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CHAPTER 12: ENERGY AND AIR QUALITY

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Energy changes, shifting to renewable, could lessen the environmental health problems associated with burning of fossil fuels and biomass fuels. Climate change is likely to have impacts on renewable energy production and distribution in southern Africa where drought conditions result in reduced hydro-electric generating capacity.

12.1. Introduction

Energy is seen as being crucial to any country's economic and social development. However, the combustion of biomass and fossil fuels for use as energy leads to a wide spectrum of air emissions such as carbon dioxide (CO_2), nitrogen oxides (NOx), volatile organic compounds (VOCs), sulphur dioxide (SO_2), total suspended particulates (TSP), carbon monoxide (CO), and polyaromatic hydrocarbons (PAH). These emissions have severe consequences for human health and the environment. In particular, the combustion of fossil fuels for electrification has received much global attention as it has been shown to contribute to many health-damaging air pollutants, and to significant amounts of global anthropogenic greenhouse gases (GHGs) that are linked to climate change.

While international policy has endeavoured to mitigate the main climate change pollutant (CO_2) resulting from energy production and consumption, the focus of many developing countries is on addressing the health impacts associated with poor air quality. These issues are particularly relevant within southern African countries. While energy production within these countries contributes least to climate change emissions globally, the energy production and consumption patterns place a large proportion of the region's population at risk of incurring air pollution-related impacts.

This section provides an overview of the key energy sources that are used in southern Africa, and reflects on the implications of these energy sources for air quality. The key drivers and responses to address these issues are also considered.

12.1.1. Overview of energy in southern Africa

The energy resources that occur within the SADC region are composed of both traditional and renewable energy resources (Mabhaudhi et al., 2016). Grid-electricity in the SADC region is secured through the Southern African Power Pool (SAPP), an alliance of 12 energy producers inter-connected through a regional grid to provide electricity across southern Africa (Conway et al., 2015). The SAPP was formed through the signing of an intergovernmental memorandum of understanding for the formation of an electricity power pool by SADC member countries (excluding Mauritius) in 1995 at the SADC summit in Johannesburg, South Africa (SAPP, 2015). The primary energy sources exploited by SAPP include hydro-electric, coal and natural gas, with only a few countries in the region exploiting distillate fuel and wind energy (Table 12.1) with electricity chiefly produced from coal resources (Conway et al., 2015).

Given the lack of electricity-generating capacity as shown in Table 12.1 and limited distribution networks (with the exception of South Africa, Botswana, Namibia and Mauritius), less than 45% of the population of most southern African countries have access to electricity (Figure 12.1). Poverty, lack of disposable income, high levels of corruption, large numbers of people in rural areas and high population densities are considered to be important factors that limit electricity access in sub-Saharan Africa (Onyeji et al., 2012). There are further variations in the energy mix at a country level, with stark differences in energy production between urban and rural areas (Ruhiiga, 2012).

The SADC region is endowed with both crude oil and natural gas reserves. The crude oil reserves in Angola are the largest in the region but most of this is exported out of the SADC region (Eleri, 1996; Zhou, 2012). The Democratic Republic of Congo and South Africa also produce crude oil, though South Africa is the home of the main oil refineries in the region (Table 12.2). Crude oil is mainly imported into the region from countries outside of the SADC. The liquidity crises that affected Zimbabwe and Tanzania have severely reduced the oil refining capacity of these countries (Mabhaudhi et al., 2016). Limited infrastructure in southern Africa to transport crude oil across the region further creates bottlenecks for the availability of the resource for road transport and industrial use. Road and rail infrastructure are the main conduits for refined petroleum and diesel products via road and rail freight transport (Mabhaudhi et al., 2016). Road transport is an important transport medium in the SADC region, with the number of motor vehicles having increased in Botswana, Mauritius, Seychelles, South Africa, Swaziland, Zambia and Zimbabwe between 2000 and 2014 (SADC, 2016).

Limited availability of modern energy sources such as kerosene, liquefied petroleum gas and grid-supplied electricity in SADC countries – with the exception of South Africa and Mauritius – has meant that households in these countries have become dependent on the use of wood biomass fuel. Tanzania, Mozambique, DRC and South Africa are the main producers of woody biomass in the region. Wood is mainly used in rural homes and charcoal in urban areas (Mwampamba et al., 2013). Charcoal, when burnt, emits less smoke and releases more energy, which makes it appealing to urban households (Cerutti et al., 2015). In most southern African countries more than 50% of the population are dependent on biomass fuel resources including firewood, charcoal and dung to meet their domestic energy needs (Figure 12.2).

