POLICYbrief

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Factors Determining the Affordability of Renewable Energy

A Note for South Africa

Martin Kaggwa, Shingirirai Mutanga and Thokozani Simelane

When a country is deciding on a policy of introducing renewable energy as an alternative energy source, affordability is a prime consideration. Affordability depends on the type of technology, policy direction and investment considerations. All these aspects have a direct bearing on the price that will ultimately be paid by the consumer. As South Africa is on the verge of implementing its renewable energy policy through the judgement to be made on the bids submitted by renewable energy independent power producers, it will be important for decision makers to take into consideration the energy's affordability. Perceived high costs will lessen renewable energy's envisioned benefits to the socio-economic development of South Africa. However, while renewable energy is still considered to be expensive, international data reveal a trend of declining renewable energy costs. In developed countries, the experience of Germany stands out in the successive adoption and use of affordable renewable energy. The country started implementing its renewable energy policy in 2000; today it is among the world's three major renewable energy economies and its policy serves as a model of success to other European countries. In South Africa specifically, the unit production cost and consequently the unit price attached to renewable energy (in particular solar energy) is too high and unrealistic compared with international renewable energy prices. The present approach has the potential to put the country on a sub-optimal and expensive energy mix path. It is recommended therefore that solar energy costs and prices for South Africa be reassessed and the positioning of solar energy in the country's long-term energy mix strategy be reconsidered against the confirmed renewable energy unit costs and consequent affordability.

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Introduction

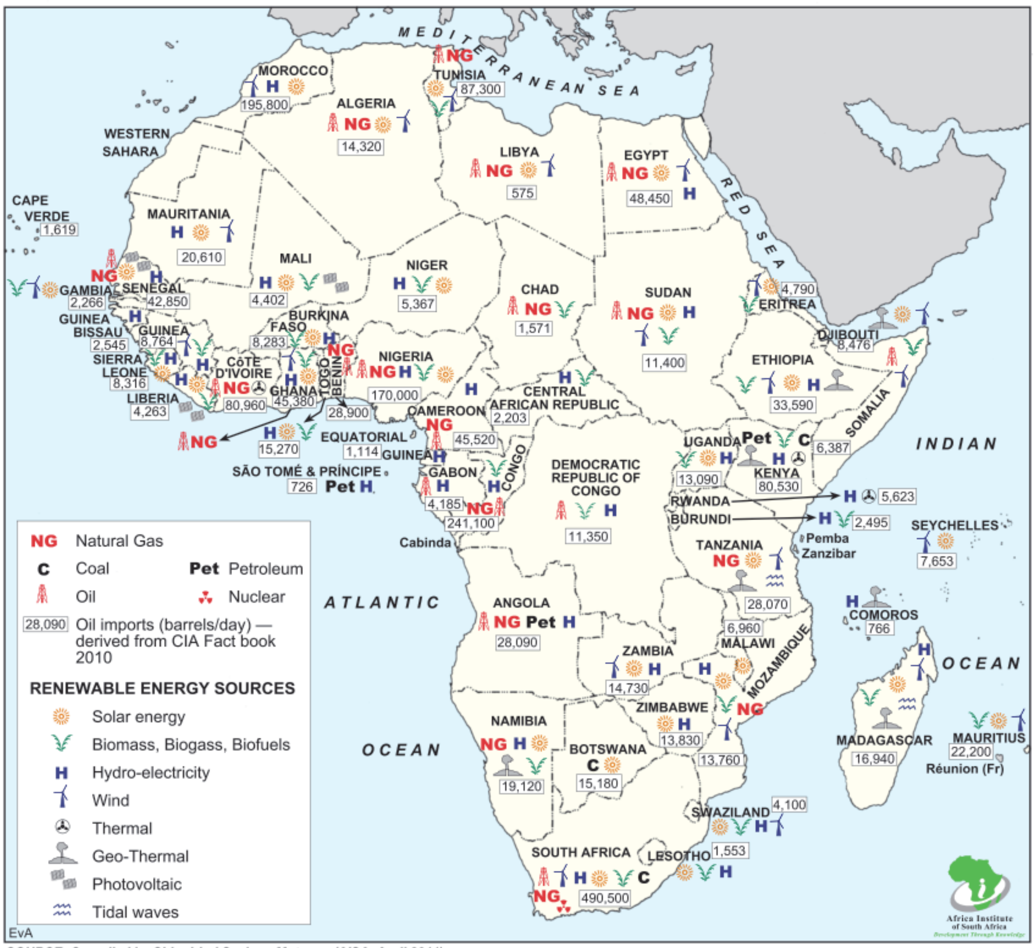
A major setback to Africa's efforts to migrate to renewable energy and the associated technologies is the cost. Over the years, African economies have been solely dependent on foreign technologies. As a result, the burden of licensing and other intellectual property requirements has been a barrier that frustrates the adoption of technologies needed to migrate to renewable energy.

