Journal of Energy in Southern Africa 21(1): 11–24
DOI: http://dx.doi.org/10.17159/2413-3051/2010/v21i1a3246

An analysis of energy consumption for a selection of countries in the Southern African Development Community*

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Abstract
This paper examines the energy consumption, supply and resources of some of the countries in the Southern African Development Community (SADC) in 2005, the base year for this analysis. The region is rich in energy resources and currently enjoys relatively stable and affordable electricity. Except in the case of Botswana, Mauritius, Namibia and South Africa, final energy demand is dominated by the residential sector in the form of biomass. Energy consumption or final energy demand in Angola, Botswana, Mozambique, South Africa, Tanzania, Zambia and Zimbabwe is projected to 2030 using a Long Range Energy Alternatives Planning (LEAP) model in a 'business as usual' scenario, the other countries being left out because of poor quality data. The projections are carried out by relating historic sectoral GDP and population growth in each country to energy demand and then using the historical link and the projections of these drivers to project energy demand. The analysis under this 'business as usual' scenario seems to indicate that we can expect to see a large increase in consumption in these countries, especially in the form of biomass and electricity. In both cases, supply is a concern. Having established what the present resources are; what some of the supply elements are currently in place; what the base-year demand is; and some basic relationships between demand and socio-economic drivers, this paper sets the stage for further studies that include the future energy supply; regional trade; and scenario analysis using indicators of sustainable development for the region. However, further analysis of the regional energy system, is only valuable if it is supported by good data. A reliable energy balance is needed for the countries not modelled here, and in the case of the modelled countries, better data is also needed, especially in the use biomass.

Keywords: biomass, SADC, energy resources, energy consumption, renewable resources, LEAP model

** The analysis could not be performed on all the SADC countries, based on the data that was available at the time.*

1. Introduction

Southern Africa faces many daunting developmental challenges. Although rich in natural resources, industrial and commercial development remains slow, poverty remains high, and access to clean affordable energy for households remains low. It is estimated that only 24.7% of households in the region have access to electricity and biomass remains the primary energy source in many of the countries (World Bank, 2005). Regional trade and cooperation between countries in Southern Africa is seen as a way to advance economic well being, social development, and peace and security in the region.

To this end, the Southern African Development Coordinating Conference was formed in 1980 with nine Southern African member states namely

Angola, Botswana, Lesotho, Malawi, Mozambique, Swaziland, Tanzania, Zambia and Zimbabwe. In 1992 this was replaced by a Declaration and Treaty which establish the Southern African Development community (SADC). SADC currently has 15 member states, each with their own government and currency. The additional states to the ones already listed are the Democratic Republic of Congo (DRC), Madagascar, Mauritius, Namibia, South Africa, Seychelles, and Swaziland.

Energy resources, supply and demand in countries in the SADC varies greatly. The extensive energy resources in the region are used within SADC as well as exported from the region. Energy is also traded between states: for instance, South Africa imports and exports electricity to and from neighbouring states, and also imports natural gas from Mozambique. Modelling future demand in the SADC regions allows us to explore possible opportunities for further inter-state trade of energy within the region, and the impact of energy policies on the region.

2. Background

2.1 Energy intensity

The energy intensity of the countries in the SADC is generally low compared to many other developed and developing countries. For instance, the International Energy Agency (IEA) (2005) reported a per capita energy intensity (GJ/person) of 174 for Japan, 175 for Germany and 330 for the United States. The corresponding intensities for the SADC countries are shown in Figure 1. The energy intensity of South Africa is the highest in terms of GJ/person and GJ/ GDP due to the processing of raw materials (aluminium, steel, cement production), mining activities and coal to liquid conversion. Mauritius has the highest GDP/capita in terms of purchasing power parity (PPP). In many of the countries the GDP (ppp)/capita is extremely low; Mozambique, Malawi, Zambia, Tanzania and the DRC have an annual per capita GDP (ppp) of below 2000 dollars (excluding informal trade).

In most of the SADC countries, biomass dominates energy supply. The reliability of data regarding the quantities of biomass used that is reported by countries is questionable and will impact on the energy intensities shown.

2.2 Key statistics

The GDP and population of the SADC countries are shown in Table 1 as well as the final energy consumption for all sectors in 2005. South Africa is a clear outlier, consuming far more energy than its neighbours. Final energy consumption figures were not available for Lesotho or Madagascar.

The relative contribution to GDP by agriculture, manufacturing, other industry and commerce, varies greatly between countries. Angola, Swaziland and Botswana rely on industry; the DRC, Tanzania and Malawi receive the major contribution from agriculture, whilst South Africa, Zimbabwe, Namibia and Mauritius receive their major contribution from the commercial sector. For 2005, the percentage contribution of the four key sectors contributing to GDP can be seen in Figure 2.

2.3 Energy resources

The Southern African region has abundant hydro power potential in the north, large coal fields in the south and oil reserves off the west coast. There are also large biomass resources. Table 2 contains a summary of the fossil resources available in the SADC region. Table 3 summarises the renewable

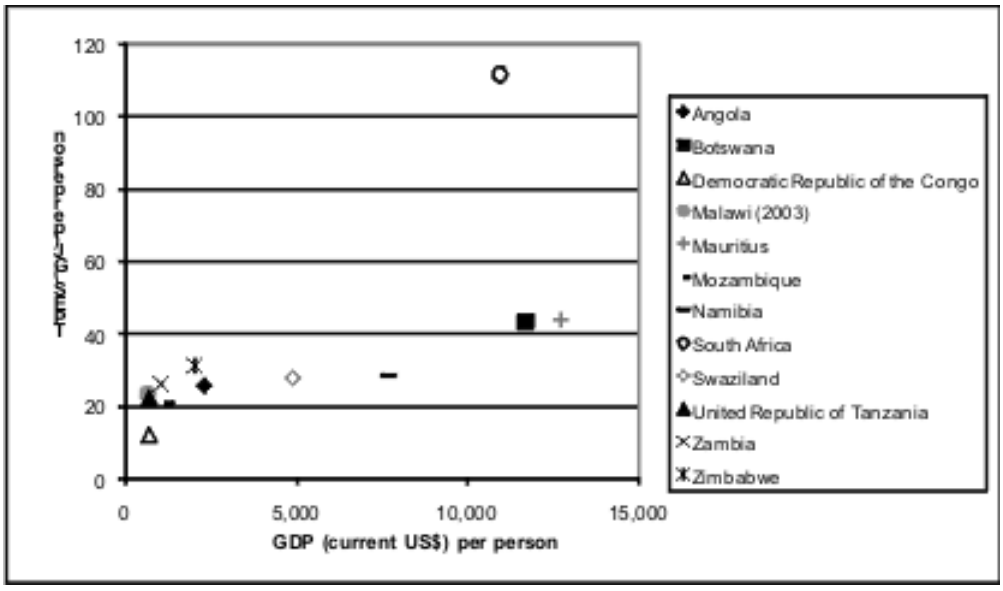

Figure 1: Energy intensity, TPES (GJ) per person, and per GDP (current US$) for 14 SADC countries

