectors (mining and agriculture), should ensure that enough energy is released in order to power emerging non-traditional sectors.

This is quite important if the term 'structural effect' is defined as the energy input (G/KWh) per unit output (value). Although I concur with the energy intensity differentials by sectors, I am of the view that there is inefficiency in the consumption of energy in the agricultural sector and South Africa as a whole. The slow replacement of non-energy-efficient technologies, the prioritisation of profit by industries over investment in energy-efficient technologies as well as traditionally low prices charged for electricity (far below the real market price for energy) are some of the major causes of energy crisis in the country (Bird & Hernandez 2012). This is because traditional building regulations paid little or no attention to energy-efficient designs. Studies have shown that 40% to 50% energy savings can be obtained by modifying building regulations. The putting in place of building standards and best practices containing energy saving measures such as the installation of ceilings and wall insulation, water heater blankets, solar water heaters and low-flow shower heads, monitored by energy auditors, could lead to a significant drop in the quantity of energy consumed. The cost of installing energy-efficient measures would be compensated by the economic benefits accruing from the energy saved.

The contribution of GDP by agriculture is approximately 3%. It could be as high as 12% if backward and forward linkages are considered. The agricultural transport sector is one of the areas where fossil fuel has not been effectively substituted (European Commission 2013). The most common replacement for fuel has become natural gas, although there are different sources of renewable energy. Although these forms of fuel substitutes have been established, vehicles designed to use these substitutes seem to be experiencing difficulties (US Department of Energy 2007). The consumption of energy by the agricultural sector is slightly above 3% (Department of Energy; South Africa, 2012) and appears to be operating at an energy efficiency level. However, the use of energy in this sector is inefficient since most of the motors used by farm machineries and equipment are energy inefficient compared with those in developed countries in Europe. In a study conducted by Blancard and Martin (2014) to examine energy efficiency and its components (technical and allocative efficiency in energy contents) in a deterministic case (i.e., when one knows the energy content), it was revealed that energy efficiency varies across farms in France (from 0.305 to 1). They concluded that energy efficiency improvement policies should target the most energy-inefficient farms, and precise energy policies designed for such farms may involve giving them incentives to reallocate inputs in a manner that corresponds to that of energy-efficient farms. The development of energy efficiency standards whose enforcement would be monitored by energy auditors for transport (vehicles and train) is, perhaps, the most important requirement to move towards an energy-efficient world. Transport is not the only measure through which energy efficiency could be achieved.

A major portion of the energy supplied is consumed by the industrial sector. Energy savings in industry may be achieved through energy-efficient industrial motors, wiring and cogeneration plants. Firstly, industrial motors present a significant occasion to save energy. Large industrial motors, such as those used in the paper industry, consume electricity costing about 10 times their own capital cost per year. Savings in energy could be obtained through the replacement of standard induction motors with high energy efficiency motors that save electricity. Furthermore, switching off idling motors that are not in use will also save a significant amount of energy and reduce costs.

According to Govender et al. (2014), the use of larger diameter electrical cables (wiring) from the distribution board to industrial machines can also reduce power loss. This may be done through wiring regulations that stipulate the minimum wire size in order to reduce the possibility of fires, and not to save energy through reduced power losses and costs. Using wires with twice the required diameter will incur high costs initially but would lead to energy saving within a short period of time. According to the California Energy Commission's Cogeneration Handbook Report 500-82-054, cogeneration is described as the simultaneous production of electrical energy. A cogeneration system operates at an overall thermal efficiency as much as 2.5 to 3 times that of conventional electrical generating systems. The normal wasted exhausted heat during electrical generation systems is captured and used for electrical energy production, thus saving energy and improving energy efficiency in industry.

The World Energy Council (2013) describes energy audits as on-site inspection of existing energy activities of consumers by an energy auditor (energy rating) followed by an identification of energy saving potential. Audit schemes are a practical way of informing consumers about the possible actions to improve energy efficiency. Profitability or margins should be used to allocate energy prices as sectors with larger profit margins, utilising non-energy-efficient technologies, should pay higher prices than those with energy-efficient technologies. This may force companies to switch investments towards energy saving technologies, which will be beneficial to the economy as a whole. The California Public Utilities Commission (CPUC 2013) adopted a state-wide Agricultural Energy Efficiency Programme premised on strategic energy planning, audits, rebates and incentives to customers in order to accelerate the adoption of energy efficiency measures and provide energy analysis services, leading to improved energy efficiency of agricultural facilities, including on-site food-processing facilities. These strategies have been developed in industry and in non-residential buildings and are increasingly made mandatory. Energy audits are usually funded by public agencies. Mandatory audits, unlike voluntary audits, assume a certain quality of the auditors as well as of the staff responsible for energy management in companies (energy managers). This can be assured by the certification of the auditors and training of energy managers.