In this era of energy transition, it needs to be emphasised that Africa is very well endowed with renewable energy resources. Hydropower alone has the potential to contribute not less than 1 750 TWh to the energy mix of Africa.[1] This derives from the fact that the Inga River standalone project (in the Democratic Republic of Congo) has the potential of generating up to 40 000 MW of electricity, with additional capacities coming from rivers such as the Nile and the Zambezi.[2] The combined capacity of all African rivers is sufficient to meet all the energy demands of the continent.

Biomass resource is also sufficient to serve as a reliable alternative source of energy for the continent.[3] In addition, Africa has the potential to generate no less than 14 000 MW from geothermal sources.[4] Furthermore, a great potential exists for solar power, which can be obtained from the continent's desert areas, which include the Sahara Desert in the northern hemisphere and the Kalahari Desert in the southern hemisphere. Despite these vast resources, the utilisation of solar power in Africa is still minimal and varies between countries. South Africa operates a solar thermal power system plant that generates only 0,5 MW.[5] Egypt plans to install one that will generate between 30 and 300 MW by the year 2020.[6]

Despite the scattered renewable energy initiatives and low renewable energy uptake on the continent, the diversity of renewable energy sources in Africa is such that the continent has the potential to play a leading role in the supply of renewable energy to the world (Figure 1).

POTENTIAL RENEWABLE ENERGY MIX IN AFRICA



SOURCE: *Compiled by Shingirirai Savious Mutanga (AISA, April 2011)*

Figure 1: Africa's diverse renewable energy sources.[7]

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Technology as a Critical Factor of Affordability

Conversion technologies are a major determinant of the unit cost of renewable energy harnessing. As such, these technologies have a bearing on the price that consumers will ultimately pay for using a specific renewable energy source.[8] At present, the cost of harnessing energy from renewable energy resources has been estimated as being higher than that of fossil fuels.[9] Renewable energy resources in Africa have a potential to meet many countries' energy demands, but without the right conversion technologies and affordability of renewable energy to the average African, the envisaged socio-economic benefits of the continent's migration to renewable energy use will remain minimal.

Despite this general belief that the cost of renewable energy is still high, there are international success stories of the use of renewable energy conversion technologies in national development efforts. Germany, which took a policy decision in 2000 to migrate to wider use of renewable energy in its economy, has been able to achieve cost reductions and improve renewable energy efficiency. Today, Germany's economy is among the world's three major renewable energy economies and its policy serves as a model of success in more than 47 European countries. Germany stands out as a good benchmark for renewable energy policy

Ultimately, assessment of renewable energy affordability in Africa requires insight into renewable energy conversion technologies being used on the continent, given the importance of these technologies in determining unit renewable energy cost.

Renewable Energy Technologies used in Africa

The most common renewable energy technologies so far adopted and used in Africa include biomass, hydropower, wind and solar technologies.

Biomass conversion technologies

There are two main technologies for generating energy from biomass: heat, electricity and fuels. These are thermo-chemical conversion and biochemical conversion technologies. The thermo-chemical technologies involve the heating of biomass at different temperatures and with different air content to change its content in order to generate energy using either pyrolysis or gasification processes.[10] The biochemical technologies involve the decomposition of biomass through bacterial action, in the absence of oxygen, to yield biogas (methane) and carbon dioxide via digestion, fermentation or extraction processes.