Table 1: Summary of key statistics, GDP, population and energy consumption

Country	*GDP (2005 bill US$)*[a]	*2005 oopulation*[a] *(million)*	*Average annual population growth 1975-2004*[a]	*2005 consumption*[b] *(PJ)*
Angola	37.2	16.10	2.8	307.3
Botswana	21.5	1.84	2.4	61.5
DR Congo	41.2	58.74	2.9	665.9
Lesotho	6.1	1.98	1.6	
Madagascar	17.2	18.6	2.9	
Malawi	8.6	13.23	3.0	333.4
Mauritius	15.8	1.2	1.1	51.1
Mozambique	24.3	20.53	2.1	360.1
Namibia	15.5	2.02	2.8	54.3
South Africa	524.5	47.94	2.1	2474.1
Swaziland	5.5	1.12	2.3	15.5
UR Tanzania	27.2	38.48	2.9	660.4
Zambia	11.9	11.48	2.8	224.9
Zimbabwe	26.9	13.12	2.5	344.1

Notes:
a. Source: UNCDB (2007) b. Source: IEA (2007); SADC (2003)

resources available. Where no information is given, no data could be found, for example, in many cases the wind resource potential in the SADC countries is unknown.

The largest hydro resource in the region lies in the DRC and is estimated to be 100GW. Inga, the largest single site in the country, is a potential resource of 44GW and is the most concentrated hydroelectric potential of any site in the world, with capacity steady all year round. Angola has smaller but also significant hydroelectric resources. The economically recoverable hydro potential in SADC is estimated to be between 70 800 and 134 800 MW (Winkler, 2006).

The largest geothermal potential lies in the Great East African Rift System (EARS), a major tectonic structure that extends from the Middle East to Mozambique; Kenya and Ethiopia are currently tapping into this resource. SADC countries including Malawi, Zambia, Tanzania and Mozambique could also potentially make use of this resource, but have not done so too date.

Much of the demand for thermal energy in the region is met by biomass in the form of fuel wood. Although there are large biomass resources in most of the SADC countries, in some countries (such as Botswana) the current rate of harvest is not sustainable.

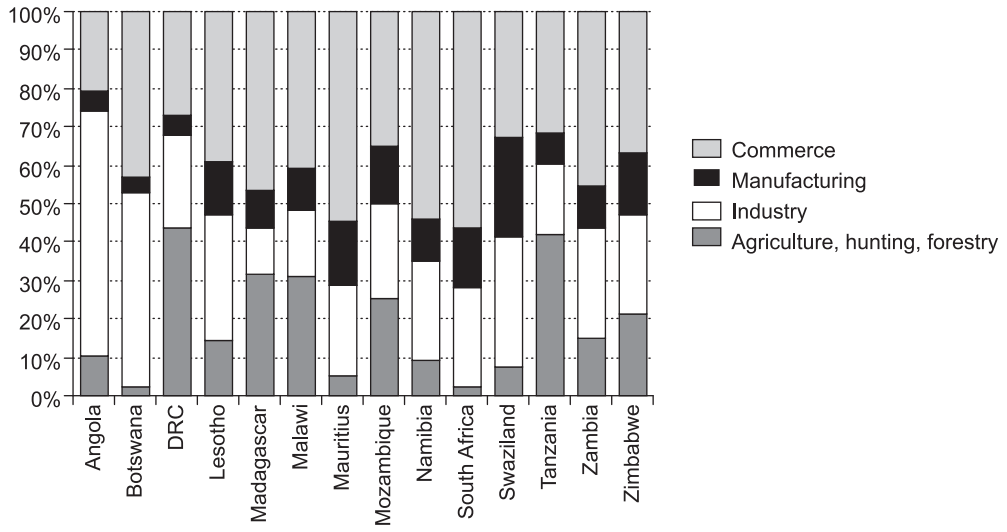

Figure 2: Structure of the economies of selected SADC countries (UNCDB, 2007)

Table 2: Fossil resources

Source: SADC (2003); Fossil fuels in the SADC; 2005 Chamber of Mines facts and figures

	Coal	*Oil*	*Gas*
Angola		10 bbl proven reserves	10 tcf
Botswana	212 bill tonnes	No known reserves	12.5 tcf of gas from coal bed methane
DRC	15-18EJ, 100 Mt known reserves (high ash content and poor calorific value)	100 mill barrels proven	35 tcf estimated
Lesotho	No known reserves	No known reserves	No known reserves
Madagascar	100Mt resources (possibly as high as 2GT)	Possible	Strong showings, but no commercial quantities identified
Malawi	Estimated 1 billion tonnes	No known reserves	No known reserves
Mauritius	No known reserves	No known reserves	No known reserves
Mozambique	Estimated reserves 16 b tonnes, 2 b tonnes proven	No known reserves	Estimated reserves 2.5 tcf
Namibia	350 mill tons reserves in the Aranos basin at a depth of 200-300m	No known reserves	Kudu: 50 bill M3 (1.3 tcf) proven
South Africa	Mined extensively, 121 b tonnes of resources, 30- 50 b tonnes economically recoverable	Currently producing 1Mt / annum (+-7.3mil bbl/yr) from small offshore fields	Limited resources being exploited on the east coast, possible further small resources on west coast, 1tcf coal bed methane in the Waterberg
Swaziland	200 mill tonnes	No known reserves	No known reserves
Tanzania	1.5Gt of coal resources, 0.3Gt proven	No known reserves, but good potential	44 bill M3 (1.14 tcf) of proven reserves
Zambia	30 Mt proven reserves off Maamba, several hundred m tonnes of probable reserves	No known reserves, and very low potential	Possible resource near Angolan border, the fields remain unquantified
Zimbabwe	11 billion tonnes estimate	No known reserves, and very low potential	Coal bed methane reserve

2.4 Electricity supply in SADC

The Southern African Power Pool (SAPP) generally supports reliable and affordable electricity supply to consumers in the region. All SADC countries are represented in the SAPP, except the island states of Mauritius, Seychelles, and Madagascar. Of those in the SAPP, South Africa is the largest player with Eskom being the main electricity supplier in the region. SADC is faced with diminishing surplus generation capacity and therefore the SAPP is attempting to encourage investments in the region. In order to address the shortage, the SAPP is looking at rehabilitation and short-term generation projects which will add around 7600 MW to the grid by 2013 and longer term generation projects such as the Western Power Corridor Project. In addition, new transmission projects will connect Angola, Tanzania and Malawi to the SAPP grid.