Table 12.1: Electricity generation capacity (MW) of southern African countries in the year 2014/2015, including the primary energy sources for each country [SAPP, 2015; NEWJEC in Engineering and Consulting Firms Association (EECFA), 2009].

Country	Technology				
	Hydro-electric (MW)	Coal (MW)	Gas (MW)	Distillate (MW)	Wind (MW)
Botswana	0	732	160	0	0
Mozambique	2 573	0	0	151	0
Angola	1528	492	190	0	0
Malawi	351	0	1	0	0
South Africa	2 000	35 721	0	2 409	2 492
Lesotho	74	0	0	0	0
Madagascar[1]	105	211	0	0	0
Namibia	348	132	0	21	0
Swaziland	61	9	0	0	0
Democratic Republic of Congo	2 442	0	0	0	0
Tanzania	717	0	585	78	0
Zimbabwe	750	1 295	0	0	0
Zambia	2 156	0	0	50	0
Mauritius[2]	56	389	0	0	0
Total	13 161	38 981	936	2 709	2 492

1 Electricity generation capacity for the year 2007;
2 Electricity generation capacity for the year 2013.

Table 12.2: Oil production and refinery capacity in the SADC region (Zhou, 2012)

Country	Crude oil (bbl/day)	Refinery capacity (bbl/day)
Angola	1250 000	39 000
DRC	20	-
Madagascar	-	15 000
South Africa	215	504 547
Tanzania	-	14 900
Zambia	-	23 750

