

## Hydropower generation in a climate-constrained world:

### Lessons for South Africa's alternative energy supply

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Worldwide, there is a growing trend to plan hydropower projects that meet both local demand and the export market. Technologies with a lower environmental impact such as run-of-river, small hydro and low-head turbines are proving to be extremely popular as they both appease critics of hydro-electric power and meet energy needs. Considering the huge initial capital investment and socio-environmental implications of large-scale hydropower schemes, this brief argues that small hydropower schemes which are reliable and of low cost can play a critical role in meeting energy demands. The brief interrogates South Africa's position on small-scale hydropower projects. Some of the questions the brief grapples with are: To what extent do these small hydropower systems contribute to meeting South Africa's energy demand? What lessons can South Africa draw from other African countries' success stories? In today's climate-constrained world, can hydropower survive as an industry? The brief argues that there is a need for more investment in small-scale hydropower projects, given South Africa's enormous potential. The small hydropower schemes will not only provide employment opportunities, but also contribute towards access to affordable and reliable energy services, a prerequisite for economic development. The brief also recommends decentralisation of renewable energy as a plausible strategy, allowing entrepreneurs to invest in small hydropower schemes as an alternative energy supply in remote and rural areas.

**Key Words:** South Africa, Small Hydropower Systems, Climate Change, Small-Medium Enterprises

#### Introduction

Worldwide there is a growing trend for expansion in small hydropower schemes that meet the

demands of both domestic and external markets. Small hydropower technologies, which are reliable yet have a lower environmental impact and low costs, are proving to be extremely popular to both

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appease critics of hydropower and meet energy demands.<sup>1</sup> Given its long history, hydropower is the most mature of the renewable energy industries. In Africa it contributes ninety per cent of renewable energy generation.<sup>2</sup> A forward-looking energy strategy calls for involvement in climate-related initiatives. Expansion of small hydropower is one way of fulfilling this initiative. The hydropower sector is evolving booming technologies for small-scale hydropower plants. These schemes can be either stand-alone or hybrid systems with other energy sources, and can play a key role in meeting the exponential demand for energy.<sup>3</sup> Small hydroelectricity growth is desirable to fill the gap of decentralised production for needs such as private and municipal energy production, supplying to the national grid of electricity delivery or, alternatively, furnishing energy to the industry and isolated zones.

In the United States (US), the regulator of hydro projects, the Federal Energy Regulatory Commission (FERC) has signed memoranda of understandings with five states to streamline the licensing of small projects.<sup>4</sup> Grid-connected hydroelectric installed capacity is projected to increase from 22 Gigawatts (GW) in 2007 to 42 GW in 2035, at an average annual rate of 2,4 per cent.<sup>5</sup> This represents a phase of resurgence in the hydropower industry.

Hydropower is arguably among the industries most vulnerable to changes in global and regional climate. The negative impacts of climate change such as drought, floods, and higher temperatures point to a bleak future for hydroelectric power generation.<sup>6</sup> Nevertheless, international climate negotiations highlight the need for a fundamental shift in energy production globally towards a system of clean, climate-friendly energy choices. For developing countries like South Africa, these clean choices must go hand in hand with development goals and reducing 'energy poverty'.<sup>7</sup> Certainly hydropower energy is among these clean energy technologies which can reduce the very effects of climate change. Fortunately, the costs of clean energy are increasingly competitive, and decentralised renewable energy is often the most cost-effective way of providing energy for the world's energy-poor.<sup>8</sup>

### **Hydropower as an alternative energy system**

This section highlights the evolving hydropower generation technologies and the role they play

in ensuring energy security. The section briefly describes Africa's riches in hydropower potential. It culminates by illuminating the role that decentralisation can play through small/medium enterprises in promoting small hydro schemes as a promising alternative energy source.