The precursor to SAPP, the Operating and Planning Committee with BPC, Zesa and Zesco as members was formed in 1993. SAPP was created in 1995 with the addition of new members at the SADC summit. Table 4 lists the installed capacity of major utilities in the region, maximum demand and maximum demand growth as reported by SAPP in the 2006 annual report.

2.5 Liquid fuels supply in SADC

Within SADC, Angola and the DRC have large economically recoverable oil reserves. Angola, DRC, Madagascar, South Africa, Tanzania, Zambia and Zimbabwe have refining capacity. South Africa is the only country with large refining capacity. South Africa also boasts a coal-to-liquid and gas-to-liquid plant owned by Sasol and PetroSA respectively. Botswana, Lesotho and Swaziland import all refined products from South Africa. Namibia relies on South Africa for 95% of its imported products and Malawi currently imports 93% of its liquid fuels, supplying 7% of demand with ethanol. Mauritius and the DRC import all refined products. Table 5 summarises the refining capacity in the SADC countries.

2.6 Access to electricity and urbanisation

Relatively low proportions of the populations in the SADC countries are urbanised. The majority are subsistence farmers, who only have basic amenities at their disposal (Alfstad, 2005). Electrification in both rural and urban areas in most of the SADC countries is below 50%, the only exceptions being Mauritius, the urban areas of South Africa and Zimbabwe (UNCDB, 2007).

Table 3: Renewable resources in SADC
Source: SADC (2003), SAPP (2005)

	Hydro potential	*Biomass consumption and potential, where available*	*Wind potential*[1]	*Solar insolation kWh/m²/day*
Angola	Potential for economic development 152 TWh/a, 140MW mini hydro potential for rural electrification	Pot.: Fuel wood (510-1020 mill cubic m/a)	Poor-average	4-7
Botswana	No hydropower	Fuel wood, current harvesting practices are not sustainable	Poor	5-7
DRC	100 GW potential	Pot.: 122 mill ha of forest	Poor	3-6
Lesotho	Potential for 3GW pumped storage, 450MW conventional	Pot.: Fuel wood (39,000 ha)	20MW potential	Av. 5.5
Madagascar	Economic potential of small-hydro of 49 000 GWh/year.[2]	Forest area of 12 800 ha	Good along the coast	4-6
Malawi	Estimated potential of 900MW	Con.: Ethanol (7% of liquid fuel, 12 million litres pa) locally produced and blended with petrol	Poor	4-6, av 5.8
Mauritius	59MW existing, potential almost fully tapped	Bagasse, fuel wood and charcoal	Good	Av 6
Mozambique	14GW potential (2488MW developed)	3.5 – 4 bill tonnes	Average	4-6, av 5.2
Namibia	Hydro potential along the lower Kunene, Okavango and Orange Rivers	Abundant in north, scarce in south	Good along the coast	5-8, av 6
South Africa	668MW installed capacity	Bagasse, fuel wood	Good (32GW/ 67.8TWh from sites with capacity factor >25%.[3]	4-8
Swaziland	300 GWh/year potential of which about a third has already been tapped[1]	1.5 mill tonnes of bagasse, 625 kha of forest (162kha is commercial plantations)		Poor 4-6
Tanzania	Potential for 4.7GW of which 12% is currently developed	Fuel wood and charcoal from natural forests and plantations	Good along the coast	4-7
Zambia	Possible hydro projects: 1600MW at Batoka Gorge, 1200MW at Devils Gorge	Fuel wood and charcoal	Poor	4 -7
Zimbabwe	Possible 37TWh on Zambezi, 10TWh harnessed	13 mill tonnes fuel wood yield pa	Poor	5-7

Notes:
1. www.afriwea.org/en/country.htm, www.geni.org.
2. www.afriwea.org/en/country.htm, www.geni.org.
3. Marquard (2008)

Table 6 shows the urban-rural split of population in the SADC (and how this is expected to change in the coming years), and the percentage of households with access to electricity. Other fuels used by households are paraffin, charcoal, coal, LPG, candles, dung and crop residue.

3. Energy consumption in SADC

Much of the demand in the residential sector is supplied by traditional fuels; biomass is used by households to meet around 75% of basic energy needs for cooking, space heating and even lighting (SADC, 2003). Typically these needs are met by appliances with low conversion efficiencies. For example, a coal brazier has a cooking efficiency of about 8%, a wood stove around 25% compared to a gas stove's 57% or an electric hot plate's 65% (Haw, 2007). Therefore, final demand for energy is much higher than it would be if all households had access to – and could afford – modern fuels and appliances. As a result, when households access modern fuels and appliances with higher efficiency of conversion from final energy demand to useful energy, the household consumption in final energy can be dramatically reduced, even if the number of end users increases.

Table 4: Installed capacity, maximum demand and maximum demand growth in the SADC region

Source: SAPP Statistics (2005/6), www.sapp.co.zw

Country	*Utility*	*Installed capacity (MW)*	*Maximum demand (MW)*	*MD growth %*
Angola	ENE	745	397	9
Botswana	BPC	132	434	7.96
DRC	SNEL	2442	1012	2.53
Lesotho	LEC	72	90	0
Madagascar				
Malawi	ESCOM	285	242	6.5
Mauritius	CEB	663		
Mozambique	EDM	2340[1]	1135[2]	7.1
Namibia	NamPower	393	491	6.51
South Africa	Eskom	37 761[3]	33 461	-2.2
Swaziland	SEB	51	172	1
Tanzania	Tanesco	839	531	4.3
Zambia	Zesco	1732	1330	2.8
Zimbabwe	Zesa	1 940	2 066	-0.1

Notes:
1. EIA, includes Cahora Bassa Hydro
2. SAPP demand (EDM) + MOZAL I, II
3. Eskom Annual Report 2007

Table 5: Refining capacity

Source: Fossil fuels in the SADC

Country	*Existing refining capacity*		*Planned refining capacity*
	Location	*Installed capacity (bbl/day)*	*Installed capacity (bbl/day)*
Angola	Lobito	39 000 extended to 60 000	200 000 (expected to come into production in 2010)
DRC		Refinery closed in 1998	
Madagascar	Tamatave	14 400	
Mozambique			Plans to build a small 10 000 bl/day refinery with Malawi and Zimbabwe
South Africa	4 Crude oil refineries (Cape Town, Durban (2), Sasolburg)	513 000	150 000 bbl/day refinery in Coega
	Coal to liquid (Secunda)	150 000	80,000 bbl/day coal to liquids plant
	Gas to liquid (Mossel Bay)	45 000	
Tanzania	TIPER, Dar Es Salaam	17 500	
Zambia	Ndola	24 000	
Zimbabwe	Feruka	10 000	

Transport sector demand is low in most of the SADC countries. Where demand is higher, this corresponds to those countries with the highest GDP/capita, namely Mauritius, South Africa, Namibia, Swaziland and Botswana. Transport is dominated by road transport, with a road network linking all the SADC countries.