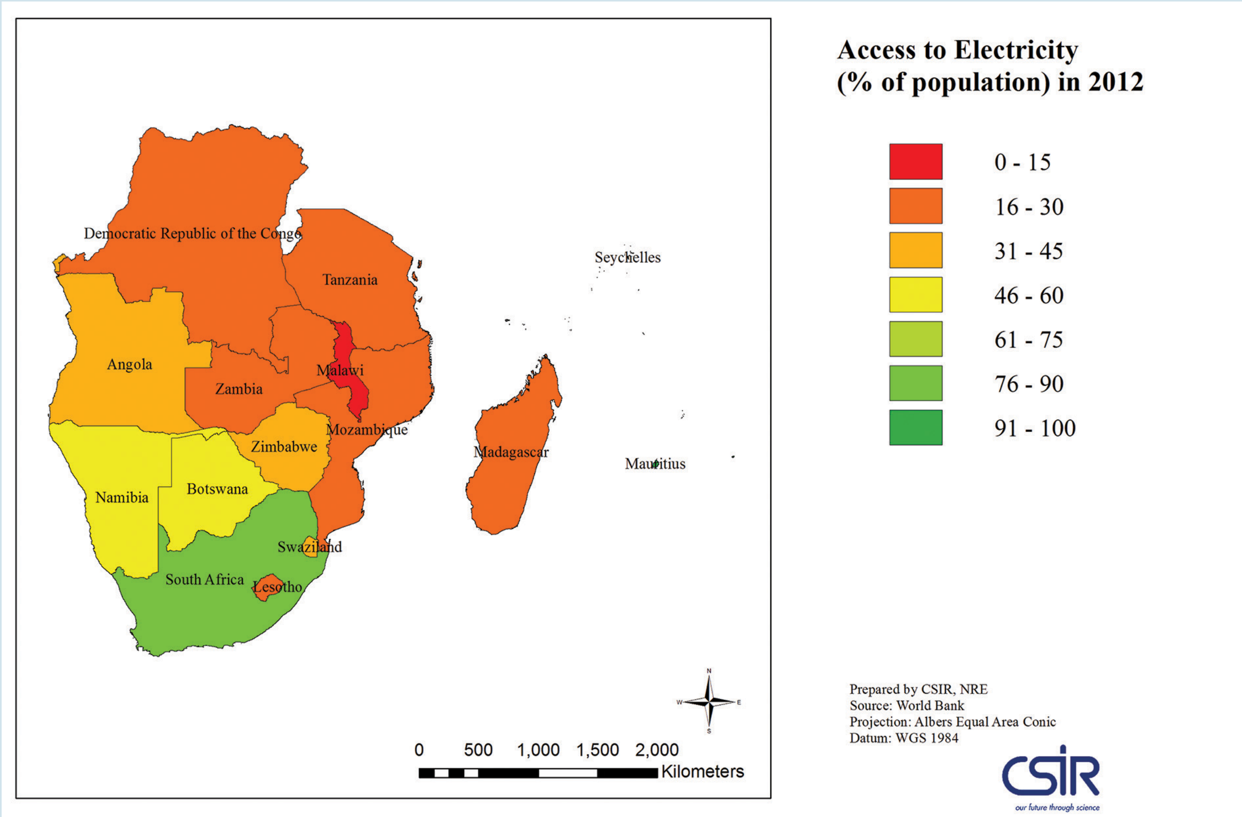

Figure 12.1: Percentage of the population with access to electricity in 2012 (World Bank, 2015).

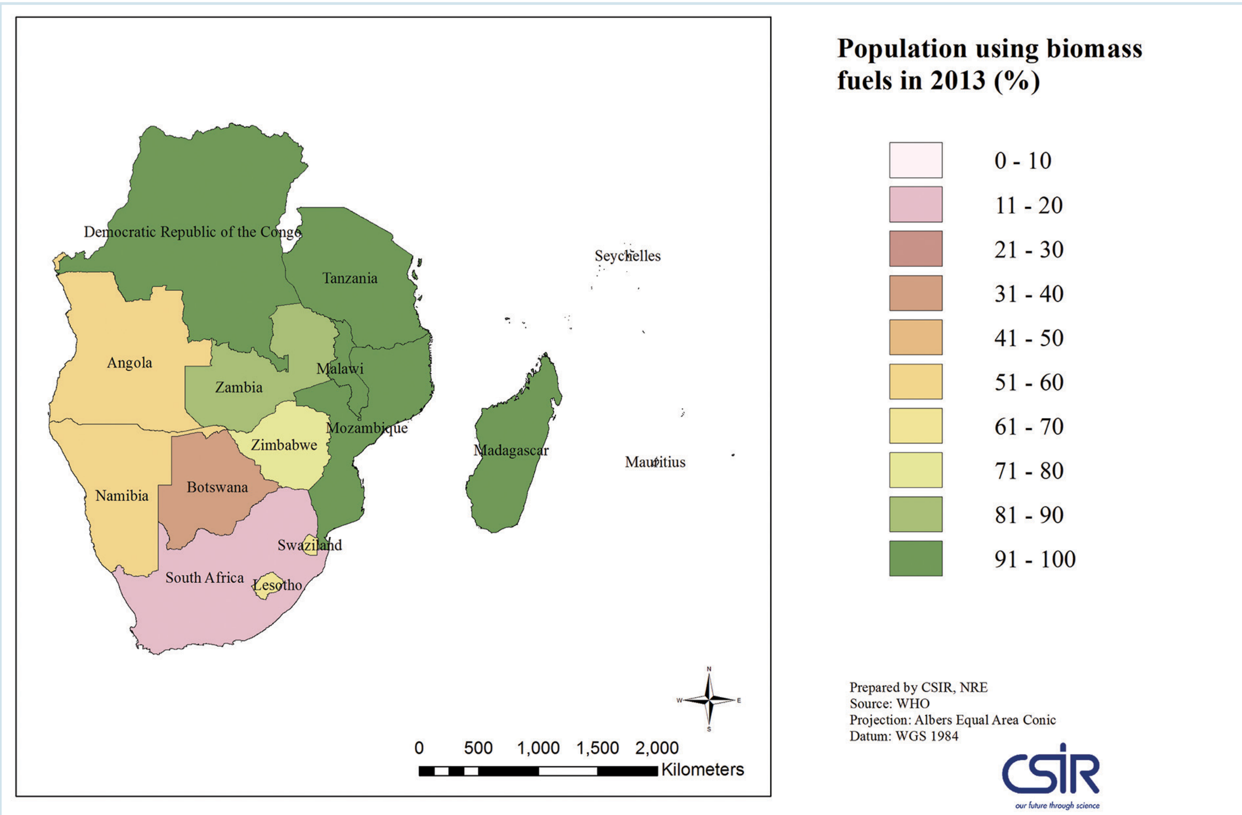

Figure 12.2: Percentage of the population using biomass fuels in 2013 (WHO, 2015b).