### **Hydropower technologies**

The basic conversion technology for hydropower energy involves the building of big dams across flowing waters and creating reservoirs.<sup>9</sup> 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.<sup>10 11</sup> This electricity is then connected to a grid and distributed. 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.<sup>12</sup> The amount of electricity generated from a system depends not only on its capacity (size of turbine and generator) but also on the amount of water available.<sup>13</sup> In times of drought, water for hydroelectricity systems is limited and this reduces their electricity output.<sup>14</sup>

Alternative technologies for hydropower include pumped water storage,<sup>15 16</sup> river current energy conversion systems (RCECS)<sup>17</sup> and the technologies for micro hydropower stations.<sup>18</sup> As for the small hydropower plants, there is no clear consensus regarding the classification of scales of these schemes. This brief adopted the definition of the World Commission on Dams (WCD) of 10 megawatt (MW) installed capacity as large, while a mini plant is generally 1 MW and a micro plant is generally less than 100 kilowatts (KW).

### **Role of hydropower in ensuring energy security**

Energy derived from moving water is environmentally benign compared with that obtained from burning fossil fuels.<sup>19</sup> Hydro energy does not lead to the emission of greenhouse gases (GHGs) and therefore does not contribute significantly to global warming (See Figure 1). It was previously held that dam reservoirs do not emit any GHGs. However, this view is changing due to the Clean Development Mechanism (CDM) studies that were undertaken. An analysis of 85 existing hydropower reservoirs found that they collectively emit one-sixth of the GHG emissions as currently assumed and 'are not major contributors to the greenhouse gas problem.'<sup>20</sup>