Biochemical technologies are generally viable at very small household levels, as long the household can generate or source the feedstock. The required initial investment is not so high and the technologies are not sophisticated enough to require specialised skills for operation. However, while new technologies are available internationally that increase the efficiency of energy extraction from biomass, the African continent is generally still stuck with the outdated technology of biochemical conversion that concentrates on extraction of biogas and bio fuels from animal manure and plant feedstock, and charcoal from plant products.[11] Efforts to acquire the technology to increase energy harvesting from biomass have tended to focus on animal manure, limiting the scope of the technologies that the continent has sought to acquire and master.

Hydro-energy technologies

The basic conversion technology for hydro energy involves the building of big dams across flowing waters, creating reservoirs. Water in the reservoirs is subsequently released, in a controlled form, to maximise the kinetic energy of the flow. This kinetic energy is then used to turn turbines that feed into a generator, then to a converter or inverter and finally to a transformer that converts the energy into electricity.[12] This electricity is then connected to a grid and distributed.

An alternative technology for hydropower generation has been spearheaded in Africa by South Africa. This technology entails the pumped water storage approach, which uses two reservoirs – an upper and a lower one. Water from a natural source is stored in both reservoirs. In generating power, water is allowed to flow from the upper reservoir to the lower reservoir via two reversible pump turbines, and hydropower is generated in the process. During off-peak periods, the water collected in the lower reservoir is pumped back to the upper reservoir, using the generated power from the downflow of the water. The pumped water storage technology thus converts excess hydro power into kinetic energy during energy demand off-peak periods, and then reconverts the kinetic energy into hydro power during the peak demand periods.[13]

Another emerging technology in the field of hydro energy is River Current Energy Conversion Systems (RCECS). RCECS are electromechanical energy converters that convert kinetic energy of river water into other usable forms of energy.[14]

Thus far, hydro-energy conversion technology is only feasible on a large construction and operation scale. It requires high initial investment and it is costly in terms of the environment. A key prerequisite for utilisation of hydropower conversion technologies is the existence of reliable natural water sources. As such, hydropower technologies are most relevant to areas that have permanent rivers. This explains why hydropower stations are mainly situated on major rivers.

Technology for micro hydro power stations is, however, also available. It consists of a scheme that diverts water from a river using a dam or weir. The water is transported to the forebay using a canal or pipeline. From the forebay the water is taken to the turbine by the penstock. The turbines drive a generator either directly or by means of a mechanical transmission. Although the micro hydro power conversion technologies are mature, overall the undertaking of micro hydro power generating projects is not yet competitive in cost compared with power generation from fossil fuel. It is nevertheless expected that as the technology improves, micro hydro energy production in Africa will become economically viable and competitive.

Wind energy conversion technologies

This relates to converting the force of wind, which is kinetic energy, into rotational energy, and finally into torque, which is mechanical energy. The rotational energy is then used either to generate electricity or to directly move machines or equipment such as mills or water pumps.[15] The intermittent energy of wind necessitates means of storing energy during off-peak time to be used in peak periods. Intermittence of wind energy also means that for its practical use, the energy has to be supplemented with other energy sources to cater for periods of low-feed kinetic energy. Wind energy technologies have focused on maximising energy transformation and transmission from kinetic and rotational through to electricity.

Although wind conversion technology is relatively easy to master, with low maintenance costs, wind plants require high initial investment in the sense that for such projects to be economically viable there should be a significant demand for energy to be produced. Without a significant demand to support wind energy producing plants, the project is not likely to breakeven within the estimated time of 15 years, which is the project lifespan. By implication, small projects for harvesting wind energy are less likely to be economically and financially viable. Moreover, the wind energy conversion projects are location specific. There should be enough wind to keep the rotors rotating. In addition, the need to supplement wind energy with other energy sources in order to make it reliable makes wind energy relatively expensive.

Solar conversion technologies

The solar technology used falls into two categories. These are solar thermal systems and electric or photovoltaic (PV) systems, which generate electricity from solar power to use in a wide range of devices including water pumps. Solar thermal systems are used mainly for tapping of heat from solar energy and comprise solar thermal plants, solar water heaters, solar drying, solar cookers, solar distillers and solar coolers.