The region is rich in minerals, and industry is dominated by mining and processing of raw materials. Nevertheless, industrialisation levels are low with the exception of South Africa which has a well-developed industrial sector.

4. Development of the LEAP demand model

LEAP can be used to analyse either national or multi-regional energy systems using the end-use approach. End-use projection models are more detailed than econometric models (Cobb-Douglas), although their analytical formulation can be relatively simple. The advantage of end-use models is that projections can be formulated to capture changes in the fundamental structure of energy-economic relationships, fuel switching, and technology improvements, which may not be present in historical data.

Table 6: Access to electricity (%)

Country	*2008 Access to electricity*[1]	*2008 urban with access*[1]	*2008 rural with access*[1]	*Urban population (2006)*[2]	*Urban population (2015)*[2]
Angola	26	38	11	54	60
Botswana	45	68	12	58	65
DRC	11	25	4	33	39
Lesotho	16	44	6	19	22
Madagascar	19	53	5	27	30
Malawi	9	25	5	18	22
Mauritius	99	100	99	42	44
Mozambique	12	21	6	35	42
Namibia	34	70	13	36	41
South Africa	75	88	55	60	64
Swaziland	..	42	2	24	28
Tanzania	12	39	2	25	29
Zambia	19	47	3	35	37
Zimbabwe	42	79	19	36	41

Notes:
1. Source: IEA (2008)
2. Source: UNCDP (2006)

End-use models are therefore more appropriate for medium to long-term projections.

In the 'end-use' approach, energy demand is the product of two factors: the activity level and the energy intensity of the activity. The activity level or the demand driver can be, for example, the number of rural/urban households, or commerce GDP in US$. The intensity can either be specified in final demand terms or useful terms. In the latter approach, the final demand is calculated based on specified appliance/fuel share and efficiency. In the case of demand for residential cooking, the intensity is the demand for cooking services per household.

A LEAP model was developed to analyse the final energy demand, how it could evolve over the medium term (up to 2030) for seven of the SADC countries, under a 'business as usual' scenario. The countries were selected on the basis of whether or not sectoral demand data was available, as was the case for Angola, Botswana, Mozambique, South Africa, Tanzania, Zambia and Zimbabwe.

4.1 The base year and model structure

Consumption data within the SADC region is generally poor and often inadequate for planning purposes, quantitative data often varies widely between sources and between years. Of the 15 countries, only 7 have reasonably reliable energy balance final energy consumption by sector.

The base year was set to 2005 and was calibrated using data drawn predominantly from the IEA energy balances. In most cases, the IEA data was more or less consistent with the energy balances reported by the countries themselves (where available), and with those reported in the SADC yearbook. In cases where the IEA energy balances lacked data, data was taken from the SADC Yearbook (SADC, 2003) and from a report by Alfstad (2005).

There are many examples of what appears to be data inaccuracies in the balances; it is unclear how much of the variance is due to data quality, for instance, biomass use in Swaziland appears to be too low and there is no biomass use reported for the residential sector although less than 30% of people have access to commercial energy. Another example is the omission of household demand for energy supplied by solar water heaters in Mauritius. In Tanzania, the commercial sector suddenly stops consuming energy after 1993. Where possible, when no alternative data was found, the amount of energy used in each sector was imputed using historical energy balances.

The sectoral disaggregation of national demand (and the corresponding end-uses) for each country within the model is as follows:

1. Agriculture/forestry (heating, motor, other electric)
2. Commercial and public services (heating, cooling, lighting, other electric)
3. Industry sector (heating, motor, other electric)
4. Residential sector
   a. Urban (cooking, lighting, space heating, water heating and other electric)
   b. Rural (same end-uses as for urban)
5. Transport sector
   a. Freight (road, rail)
   b. Passenger (rail/road public, road private, air)

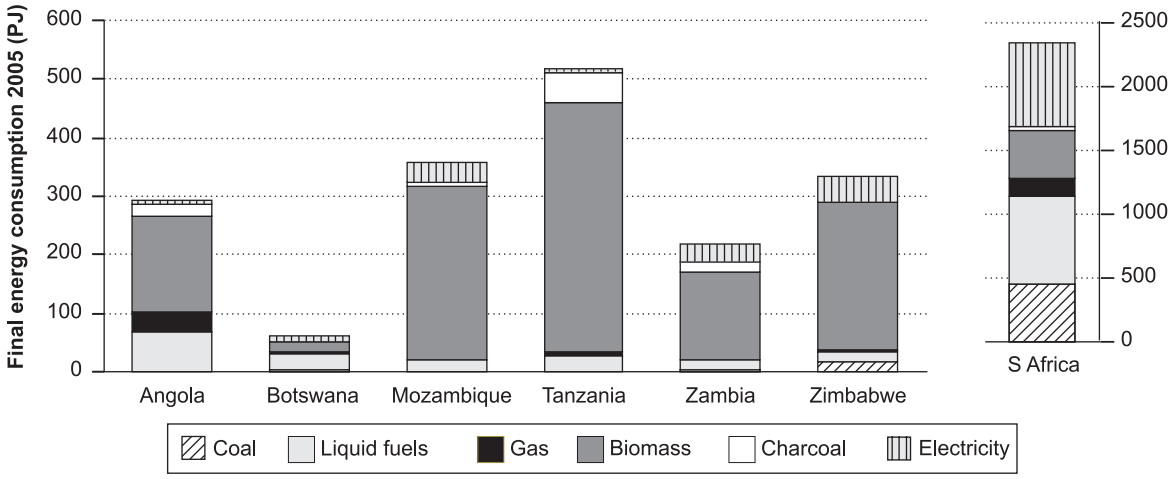

Figure 3: Final energy use by fuel for selected SADC countries

The disaggregation of the model structure was limited by the available data. Sub-sectoral data, by fuel and end-use, is only available for South Africa (Winkler, 2006), but the structure was defined generically, in such a way that structural changes in the economy, urban migration, mode switching (road/rail), technology improvements and fuel switching can be captured, along with improvements in data resources.

Final energy demand by fuel in 2005 is shown in Figure 3 for the 7 countries where data seems more reliable. South Africa, shown on a different scale, is the only country, other than Botswana, where final energy demand is not dominated by biomass.

Figure 4 shows the proportional final energy use in each sector for 2005 for the same 7 countries. Again, South Africa and Botswana are again unique in that their final demand is not dominated by the residential sector.

The demand drivers for agriculture/forestry, commercial and public services, and industry are based on the level of economic activity, defined by the value added in each of those sectors in constant (year 2000) US$ (ppp). Historical data on value added in each of the sectors for each SADC country can be obtained from the UN Common Database (this database gives value added in constant national currency which was converted to constant US$ (ppp).