12.2. Key drivers and processes of change within the sector

12.2.1. Energy

At the macro-scale, key drivers of energy consumption within the SADC region include economic growth, industrial development, motor vehicle transportation demand, urbanisation, and population growth (Schwela, 2012). In the context of economic growth, the SADC region is affected by a slump in the regional economy. The increase in the gross domestic product (GDP) growth rate from 2012 to 2013 was smaller than the increase in the GDP growth rate from 2009 to 2010 (Figure 12.3). Economic growth has slowed down not only for the SADC region, but also for the whole of the sub-Saharan African region. Industrial development has also been low in the region, mainly dependent upon the informal sector and concentrated in a few large cities found in each country. South Africa has been an exception due to greater global competitiveness supported by government and the prevalence of a large domestic demand for goods (Wekwete, 2014).

The greater dependence on primary resources such as biomass fuel with little to no additional processing is a common problem among both rural and urban households. At the country-scale, limited financial resources of southern African governments to fund energy projects constrain the capacity of governments to improve electricity access (Onyeji et al., 2012). Energy projects are typically expensive to start up even before production can begin. The costs of fossil fuel-based electricity remain too high for households, which opt for cheaper biomass fuels (Cerutti et al., 2015). Decentralised electricity grids and renewable energy sources are seen as the most appropriate solutions to expanding electricity access in southern African countries (Onyeji et al. 2012). However, the start-up of renewable energy projects remains affected by high associated costs (van Zyl-Bulitta et al., 2009).

Countries in southern Africa are often at a disadvantage when it comes to the development of renewable energy projects as a result of the high financing costs of the technologies for developing countries. For example, wind power generation in a developing country is 40% more expensive compared with a developed country (Figure 12.4).

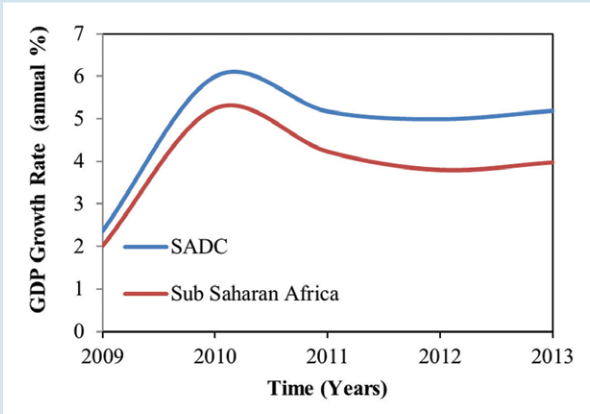

Figure 12.3: Economic growth represented by the GDP growth rate (annual %) from 2009 to 2013 (World Bank, 2015).