Solar thermal plants can use a complex concentration of solar collectors to produce a high temperature that is enough to produce steam, which is later converted into electricity through steam power stations.[16] Feasibility studies have shown that Africa has a great potential for solar technologies. Several countries in North Africa are already in the process of establishing solar plants of varying capacities, being buoyed by the interest shown by European countries in acquiring renewable energy from North Africa.[17] Generally, all African countries have adequate solar radiation that could sustain solar energy production throughout the year.

The total area of high radiation in South Africa is approximately 194 000 km^2. This includes the Northern Cape, one of the best solar resource areas in the world.[18] Assuming electricity production per km^2 is 30,2 MW, and only one per cent of the area of high radiation is available for power generation, then the generation potential of South Africa is estimated at 64 GW.[19,20] Howells[21] has estimated South Africa's potential for solar energy to be at 8 500 000 PJ/yr, compared with the final consumption of 587 PJ in 2000.[22]

Of all solar technologies, PV is the most reliable and predictable. The technology is also gaining popularity due to the fact that its investment costs have declined in the past years. For instance, the United States (US) is in the process of converting all its solar projects into PV technology.

In South Africa, PVs account for only 9,4 per cent (i.e. 8 400 MW) of the total renewable energy supply.[23] According to Pegel,[24] most PVs in South Africa are decentralised in buildings and homes. This situation is likely to increase once new contracts for solar energy are awarded. In the midst of this, it can be said that PVs have been found to be effectively suited to power stations of

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50 Megawatt peak (MWp) and larger. PV is most valuable when maximum production coincides with peak electricity demand, which represents in most countries 20 to 30 per cent of the annual demand.

It has to be acknowledged that while conversion technologies have a strong bearing on renewable energy cost, there are other contributing factors to this cost and subsequent prices paid by consumers. These factors may be direct or indirect. For completeness, policy decisions on renewable energy based on affordability need to take into account these factors.

Price as a Differentiating Factor between Technologies

The unit price is an important differentiator that should guide the policy of a country when it considers the possibility of supplementing its energy with renewable energy. As long as renewable energy is considered to be expensive, there will be less enthusiasm to adopt them. This is important for South Africa, as it is on the verge of making the decision to introduce renewable energy as an alternative source of energy. Determining the true cost of renewable energy relative to the cost of other energy sources is critical. Without the knowledge of the actual renewable energy unit cost, South Africa may run the risk of making costly policy decisions. The estimation of the actual cost of different energy sources is constrained by a lack of consistent and reliable data. International estimates for the unit cost of producing one KWh from different energies, including minimum prices for carbon emission, give variable indications (Table 1).

It is noticeable from Table 1 that combined solar and PV panels have the lowest production unit cost of all renewable energy sources. More important is that the unit production cost of PV is less than that of coal-fired power plants, which are the main source of electricity for South Africa. Based on this, it seems plausible to recommend that South Africa give priority to PV, which appears to be cheaper and more affordable.

A comparison of tariffs also reflects a wide variation between the developed and the developing countries and within African countries, where the highest tariffs exist in Central and Eastern Africa (i.e. 15,9 per kWh in Kenya and 14,94 per kWh in Cameroon). These appear not to be correlated with production costs, that is the technologies used (Table 2). North Africa (e.g. Libya) and South Africa have relatively lower tariffs than most African countries. As these countries are unable to provide reliable energy, what can be deduced is that the inability to afford energy has a direct bearing on economic growth, and in most cases retards economic growth.[27]

Table 1: Estimates of unit production cost of 1 KWh selected energy sources

Energy cost / Energy source	Coal fire	Coal fired with 75% geo-seques-tration	Nu-clear	Com-bined solar and PV panels	Geo-thermal steam	Wave power	Con-centrated solar PV	Para-bolic Con-centrated solar steam	Con-centrated solar steam	Con-ventional PV
Cost per KWh to produce (US$)	0,16	0,26	0,26	0,04	0,15	0,15	0,14	0.14	0,25	0,25

Source: Unenergy, 2009[26]