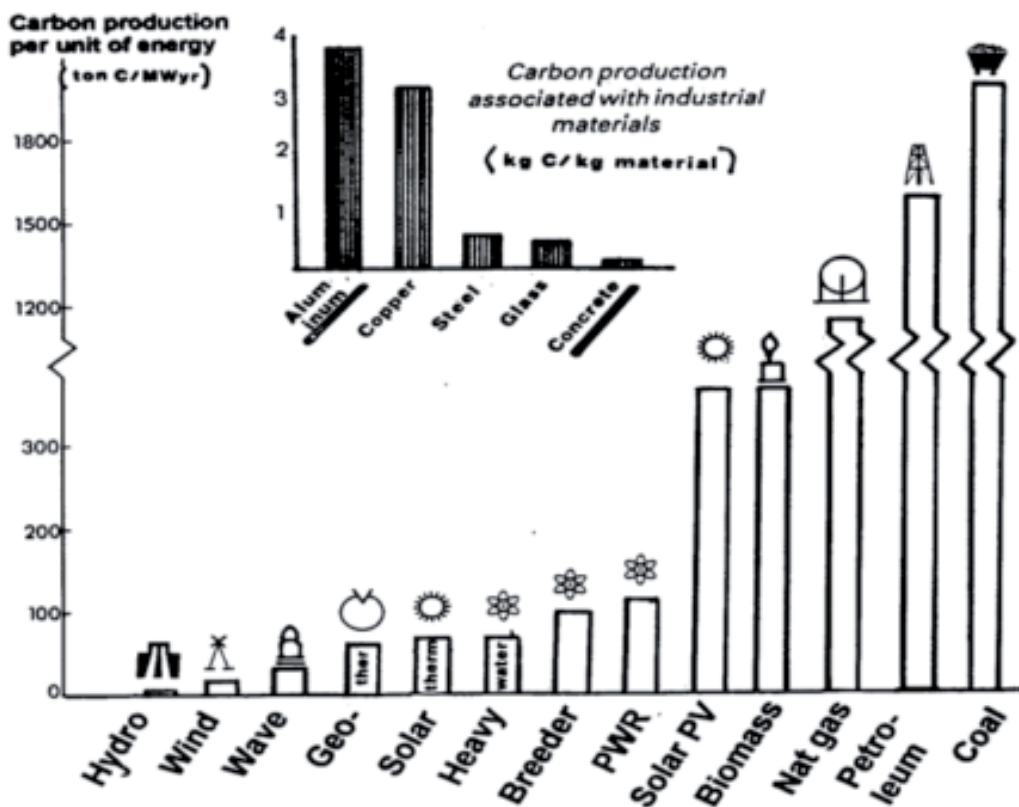


Figure 1 Carbon production from various energy systems<sup>23</sup>

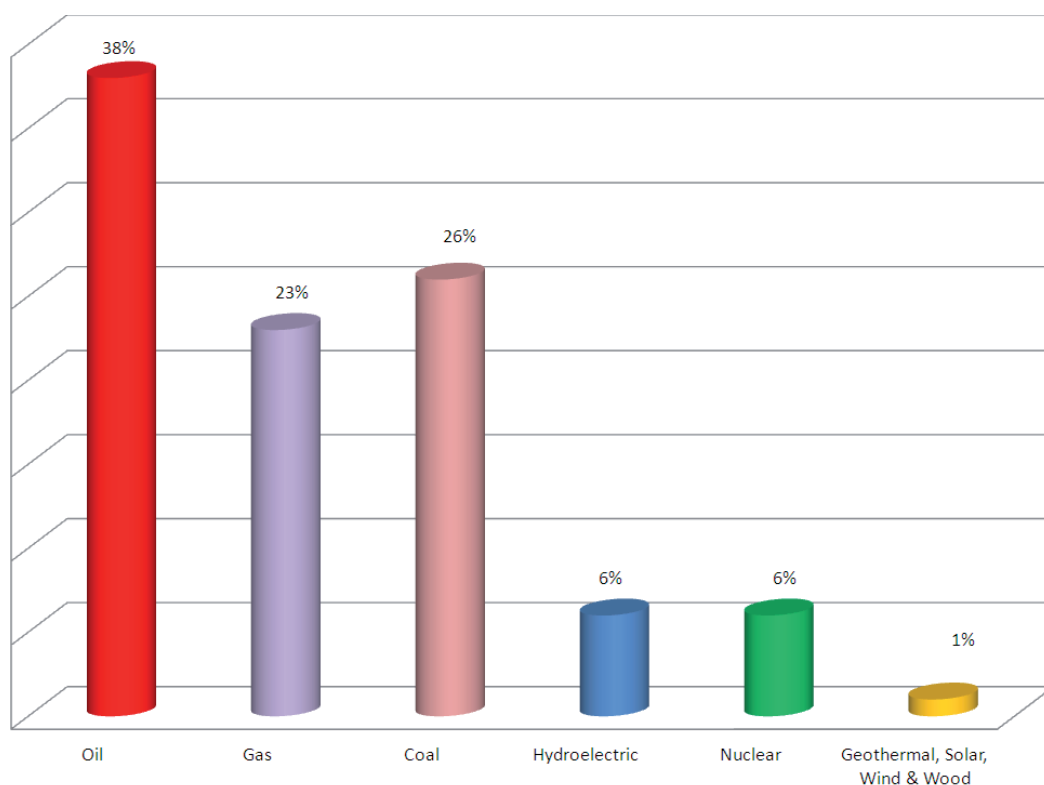
Under the Kyoto Protocol, industrialised nations are committed to reducing their GHG emissions, including carbon dioxide and methane.<sup>21</sup> One mechanism for achieving emission reductions is the CDM approach, by which countries can reduce emissions by purchasing emission credits from other countries that invest in projects and programmes that avoid GHG emissions, thus producing a net global reduction in emissions<sup>22</sup>.

International Energy Outlook 2003 predicted that the consumption of renewable energy worldwide would grow by 56 per cent, from 32 quadrillion Btu (British thermal units) in 2001 to 50 quadrillion Btu in 2025.<sup>24</sup> Much of the projected growth in renewable energy generation is expected to result from the completion of large hydroelectric facilities in developing countries. These will be located in developing Asia in particular, where the need to expand electricity production often outweighs concerns about environmental impacts and the relocation of populations to make way for large dams and reservoirs.<sup>25</sup>

### Hydropower in Africa

The African continent has enormous exploitable hydropower potential, and yet the lowest hydropower utilisation rates.<sup>26</sup> In terms of energy generation trends, hydroelectricity is on a mere