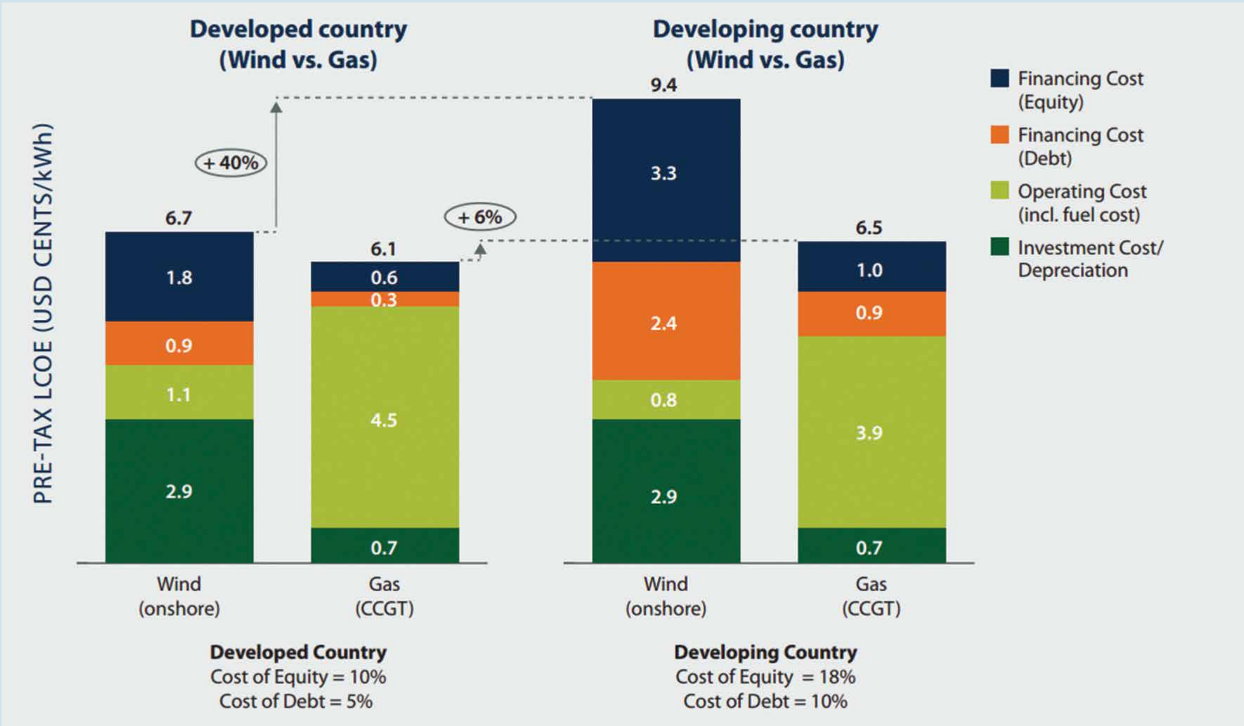

Figure 12.4: Impact of high financing costs of renewable energy on cost competitiveness (UNDP, 2014).

12.2.2. Ambient air quality

At the local and regional scales, the main drivers of air pollution include the consumption of biomass or fossil fuels for either industrial processes, heating and cooking needs, and transportation. The resultant air pollutant emissions are dependent on the type of fuel used, the properties of the fuel and the combustion device. For ambient (outdoor) air quality, the amount of air pollution experienced in a particular area will vary in relation to the amount of air pollution emissions released in the vicinity or transported to the region and on the prevailing meteorology. Specifically once gaseous pollutants disperse into the ambient environment, the local transport, distribution and fate of the pollutants are dependent upon the prevailing meteorology associated with temperature, rainfall, wind and atmospheric water vapour. Large-scale weather phenomena also contribute to the regional transport and distribution of pollutants over southern Africa. Subtropical anticyclones are the main large-scale weather systems that recirculate pollutants over distances spanning hundreds of kilometres (Tyson et al., 1996). A haze layer up to 500 hPa in depth within the atmosphere, blankets southern Africa containing aerosols and gaseous pollutants. The haze layer is composed of outgoing air parcels and incoming air parcels that were recirculated over the region (Tyson & D'Abreton, 1998).

Motor vehicle use in southern Africa, largely in urban areas, has substantially increased since 2000 (SADC, 2016). With the exception of South Africa, there is limited knowledge of the extent that motor vehicles and industrial activities contribute to ambient air pollution in southern Africa. Very few countries in the region have adequate industrial emission controls, vehicle emission standards and motor vehicle import control; and furthermore have poor fuel quality standards (Bhattacharjee, 2016). The lack of ambient air quality management and monitoring is a contributing factor to the air pollution that is experienced.

12.2.3. Indoor air pollution

Indoor air pollution from fossil fuel and biomass combustion is dependent on the type of fuel that is used and the combustion device used. Exposure to air pollutants in the case of indoor combustion is linked to the amount of ventilation present and the amount of time spent indoors. The activity of indoor burning usually takes place as open fires or within poor performance stoves, in rooms that have poor ventilation (Bruce et al., 2000). There are numerous political and social barriers to solving the problem of indoor air quality and energy poverty. For example, the introduction of alternative energy sources into rural or informal homes is problematic, as electrified grid connections are seen as the "ideal" form of energy by many within such communities who argue that other sources of energy is a further perpetuation of the second class services provided to the impoverished. It has also been found that the provision of electricity to rural and informal homes is not necessarily followed by its use as many people revert to using cheaper, dirtier forms of energy (Bruce et al., 2000). Furthermore, when dealing with non-permanent infrastructure such as that of informal settlements, complications arise as the source of cleaner energy needs to be autonomous in order to be sustainable.

12.3. Vulnerability of sector to climate change

12.3.1. Energy

The transmission of grid-supplied electricity is likely to be affected by climate change, with changes to temperature, evaporation and air pollution levels likely to contribute to problems with insulators on transmission lines (Mulumba et al., 2012). Fossil fuel power plants use water as a cooling medium to prevent overheating during the electricity production process (Madhlopa et al., 2014). Climate change-induced drought conditions may impact on electricity production, due to the decline of water supplies during such times. Furthermore, the occurrence of extreme rainfall events will negatively impact power plants due to an increase in the water content of coal (Schwela, 2012). Specifically, coal that is stored in open stockpiles during heavy rainfall may result in disruptions to the conveyor systems, with potential for crushed wet coal to clog mill equipment and piping. Such impacts are likely to increase the operating and maintenance costs of coal-fired power plants.