Table 2: Comparative tariff (cents US/kWh) for selected African countries

Utility Country		KPLC Kenya	UEGCL Uganda	GECOL Libya	EEHC Egypt	ESKOM South Africa	ZESCO Zambia	SNEL DR Congo	AES_SONE Cameroon
Social Tariff (100KWh/month)	1kW	9,7	23,74	1,52	1,34	4,62	1,13	2,65	11,55
Single phase domestic usage (E = 200KWh/month)	2kW	13,5	24,79	1,52	1,56	4,62	2,04	3,9	11,55
	4kW	13,5	24,79	1,52	1,56	4,62	2,04	3,9	11,55
Triphase domestic usage (E = 600KWh/month)	6kW	15,4	25,49	1,52	2,5	4,12	2,18	8,7	12,73
	10kW	15,4	25,49	1,52	2,5	4,12	2,18	8,7	12,73
Commercial usage (E = 1800KWh/month)	12kW	15,9	24,25	3,64	8,02	3,64	4,13	11,0	14,94
	15kW	15,9	24,25	3,64	8,02	3,64	4,13	11,0	15,7
Semi industrial and motive power (E = 2500KWh/month)	20kW	8,45	25,5	3,98	8,33	3,38	4,52	15,0	14,09
	25kW	8,45	26,0	3,18	8,33	3,55	4,52	15,0	15,0
Medium voltage (E = 35 000KWh/month)	250kW	7,25	11,83	2,35	3,2	2,81	4,74	9,8	13,17

Data extracted from UPDEA data, 2009[28]

From an energy policy perspective, price differences between production cost and energy tariffs have to be taken into account when deciding on affordable technology. It is the all-inclusive production cost and the consequent market price that should be the basis for decision. In South Africa specifically, the unit cost of solar energy relative to other renewable energy sources is rather high. Under the Renewable Energy Feed-in Tariffs (REFIT) programme, which is aimed at encouraging private producers to supply renewable energy to the national grid, PV solar energy was considered the most expensive. This was reflected by the highest unit price that was to be paid to independent producers when they sold energy onto the national grid under the first REFIT programme (Table 3). This was again confirmed by the new prices under the revised REFIT (Table 4).

Table 3: Renewable energy prices under the first REFIT programme

Renewable energy sources	Unit	REFIT price
Large scale grid connected PV systems	R/KWh	3,94
Concentrated solar power (CSP) trough (no storage)	R/KWh	3,14
Concentrated solar power (CSP) tower (6hrs storage)	R/KWh	2,31
Concentrated solar (CSP) trough (6hrs storage)	R/KWh	2,1
On-shore wind	R/KWh	1,25
Biomass solid	R/KWh	1,18
Biogas	R/KWh	0,96
Small hydro	R/KWh	0,94
Landfill gas	R/KWh	0,9

Source: DoE South Africa

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Table 4: Renewable energy prices under the revised South African REFIT Programme compared with Germany's current REFIT prices.

Technology	RSA REFIT November 2011	Change previous RFIT Cap	German REFIT for 2011/2012	RSA REFIT comparison to Germany
Concentrated solar	2,85	-9,24%	Not supported	Not applicable
On shore wind	1,15	-8,00%	0,91	26,37%
PV solar	2,85	-27,66%	1,8	58,33%
Biomass	1,07	-9,32%	0,82	30,49%
Bio gas	0,8	-16,67%	0,71	12,68%
Land fill gas	0,6	-33,33%	0,51	17,65%
Small Hydro	1,03	9,57%	1,26	-18,25%

Source: German Renewable Energy Act, 2009 to 2011

Comparing Table 3 with Table 4, which shows German REFIT prices, it becomes obvious that while in Germany prices have declined substantially, in South Africa prices are still high. This will have a long-term effect on the affordability of electricity in South Africa.

What is clear is that the unit production cost of energy using technologies like PVs in South Africa is relatively high compared with international unit energy production costs. The production cost differential at international levels points to the fact that there are factors other than the actual cost of renewable energy technology that impact on the unit cost of renewable energy. Of major concern is that these high costs are likely to bias policy makers in positioning solar energy use, the consequence of which could be putting South Africa on a mistaken and expensive energy production mix.

What Could be the Causes of the High Cost of Renewable Energy?