6 per cent compared with coal and oil, which are above 25 per cent, as shown in Figure 2.<sup>27</sup> Recent studies have shown that some of the challenges in the generation of power from hydro include socio-economic concerns, and more recently vulnerability due to changing climate and often the application of environmental impact assessments (EIAs). EIAs are argued to derail or stop many initiatives. Moreover, issues around access and servitudes which relate to ownership of the vital resources, the legislative environment which calls for water-use permits, funding constraints and power-purchase agreements often crop up.<sup>28</sup> This may be explained by theories which include structural inequality discourse, which occurs when there is unequal access to, and control over, water resources,<sup>29</sup> a concept referred to as resource capture and ecological marginalisation.<sup>30</sup> Ohlsson and Lundqvist<sup>31</sup> developed a component of this discourse as 'induced scarcity', with a specific category that looks at the depletion of the resource base as a result of pollution. Closely related to this is the 'environmental scarcity' discourse,<sup>32</sup> which has a strong environmental dimension to it, in which depletion and pollution of the resource reduce the total volume available. These challenges certainly need to be faced if the potential of hydropower is to be fully realised. In addition



**Figure 2** Energy generation by types of energy source<sup>33</sup>

the decentralisation of renewable energy can aid in promoting small hydropower schemes in Africa.

### How decentralisation can help promote small hydropower generation

Decentralised energy services remain at the forefront of the fight against poverty. Small- and medium-sized enterprises (SMEs) are driving this effort to provide an alternative to state-owned utilities and other large energy providers in poor and developing countries.<sup>34</sup> The SME concept favours the growth of small hydropower schemes. Nonetheless price and cost pressures are of increasing significance for SMEs' survival.<sup>35</sup> Previously, wide-ranging governmental programmes and other donors' interventions have been targeting SMEs to address technology upgrading and adoption of clean production practices, but there is a need to intensify this in energy production, supply and management.<sup>36</sup> SMEs, especially those for whom energy costs represent a large portion of total production costs, can reap especially high direct economic benefits from improved efficiency of energy usage and reduction of energy wastage, yet numerous barriers and market failures have prevented widespread adoption of energy management best practices.<sup>37</sup> Many SMEs in the Southern African region are energy intensive, employing inefficient and obsolete technologies and operational

modalities that endanger their competitiveness and future growth. Investment in cost-effective Energy Efficiency (EE) measures would therefore improve their productivity and bottom-line profits.<sup>38</sup> Despite the financial attractiveness of these types of investment, and several efforts to support the development of EE investment projects and the deployment of technical assistance to deliver EE services, only a small number of projects have actually been implemented in the SME sector.<sup>39</sup> This brief argues that promotion of SMEs in the energy sector can certainly provide a platform conducive to sustainable small-scale hydropower generation.

### Tapping experiences of African countries.

This part provides some success stories of hydropower generation in Africa, highlighting striking examples in Kenya, Rwanda and Zambia. The section briefly touches on the role played by investment banks, multilateral corporations, and Chinese banks in promoting small hydropower projects.

### Small hydropower systems in Africa

Small hydropower systems (SHPs) of less than 10 MW have proved to be an attractive

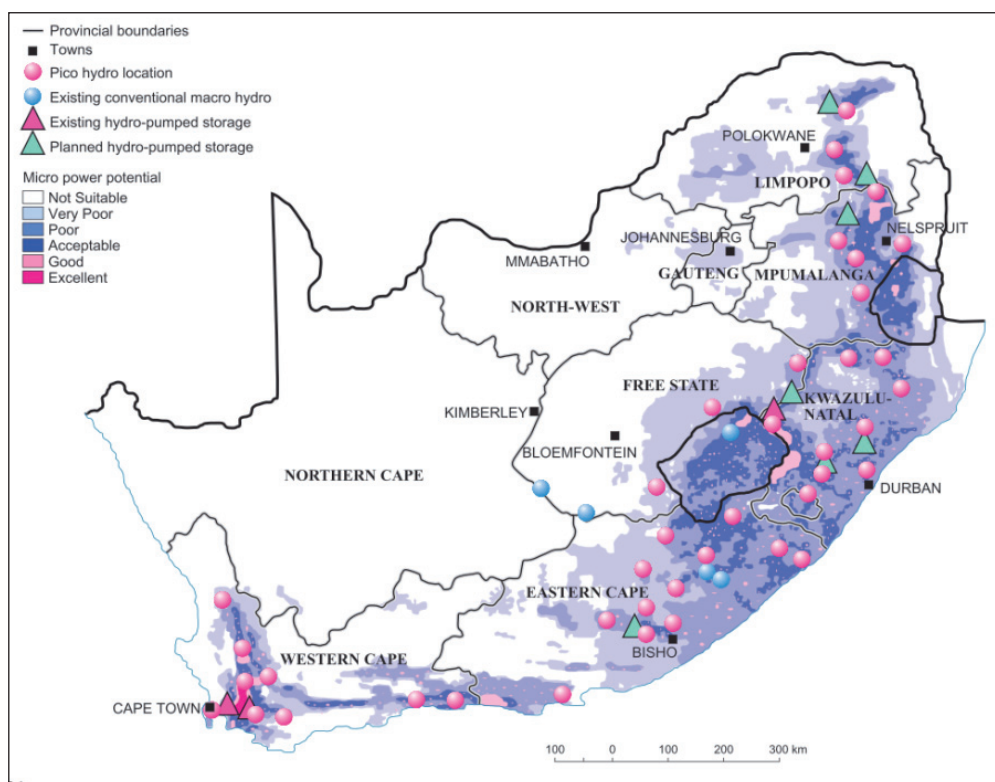
resource, especially in the most remote parts of Africa, as they catalyse developments in such communities.<sup>40</sup> In environmental terms, SHPs are more sustainable than large-scale systems. The eastern and southern regions in Africa have numerous pico, micro, mini and small hydropower sites which can be developed to supply isolated areas or feed into the national grid.<sup>41</sup> Development of small hydropower plants in these regions should be given high priority due to their linkages to rural development. Africa has many rivers and tributaries that would be suitable for micro-hydropower projects.