4.2 Demand drivers

4.2.1 Drivers of energy demand in agriculture, commerce and industry

The demand drivers for agriculture/forestry, commercial and public services, and industry are based on the level of economic activity, defined by the value added in each of those sectors in constant (year 2000) US$ (ppp). Historical data on value added in each of the sectors for each SADC country can be obtained from the UN Common Database (this database gives value added in constant national currency which was converted to constant US$ (ppp)). Projections of value added are

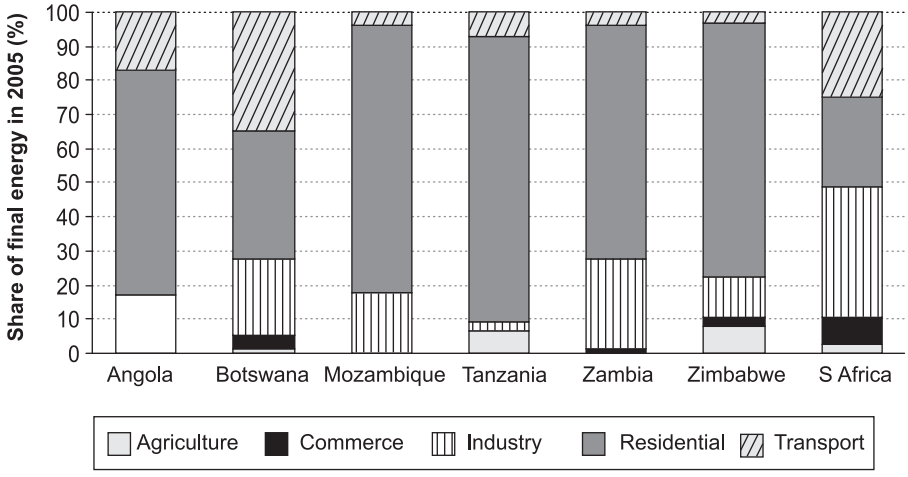

Figure 4: Final consumption by sector as a percentage of total final energy for selected SADC countries

Table 7: Historical and projected GDP growth

	Historical GDP growth					*Growth projections – scenario values*
	2001	*2002*	*2003*	*2004*	*2005*	*2006-2030 average*
Angola	3.1%	14.4%	3.4%	11.1%	14.7%	5.9%
Botswana	5.2%	5.0%	6.7%	4.9%	3.8%	5.4%
Mozambique	13.1%	8.2%	7.9%	7.5%	7.7%	6.3%
Namibia	2.4%	6.7%	3.5%	6.0%	3.5%	4.2%
South Africa	2.7%	3.7%	3.0%	4.5%	4.9%	4.8%
Tanzania	6.2%	7.2%	7.1%	6.7%	7.0%	5.8%
Zambia	4.9%	3.3%	5.1%	5.4%	5.1%	5.3%
Zimbabwe	-2.7%	-4.4%	-10.4%	-4.2%	-7.1%	2.4%

based on projections of each country's GDP over the planning period (scenario parameter), observed historical trends in the structure of the economy, and a value judgment on how the structure is likely to evolve based on observed trends in other transitioning economies.

4.2.2 Drivers of energy demand in the transport sector

The two consumption drivers for the transport sector of the model are GDP and population for freight and passenger transport respectively.

4.2.3 Drivers of energy demand in the residential sector

The demand driver for the residential sector is the number of households, both in urban and rural areas. Projections of the number of households (urban/rural) are based on projections of population growth for each SADC country, observed historical trends in the urban/rural split, and a value judgment based on observed trends in the evolution of household size for other transitioning economies.

4.3 Projections of demand drivers

Gross domestic product (constant 2005 US$ ppp) growth projections are developed for each SADC country based on historic GDP growth trends. Note that in almost all cases, the historical trend was extrapolated for a few years, then were made to peak and decline to a lower growth value, based on a similar approach used in (Haw, 2007). Historic GDP growth (2001-2005) and the average growth projected (2006 onwards) are given in Table 7. The resulting actual GDP evolution in constant 2000US$ ppp is shown in Figure 5. Since the future growth rates are unknown, the assumed growth rates are scenario parameters, for which the impact on energy demand must be explored.

Assumptions regarding the contribution of sectors of the economy to GDP in 2005 and 2030 are shown in Figure 6

Population growth projections are developed for each SADC country based on historic population growth trends. Historic population (1990-2005) and projections (2006 onwards) are shown in Figure 7. South African population growth reflects the impact expected from HIV/Aids based on a model developed by the Actuarial Society of South Africa (ASSA, 2002). Population growth models reflecting the impact of HIV/Aids were not available for other countries.

The rural/urban split assumed for countries between 2005 and 2030 is shown in Figure 8. The urban population is assumed to increase, based on historical rural-urban migration trends in the countries.

5. Final demand projections between 2005 and 2030

The results presented for Angola, Botswana, Mozambique, South Africa, Tanzania, Zambia and Zimbabwe are extracted from the LEAP model.

Figure 9 shows that, given the assumptions made, the total final energy demand for the 7 countries in 2030 is roughly 2.5 times what it was in 2005. It is important to note that this demand does not include transformation from primary to secondary fuels.

Figure 10 and Figure 11 show how final energy will change from 2005 to 2030, by fuel and by sector. The share of biomass (wood, dung and crop residue) decreases, due to households switching to modern fuels such as electricity and gas as they move from rural to urban areas. Figure 11 shows that the industrial and commercial sectors play a more important role in final energy demand in the future, displacing residential demand.

Figure 12 shows the breakdown of final energy demand by fuel at country level. Note that in this figure, South Africa is on a different scale. In Angola and Tanzania, the use of biomass increases considerably and the question arises as to whether the use of biomass at this rate is possible or sustainable. The largest increases in electricity use occur in South Africa, Zambia and Mozambique. Over the period, South Africa continues to dominate