Climate change is also likely to have impacts on renewable energy production and distribution in southern Africa. Specifically, increases in precipitation could have positive implications for hydro-electric power generation whereas flooding could result in increased sediments reducing the catchment capacity (Mulumba et al., 2012). In 2000, Tanzania reported that drought conditions resulted in reduced hydro-electric generating capacity which led to the country experiencing power interruptions (black-outs). The Democratic Republic of Congo also reported a decline in hydro-electric power in July to August 2011, which was linked to the decline of reserves in the Inga Dam (Mulumba et al., 2012). Most of the grid-supplied electricity in Malawi is derived from hydro-power, which has been severely affected by droughts. Specifically, in dry years, low water flows and sedimentation of rivers occur in almost all the areas where the electricity-generating plants are located. The resultant black-outs in all these cases lead to an unreliable electricity supply, prompting greater use of charcoal and firewood and aggravating other environmental issues such as deforestation. Under climate change conditions that result in lower levels of precipitation, drought conditions could have knock-on effects for reduced electricity generation from hydro-power and increased air pollution from the burning of fossil fuels and biomass.

In terms of other renewable energy sources, the availability of wind and solar is strongly dependent on climate, and thus likely to be impacted by climate change. However, there are estimates that suggest that by 2050 the long-term mean wind and solar resource potential in southern Africa will remain unchanged (Fant et al., 2016), though it is acknowledged that modelling advancements and further research are still needed to fully understand the potential impacts (Chirambo, 2016).

12.3.2. Air quality

The resultant air pollution from fossil fuel and biomass burning has been directly linked to adverse human health effects including lower respiratory infections; cancers of the bronchus, trachea and lungs; and ischaemic heart disease, stroke and chronic obstructive pulmonary disease (Lim et al., 2013). Southern African populations (e.g. Tanzania, Zambia and Lesotho) are included among the most vulnerable populations in the world to particular matter (PM) related pollution due to cooking using biomass fuels (Chafe et al., 2014). The lack of air quality legislation and controls on emissions from motor vehicles and industrial processes lead to significant air pollution. Furthermore, as a result of being unable to obtain clean energy and the appliances needed to keep their households free of pollutants, poor communities are exposed to numerous health-damaging pollutants and therefore suffer from a variety of health diseases, primarily affecting women and children. The number of deaths linked to respiratory infections is further compounded by HIV infections, resulting in higher numbers of deaths reported in some of these countries. In southern Africa alone, about 0.2 million people were estimated to have died from household air pollution in 2012 (WHO, 2015a).

Climate change is further expected to result in progressive changes to weather patterns that include changes to the distribution and amount of precipitation, temperature, wind speed, wind direction and large-scale weather-producing systems (Meehl et al., 2000). These factors all contribute to atmospheric stability and are key factors responsible for the dispersion of pollutants. These changes will therefore have an impact on the occurrence and severity of air pollution events. Furthermore, climate change is likely to result in changes to the heating and cooling requirements of households, which could result in more fossil fuel and biomass combustion.

12.4. Responses

Southern Africa faces substantial challenges in providing secure energy supply and ensuring that both urban and rural communities have access to these energy sources. It is suggested that financing difficulties inhibit many countries in the region from being able to fully exploit their potential for generating energy (Chirambo, 2016). A key facet to being able to unlock opportunities to provide equitable access to energy and pursue renewable energy technologies is through a policy framework that clearly outlines institutional support and financial mechanisms for delivery. De-risking instruments can be used by policy-makers to make the costs of renewables more affordable by addressing the underlying investment risks within a developing country. Direct incentives can also be used to cover financial cost creep using market-based instruments (UNDP, 2014). Legislation within this sector would also need to support private-public partnerships, creation of local markets for the development and uptake of cleaner energy sources and technologies, and the use of incentives to spur on changes within industrial, transportation and domestic sectors.

Coupled with the need for policy development, is the need to strengthen and retain human and institutional capacity within the energy sector, such that tertiary institutions provide courses related to energy so that within a country there are local capacity/experts on these issues that are able to work within government, industry and research. A strengthened research base will further assist to ensure that policy-makers and decision-makers are equipped with the pertinent information that can support the development of adequate systems, frameworks and supporting policy that regulate energy production, transmission and consumption in the country.