There are already some successful micro-hydropower projects in Africa. These exist in Zimbabwe, Mozambique, Rwanda and Kenya. The Tunga-kabri micro-hydropower project in Kenya is one such project. The Mbuiru village in Kenya, is a typical example where the people are generally poor farmers without access to electricity. Most families spend at least a third of their income on kerosene for light and cooking, or they resort to chopping trees for firewood.<sup>42</sup> This micro-hydropower project was organised by Practical Action East Africa and the Kenyan Ministry of Energy. Villagers worked once a week or more for two years to build it, and now it generates about 18 KW of electrical energy, enough to benefit 200 homes.<sup>45</sup>

Another striking example is the new mini-hydropower station built at Kavumu in Ngororero District (Rwanda), which has boosted business in the area; the local leaders had this to say:

Doing business is more profitable in the area and these activities have also increased the sector's tax revenue target from Rwf 18 million to Rwf 19 million, The power plant serves schools, health centre, bars, hair salons, shops and 45 homes in the area, with many traders operating beyond 10 o'clock, unlike in the past when we didn't have power.<sup>44</sup>

In Zambia about 10 billion kwacha will be spent on the privately-owned Mporokoso mini-hydropower project to increase power output fivefold to service Mporokoso District and surrounding areas.<sup>45</sup> The Mporokoso mini-hydropower project witnessed a partnership between an investor from Serbia and Zambia Limited in raising the US\$2 million for the upgrading of the power generation from 200 KW to one MW.<sup>46</sup> Mporokoso District has a total requirement of 0,3 MW; hence the upgrade would be enough to supply the entire district and other surrounding areas.<sup>47</sup> Often a major setback to the successful implementation of hydropower projects is the cost<sup>48</sup> and poor access to finance.<sup>49</sup> Increased private-sector investments and support



**Figure 3** Potential for small-scale and micro hydropower plants in South Africa<sup>53</sup>

of independent power producers are the enabling environments required for small-scale hydropower generation in South Africa.

Domestic and international projects in Africa have witnessed overwhelming financial support from several Chinese banks. Often these projects use Chinese companies such as Sinohydro, which constructs hydro projects, and Dong fang, a manufacturer of hydro turbines. Collectively these companies hold 80 per cent of the total market share and are horizontally integrated across the sector.<sup>50</sup> A number of initiatives through United Nations (UN) agencies are ongoing to support large and small hydropower projects in Africa.<sup>51</sup>

### Small hydropower systems in South Africa

Small-scale hydropower has huge as yet untapped potential in most parts of the country and could make a significant contribution to South Africa's future energy needs. While there are limited sites that could be used for new large-scale hydroelectric schemes, there are many potential sites for small-scale and mini power stations<sup>52</sup> (See Figure 3). Figure 3 shows the vast potential of small-scale and micro scale hydropower plants in the country.