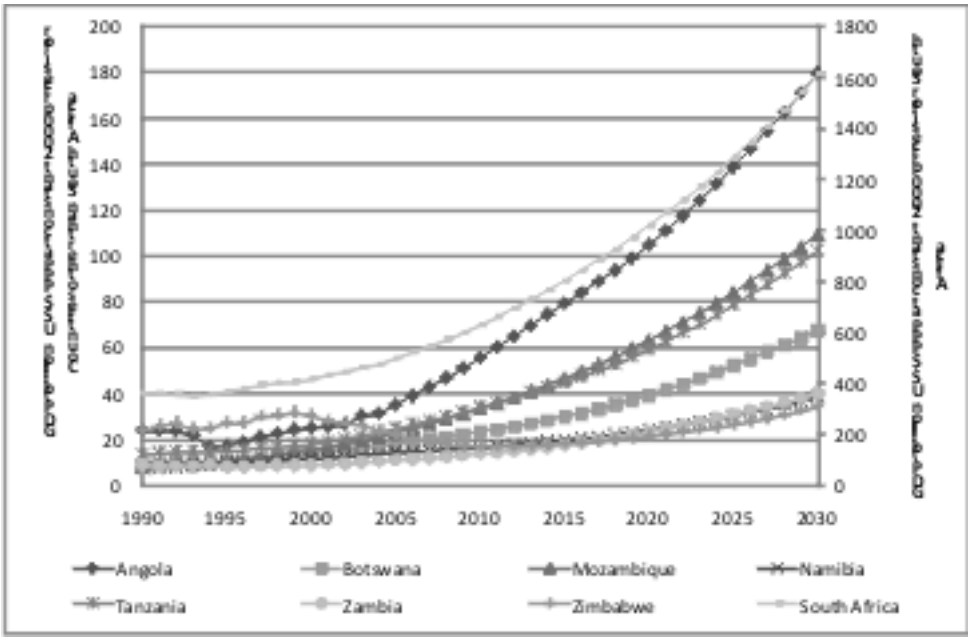

Figure 5: GDP history and projections for the SADC countries

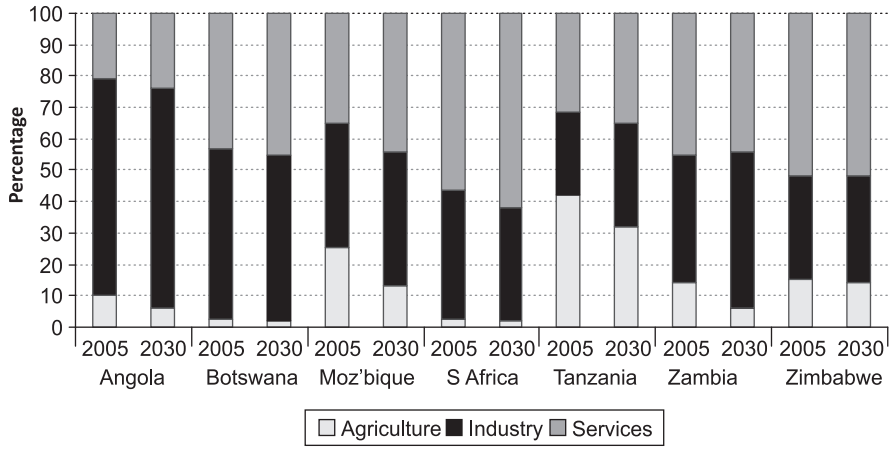

Figure 6: Snapshot of structure of the economy in 2005 and 2030

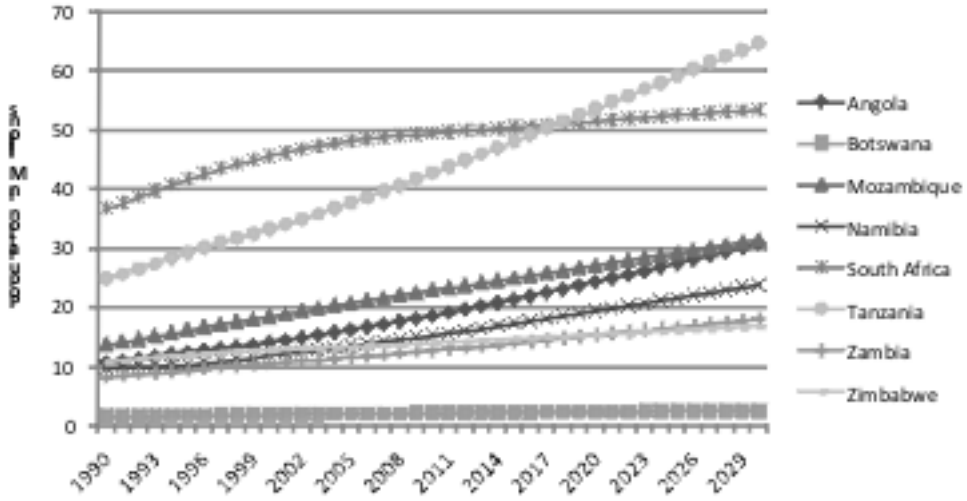

Figure 7: Population projections for the SADC countries

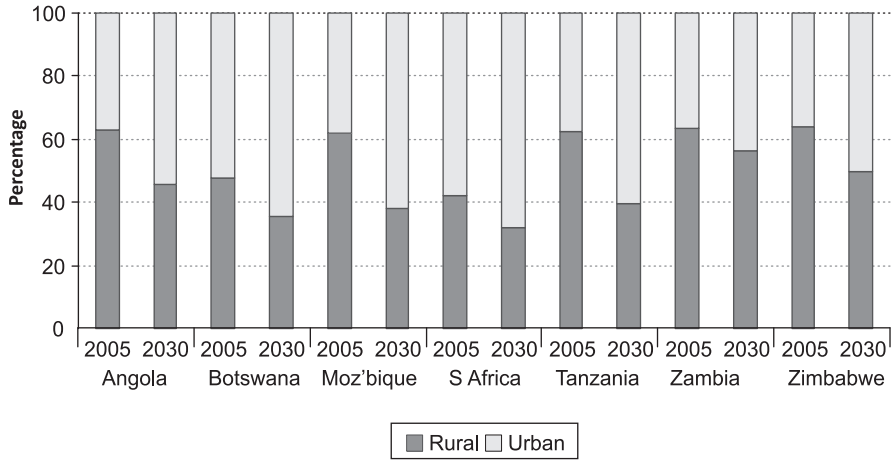

Figure 8: Rural/urban split

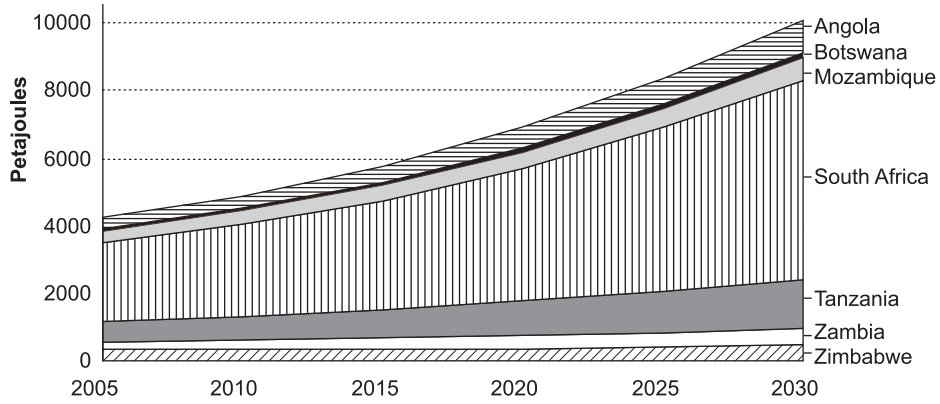

Figure 9: Total final energy demand for the selected SADC countries

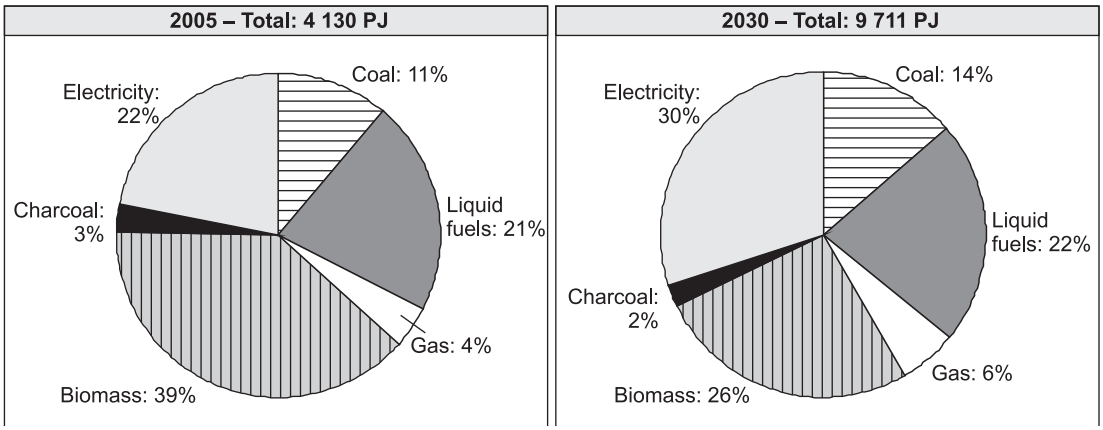

Figure 10: Final energy demand by fuel

demand in the region. Botswana's demand remains low, given its smaller population.

Figure 13 shows the percentage of final energy demand attributed to the agricultural, commercial, industrial, residential and transport sectors within the countries. The percentage of final energy demand going to industry and commerce increases in all cases, because of the projected growth assumed in these sectors.

Figure 14 shows the final energy intensity per capita and per US$ in 2005 and the projected values for 2030. In general, final energy intensity per capita increases, with South Africa seeing the greatest increase due to the continued increase of an already intensive industrial sector and the small increase in population over the period. The increase in energy intensity in Botswana is largely driven by demand in the transport sector. Botswana is a land locked country reliant on road, rail and air to transport passengers and goods over large distances.