The market for renewable energy technologies is relatively young. Its lack of maturity leads to high volatility and thus poses a great risk for investment. If technologies are politically supported by schemes such as feed-in tariffs, as is the case with South Africa, it is uncertain whether a change of legislation will alter the economics of the given project. For example, alteration of the Spanish feed-in tariffs in 2008 led to a significant fall in the growth rate of the solar technology market.[29]

Financial institutions have a tendency to factor all risks associated with technology and programmes into their credit conditions and this raises the cost of lending. This entails among others the competitive cost of renewable energy technologies, which thus becomes a barrier, not only to all developing countries but to South Africa, specifically (Figure 2).

What can be said with certainty is that instruments like REFIT have a direct influence on costs. This is the policy that has been introduced

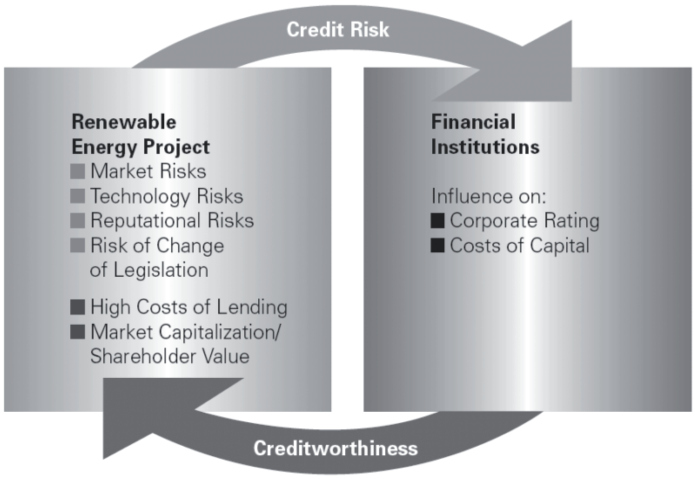

Figure 2: Risk and creditworthy cycle applicable to renewable energy investment [30]

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by South Africa. Arguably the effects of tariffs on consumer price level of electricity are indirect and difficult to estimate. They depend on the tariff level built on renewable energy investment promotion. The higher the amount of renewable energy electricity fed into the grid, the more expensive the tariff system and the stronger the impact on electricity prices paid by the consumer.

Other external factors that have a direct influence on the cost include climate change, air pollution and health issues.[31] While instruments such as carbon tax have some desirable positive effects on emissions, companies such as Eskom are among many de facto monopolies that allow the passing on of full costs to consumers. If this is allowed to happen under a new dispensation of renewable energy, it is likely to reduce incentives and interest to migrate to renewable energy.

Lastly, the cost of technology deployment and maintenance needs to be taken into consideration. Taking solar energy using PV as an example, differences in the amount of solar radiation and plant investment costs determine the production costs of PV based renewable energy. Such costs may differ from country to country. It is notable, however, that solar energy technology in general has improved to the extent that it is now economically feasible to use thermal solar energy for both heating and cooling purposes,· and the prices are expected to come closer to those of fossil fuels (Figure 2). The German model has given evidence that high REFITs have a potential of encouraging technical development.

Socio-economic Benefits of Affordable Renewable Energy

Affordable renewable energy is likely to lower the cost of energy in general and increase its use. The World Energy Assessment (WEA) has found that, if applied in a modern way, renewable energy sources can positively contribute to a country's environmental, social and economic development. At a macro level, the increase in overall energy supply will have a positive spin-off on the economy through job creation. Renewable energy sources, in particular solar energy, allow a decentralised energy supply, thus minimising distribution costs of bringing energy to remote areas (such as rural areas) that are vulnerable to poverty. What this means is that the increased use of renewable energy in South Africa would: a) increase energy supply in the country; b) stabilise national energy supply; and c) be likely to improve the welfare of the country's population via enabled jobs from increased economic activities.