Jonger Klunne has noted that previously, with the expansion of the national electricity grid and the cheap coal-generated power supplied through this grid, a large number of hydropower schemes were decommissioned.<sup>54</sup> Notably, the first provision of electricity to cities like Cape Town and Pretoria was based on small-scale hydropower. Many small towns also used small hydropower

plants. A striking example was the 450 KW turbine Sabie Gorge hydro station, which was commissioned in 1928 to serve the then Eastern Transvaal, but was closed in 1964 when Eskom connected the area to the national grid.<sup>55</sup> Given the need for fast economic development, such plants need to be resuscitated if South Africa is to migrate successfully to a low-carbon and green economy that is supported by renewable energy.

In the year 2011, the South African Government adopted the Integrated Resource Plan (IRP) as a blueprint for the energy mix desired for the power sector in the period up to 2030. The IRP prescribed the introduction of certain technologies that would change South Africa's power generation paradigm for ever.<sup>56</sup> In terms of the IRP, renewable energy technologies, including wind, solar, biomass, biogas and hydro were to be introduced as cleaner supply-side options, as well as energy efficiency options including solar water heating, while the industrial and commercial energy efficiency would complement these technologies on the demand side.<sup>57</sup> The government set a target of about 3 725 MW to be generated from renewable resources. As a follow-up, South Africa's Department of Energy (DOE) put out a request for proposals on new generation, asking independent power producers to submit their proposals for the first window, which closed in November 2011.<sup>58</sup> During the sidelines of the UN Climate Change Conference (COP 17) event, the DOE made an announcement of the preferred bidders in respect of the first window. The evaluation resulted in 28 bids with a total of 1 415 MW being selected as preferred bidders, while another 2 209 MW is available for the next four windows. A glance at the preferred bidders shows that they all fall within the solar and wind

	Allocation to Preferred Bidders: Window 1		Allocation per Determination Still Available		MW allocation per Determination
	MW	Percentage	MW	Percentage	
Solar PV	631.53	43.6%	818.47	56.4%	1450.00
Solar CSP	150.00	75.0%	50.00	25.0%	200.00
Wind	633.99	34.3%	1216.01	65.7%	1850.00
Biomass	0.00	0.0%	12.50	100.00%	12.50
Biogas	0.00	0.0%	12.50	100.00%	12.50
Landfill Gas	0.00	0.0%	25.50	100.00%	25.00
Small Hydro	0.00	0.0%	75.00	100.00%	75.00
<b>Total MW</b>	<b>1415.52</b>	<b>39.0%</b>	<b>2209.48</b>	<b>61.00%</b>	<b>3625.00</b>

Figure 4 Allocation to preferred bidders, Window 1<sup>60</sup>

technologies domain.<sup>59</sup> This brief therefore seeks to encourage independent power producers in other renewable technologies, in particular small hydro, to be ready for the forthcoming remaining bids and for the government to ensure that a renewable energy mix is there to meet the energy demands.

### What South African policy makers need to be aware of

**Regulatory Framework:** If Africa continues to grow at its present pace and even intensifies that growth, and uses only carbon-emitting forms of energy, 'it will exponentially change the picture on climate change and make it much worse.'<sup>61</sup> It is therefore imperative that the regulatory framework promotes green, clean energy technologies. The regulatory framework should support institutional investors and convince them that it is safe to put their money into these cutting-edge technologies. While South Africa has created an enabling environment through the grid feed-in tariff for small hydro of ZAR 0,94 per kWh,<sup>62</sup> this needs to include not only the grid-connected systems but also the rural off-grid systems.<sup>63</sup> The South African Government's putting the IRP into action is the tonic required for optimising the use of renewable energy potential in the country. Nonetheless, the bidding process should ensure that a hybrid system composed of various renewable energy sources, including small hydropower, is established to meet the energy supply gap.