Policy and legislative guidelines are also critical to ensuring effective air quality management in the region. Where there is an absence of ambient air quality legislation, there is a need to ensure that the government is given the authority to regulate air pollution emissions and manage ambient air quality. There is further a need to ensure that air quality management responsibilities are delegated across all spheres of governance. All key sources of emissions should be identified and inventoried. Based on the likelihood to result in harm to human and environmental health, these pollutants should have defined emission limits and ambient air quality standards put in place. There is limited continuous ambient air quality monitoring that occurs in southern Africa, with the most extensive air quality monitoring occurring in South Africa (Forbes & Rohwer, 2009). Expanding on efforts to establish routine air quality monitoring in key hot-spot areas will be critical to assessing if legislation and air quality goals are being met. Air quality management should also take cognisance of potential climate change impacts on air quality by incorporating climate change considerations into air quality management plans.

A significant focus of countries with limited grid-supplied electricity should be on indoor air quality legislation. The issue of indoor biomass and fossil fuel combustion has many impacts that require well co-ordinated, integrative plans that consider air pollution impacts in order to be effectively resolved. The availability of clean energy sources and improved energy combustion devices to poor households will yield benefits of indoor air quality improvements, which are seen as a means to help combat poverty in general (Von Schirnding et al., 2002). The World Health Organization (WHO), for example, lists different types of interventions that can be applied to reduce indoor air pollution (World Health Organization, 2002):

- Interventions at the source (fuel switching, alternative fuels, improved stoves)
- Interventions to the living environment (smoke hoods, enlarged windows, chimneys)
- Interventions to user behaviour (educating people to the health risks of indoor combustion, keeping children out of the kitchen during cooking)

For rural households in particular, interventions to assist them to move up the "household energy ladder" (dung ⟶ crop residues ⟶ wood ⟶ kerosene ⟶ gas ⟶ electrification) in order to reduce exposure to indoor air pollution are needed. As renewable energy is seen as a source of cleaner energy, implementation of these types of interventions ultimately reverts back to the need to have adequate energy policies in place and strong frameworks to ensure the implementation of these policies.

Case study: Renewable energy in South Africa

Energy sector initiatives and reforms aimed at improving people's access to modern energy and energy services have faced challenges in southern Africa, on account of incomplete policy reforms, low rates of electrification, and lack of financial investments and technological knowledge (Chirambo et al., 2016). In South Africa, however, the country has implemented numerous policy interventions that have in recent years resulted in the country being ranked among the top 10 countries with respect to Renewable Energy investments.

The road toward this renewable energy pathway began with the country's White Paper on Energy Policy (1998), which recognised that the implementation of renewable energy technologies was imminent, and that such technologies would become cost competitive and cost effective, meaning the country's vast renewable energy base would create numerous opportunities in the future. The development of renewable energy as part of this envisaged energy mix would allow for more sustainable energy generation and was considered to provide the least-cost energy service when social and environmental costs are included in the equation.

The country's White Paper on Renewable Energy (2003) outlined the vision for energy to be produced from renewable energy sources (mainly from biomass, wind, solar and small-scale hydro). The National Climate Change Response Policy White Paper of 2011 lent further support to the country's goals for renewable energy, outlining the Renewable Energy Flagship Programme, integral to deployment of renewable energy technologies. The country sought to find a way to finance and implement its policy imperatives for renewable energy.

A competitive Renewable Energy Independent Power Producers Procurement Bidding Programme (REIPPPP) was implemented in 2011. The REIPPP has supported 92 independent power producers who will contribute in excess of 6,327 MW and is highly regarded as successful in creating an enabling framework for attracting private sector investment and expertise for renewable energy. It is reported that by June 2014, the country had established 1.9GW new renewable energy capacity for electricity production and delivered in excess of 5TWh of clean energy per annum into the energy mix. Through the REIPPPP the country has been successful in unlocking market potential and creating enabling conditions for the development of renewable energy. The effective channelling of private sector expertise and investment into grid-connected renewable energy in the country has been supported by a transparent procurement framework. Further to this, the team implementing the REIPPPP had a strongly established record in private-public partnerships and thus were viewed favourably by both the public and private sectors.

While not all developing countries will have the same resources to duplicate the REIPPPP, it does offer valuable lessons to other countries in terms of how to effectively procure renewable energy (Hagemann, 2013).