Rademaekers et al. (2011) argued that MBIs are important tools in promoting energy efficiency. MBIs refer to tools that seek to address market failure, either by incorporating the external cost of production or consumption activities through taxes or charges on processes or products and facilitating the establishment of a proxy market for the use of energy services. The rationale for using MBIs in promoting energy efficiency lies in their ability to correct market failures in a cost-effective manner. MBIs have the advantage of using market signals to address market failures. Examples of MBIs, among others, include energy efficiency taxes, charges, subsidies and pricing. MBIs can be implemented across the entire energy sector (agriculture, household, mining, industries and commercial). Internationally, the most widely used forms of MBIs are energy pricing, taxes, charges, subsidies and levies (Du Plessis 2007).

The European Commission (2013) warned that consumers, industry and public authorities alike need to be aware of the importance of energy efficiency issues and be motivated to tackle them. Making available clear and accessible information about energy efficiency and providing appropriate education and training for stakeholders and individuals are key ways of achieving energy efficiency. According to the Commission, priorities for raising awareness on energy efficiency would include labelling as well as education and training programmes for energy managers in industry and utilities, and teaching aids for primary, secondary and vocational education. The impact of education and awareness campaigns can be evaluated by detailed monitoring. The impact and effect can be increased by providing positive feedback to the target group or sector during programmes on behavioural changes.

Moos (2007) maintained that world-wide experience with energy-efficient voluntary instruments has shown that ambitious targets could be a driving force for innovation and continuous energy efficiency improvement. Voluntary instruments refers to negotiated agreements between public authorities and individual firms or groups of firms, which include targets and timetables for actions aimed at improving energy efficiency or reducing GHG emissions for either a reward or a penalty. Voluntary instruments are often combined with other instruments such as energy audits. Factors influencing the success of voluntary programmes and negotiated agreements include social pressure or systems of social control, supporting instruments and regulations, positive incentives, transparent target setting, clarity on commitments on both sides, adoption of new roles and responsibility as well as good communication networks among participants (Rezessy & Bertoiti, 2011). Voluntary programmes have a range of soft effects such as capacity building, increasing awareness, empowerment and transfer of responsibilities from authorities and experts to energy end-users themselves. Energy efficiency has the potential of meeting the growing energy needs of countries. However, the penetration of energy efficiency into societies remains slow owing to a number of impediments.

Conclusion

Energy efficiency could be defined differently depending on the context within which the concept is used. For the purpose of this article, it has been defined as: (1) an improvement in energy equipment, technology, practices and products or (2) a change in behaviour or (3) the introduction of energy management systems in order to reduce the amount or quality of energy used. The agricultural sector in South Africa is energy inefficient. To achieve efficiency, programmes such as strategic energy planning, audits, rebates and incentives should be initiated in this sector. This will assist farmers to accelerate the adoption of energy efficiency measures and provide quality data on energy analysis services. This will lead to improved energy efficiency in agricultural facilities, including on-site food-processing facilities. There are various drivers that could be used to implement energy efficiency measures. These include climate change, increased demand for energy, energy security, the finite nature of fossil fuels, reduced energy-related public expenditure, developmental goals and job creation. Despite the remarkable benefits associated with energy efficiency, the overall penetration of energy efficiency remains slow and ineffective owing to impediments such as low energy prices, financing, poverty, uncertainty, split incentives, capital budgeting and ignorance.

Legislation plays a vital role in ensuring energy efficiency. non-compliance, enforcement of legislation, energy audits and poverty could be regulated by law. South Africa needs legislation that promotes energy efficiency awareness, regulates the production or importation of goods regarding energy efficiency, provides for basic energy services for the poor as well as efficiency auditing in farms. However, legislation alone cannot fully eradicate energy inefficiencies. Uncertainty, capital budgeting and energy pricing cannot be regulated by law. They remain behavioural issues which differ from person to person and most often change with time. They are, thus, left to particular individuals to moderate their ways.

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Competing interests

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Authors' contributions

J.N.L conceptualised the idea of combining the concept of energy efficiency and its application to agriculture. J.N.L is responsible for the layout, structure and agricultural-related aspects of the article and wrote the title, introduction, problem statement, research method, energy efficiency methods and policy challenges in agriculture, conclusion and has been the corresponding author. A.R.L is responsible for all the legal content of the article and her contribution stretches across the following sections: energy efficiency policies and the legislative framework in South Africa, definition of the concept of energy efficiency, research method and drivers of energy efficiency.

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