Conclusion

At this point of deciding the route that South Africa should follow in diversifying its energy sources, the country should consider the unit production cost of renewable energy as an important factor in determining the prioritisation of renewable energy in national energy policy and direction. In this regard, prices attached to

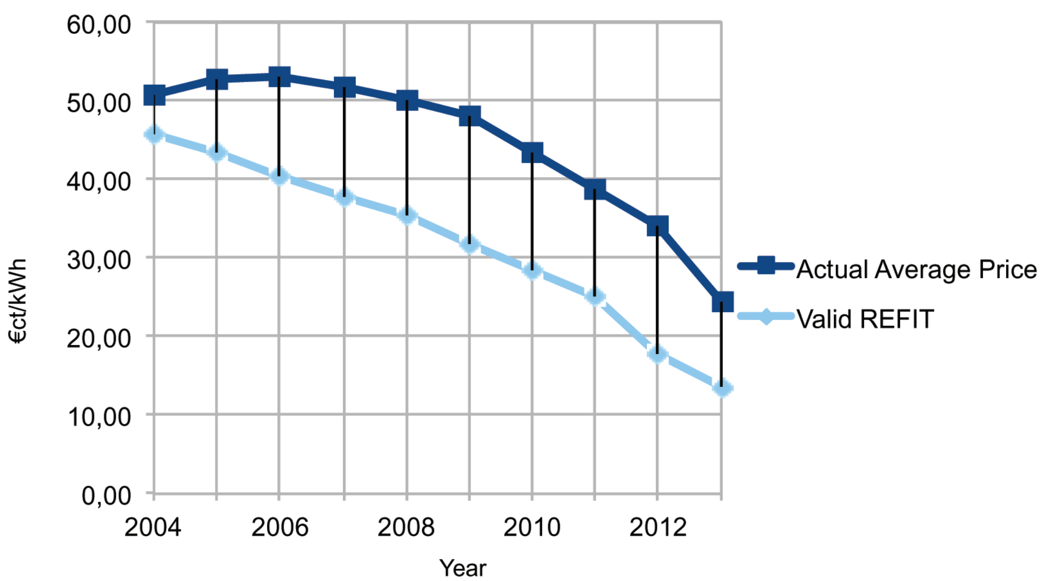

Figure 3: Long-term trend of PV REFIT as seen in Germany's system[32]

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renewable energies, in particular solar energy, are too high and unrealistic in developing countries like South Africa compared with international trends. Available data indicate that the cost of PV technologies in South Africa is overestimated, even after taking into account other secondary cost factors. The present approach has the potential to put the country on a sub-optimal and expensive energy mix path. It is recommended therefore that solar energy costs and prices for South Africa be reassessed, and the positioning of solar energy in the country's long-term energy mix strategy be reconsidered against the confirmed renewable energy unit costs and its consequent affordability.

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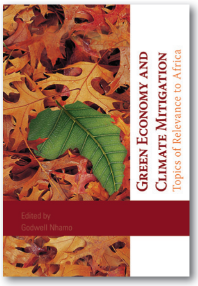

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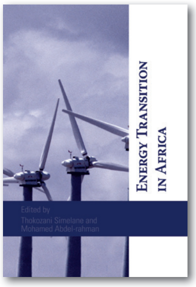

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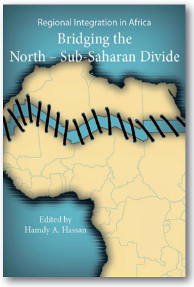

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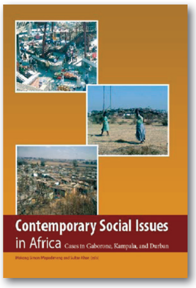

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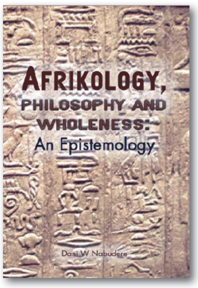

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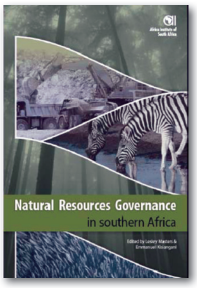

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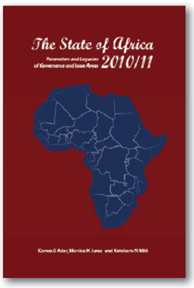

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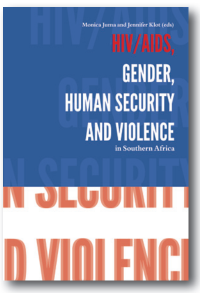

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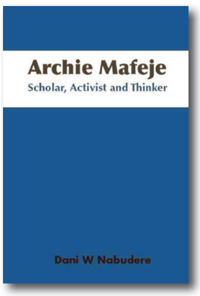

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