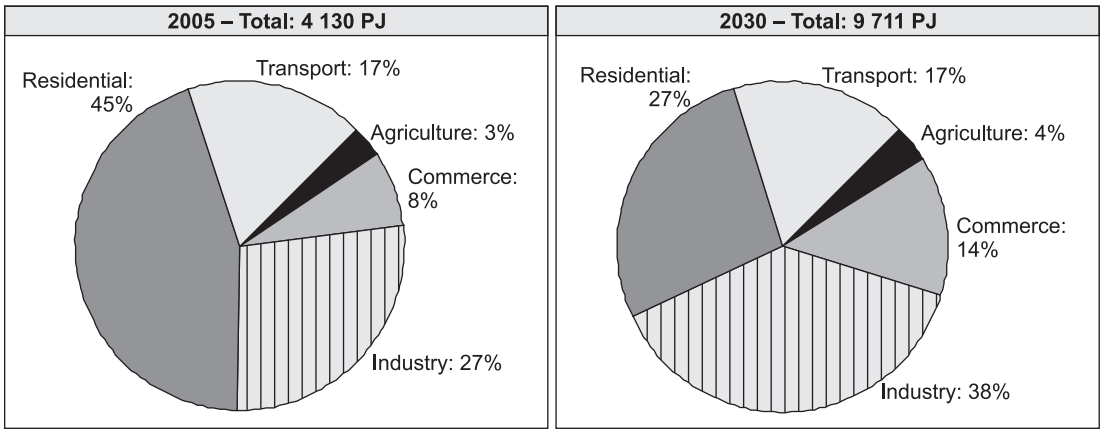

Figure 11: Final energy demand by sector

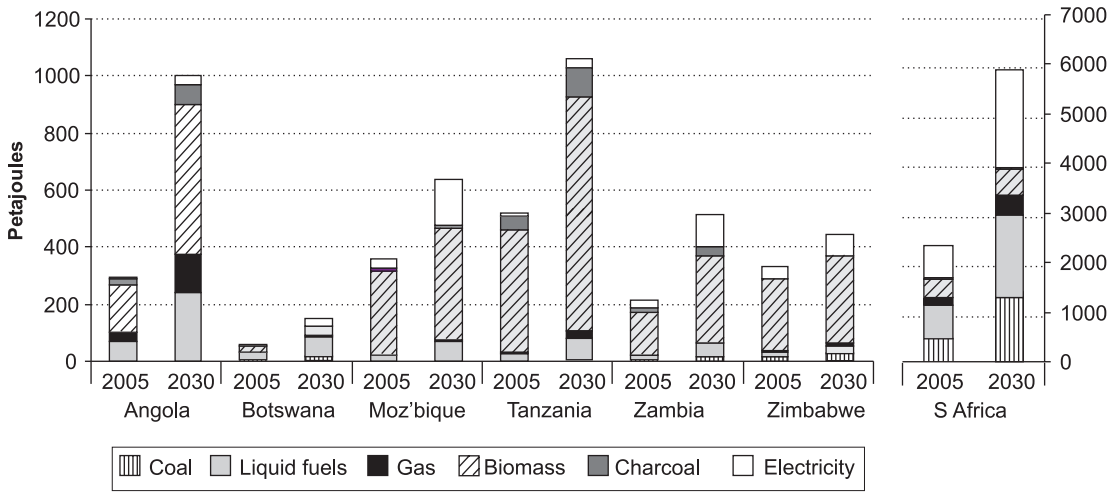

Figure 12: Final demand by country and by fuel

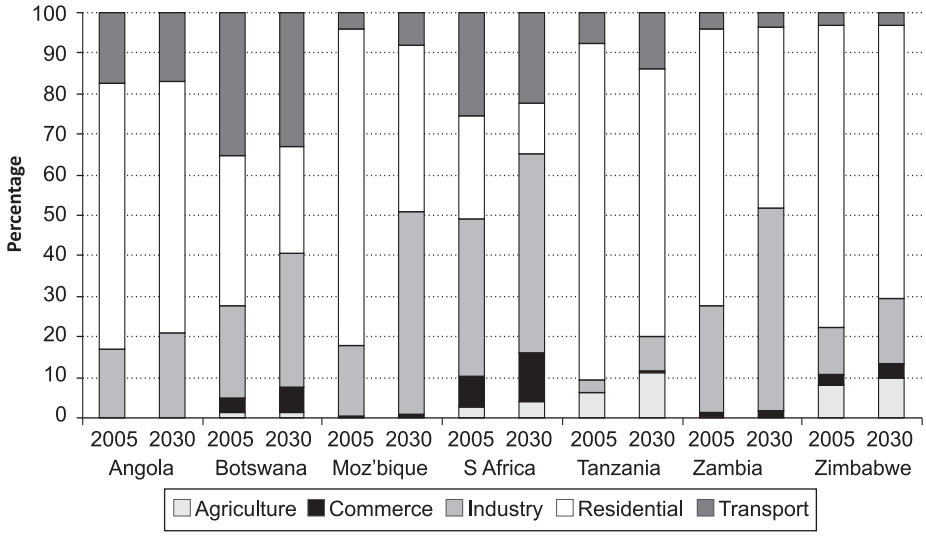

Figure 13: Share of final demand by sector

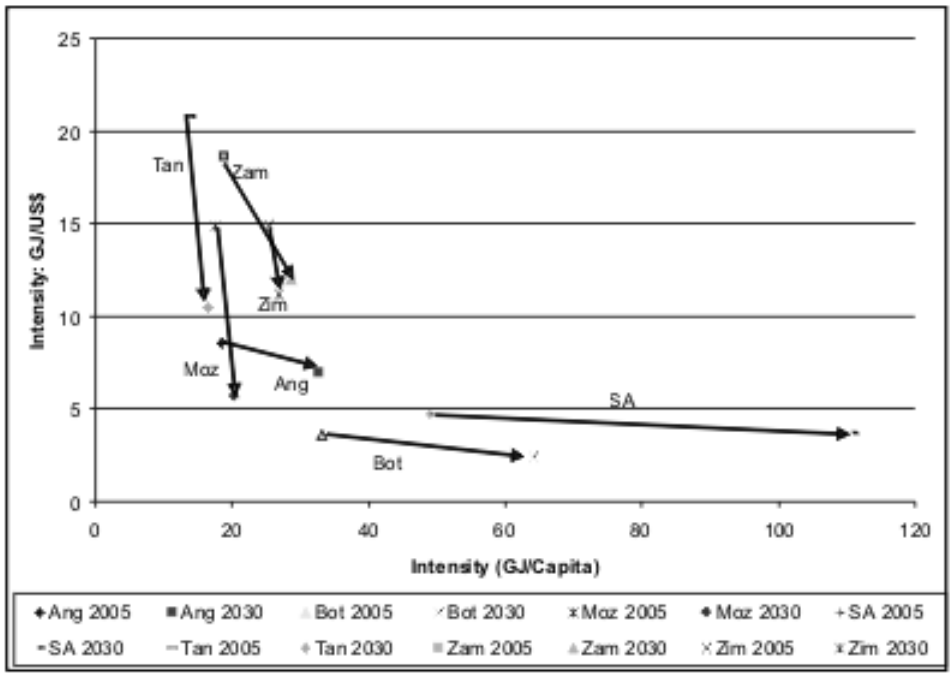

Figure 14: Final energy intensity per capita and per US$ of GDP

6 Conclusions and recommendations for future work

In this paper, the present day energy consumption, supply and resources of countries in the Southern African Development Community (SADC) are examined, by reviewing publicly available data. Most countries in the SADC have extremely low energy intensities compared to many developed countries, South Africa being the exception because of its more developed raw materials processing and mining activities, amongst others.

The data seems to indicate that the structure of the economy (in terms of contribution from agriculture, industry and commerce) varies greatly between SADC countries. It is very likely that the contribution by the commercial sector is underestimated due to the exclusion of informal commercial activity in some cases.

The region is rich in energy resources; it has large hydro power potential in the north, large coal fields in the south and oil reserves off the west coast. There are also vast biomass resources, which could be sustainably harvested. Solar potential is good in most countries while wind potential data is pretty sparse except in the case of South Africa, where a recent report (Marquard, 2008) indicates greater potential than previously thought.

The Southern African Power Pool coordinates the supply and trade of electricity in the region, where Eskom in South Africa is the largest player. SADC is faced with diminishing surplus generation capacity and therefore SAPP is attempting to encourage investments in the region.

Consumption data within the SADC region is generally poor and often inadequate for planning purposes, quantitative data often varies widely between sources and between years. Except, in the case of South Africa, Botswana, Namibia and Mauritius, final demand is dominated by the residential sector in the form of biomass for cooking.

A LEAP end-use model was used to make some projections of final energy demand for countries for which IEA energy balances are available, namely, Angola, Botswana, Mozambique, South Africa, Tanzania, Zambia and Zimbabwe. The structure of the model was designed such that energy demand responds to changes and trends in economic growth, the structure of economy (in terms of the importance of primary, secondary and tertiary levels of economic activity), population growth, rates of urbanization, technological improvements, fuel switching (e.g. switch from biomass to electricity should electrification rates improve), and to some extent, modal switching in the transport sector. However, the data available to support such a disaggregated approach was only available for South Africa.