- **Cost Implications:** The main barrier to getting hydropower projects off the ground is the cost. While the cost per unit of electricity will depend on the site rather than the size of the dam and the power station, less initial investment is required for small systems.<sup>64</sup> Recent research has shown that there is considerable scope for development and optimisation of technology to reduce the unit costs of electricity from small systems. Other infrastructure development costs can sometime be ameliorated on micro schemes. Seasonal dam storage costs can be avoided if the required flow is less than the low-river flow, hence South Africa should capitalise on the micro potential hydropower sites in order to meet the country's energy demand.
- **Finance:** The advantage of micro plants is manifested particularly in the saving on a transmission network for remote users, as typical micro hydropower plants are designed to serve a local community; thus high-voltage lines and associated energy losses are avoided.<sup>66</sup>

- **Promotion of SMEs:** Research has shown that electricity services monopolised by large state-owned or privately owned utilities fail to meet the needs of most rural and peri-urban populations. Eskom in South Africa has recently conveyed a media alert that the year 2012 might experience load shedding. SMEs allow entrepreneurs to provide alternative energy supply in remote and rural areas, while also providing jobs, lowering energy costs, and reducing carbon and other greenhouse gas emissions. Perhaps if the energy sector were decentralised, this would promote more investors in small hydropower schemes, which could help ameliorate the energy demand for the country. SMEs managed by local entrepreneurs are often more flexible in the use of technology and use of locally available resources, and understand better the needs of users. This is in line with proper climate adaptation mechanisms in ensuring the sustainable power generation critical for energy security and development.
- **Technology:** Often SMEs lack the technical resources/capacity necessary to perform sound analysis of what can be achieved at the enterprise level to reduce energy costs permanently. Investment opportunities developed by fast-growing economies seem to play a more important role in facilitating international technology transfer through the CDM.

### Conclusion

Small hydropower schemes could be the answer to many complex problems of energy supply in South Africa. Small hydropower, with its multiple advantages as a low-cost and reliable form of energy, is in the forefront of many countries' efforts to achieve energy self-sufficiency. Evidence from the selected African countries and the US has proved that small hydropower schemes can be a good capital investment. Despite the threat of climate change impacts, South Africa has enormous potential for small-scale hydropower generation, which could help reduce the country's energy demand. Nonetheless, at present there are only a few small-scale hydropower stations in operation in South Africa. The government's initiatives such as 'Working for Energy', IRP, and the White Paper on Renewable Energy require frantic efforts to ensure successful implementation of hydropower schemes. In a nutshell, the position of this brief is that small hydro is one of the best decentralised options to supply energy and

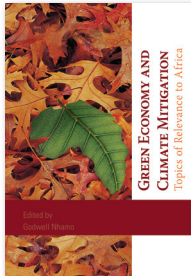
alleviate poverty. The development agencies, through international cooperation, should give much more attention to this technology, while the government should provide an enabling environment to enhance the dissemination and use of hydro energy resources in South Africa.

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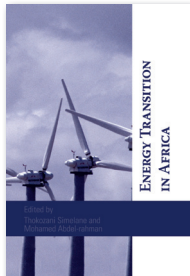
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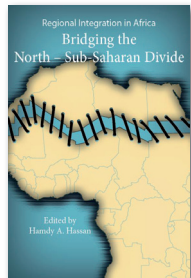
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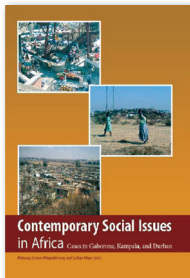
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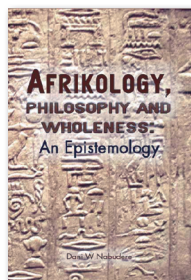
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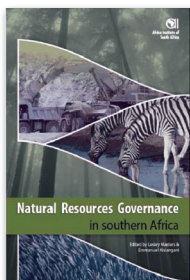
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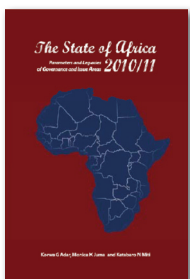
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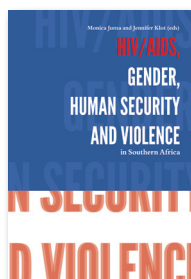
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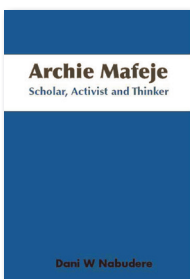
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