The model base-year was calibrated using energy data drawn from the IEA energy balances and socio-economic data drawn from UNCDB. The analysis indicates that we can expect to see a large increase in energy consumption in the SADC region, including a large increase in demand for biomass and electricity. In both cases, supply is of concern. Currently the SADC region is short of electrical generating capacity, and in some countries

supply is reliant on hydro-electric stations which are susceptible to drought. Biomass use and alternatives for biomass use in many of the SADC countries requires attention in order to promote sustainable use of the resource.

Energy models such as the one presented in this paper can be very useful to planners and decision makers in order to rationalise the use of the energy potential available to the region subject to political, social, economic and environmental constraints, in order to support the sustainable development of the region.

The analysis using the LEAP model presented here, only looks at the demand for some of the countries, in a business as usual scenario. Much more insight could be obtained if, several more scenarios were analysed exploring the range of uncertain factors and their impact on the SADC energy system. Analysing demand without taking into account supply constraints is over-simplistic and limiting. One cannot account for supply constraints that could inhibit the demand, and the trade opportunities that would rationalise the use of the resources available to the region. Previous studies (Alfstad, 2005) have already identified potential savings in costs to supply demand in the region if trade between countries was better supported. There is a need for more analysis of this type to support policy makers and decision makers in the region.

The demand component of the SADC model itself could be improved. The industrial sector warrants further disaggregation into intensive (e.g. mining) and less intensive industries (e.g. textiles). The difficulty would be in determining how the contribution to the economy of these sectors would evolve over time. The residential sector could be further disaggregated into low income/high income or different household types. But disaggregation and more detailed analysis are only valuable if it is supported by data. It is therefore very important that efficient data collection practices are established in the region. Without good data and proper analysis, decision makers do not have the means to build sound practises.

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Received 24 February 2009; revised 9 February 2010