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Optimising trans-national power generation and transmission investments: a Southern African example

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Abstract

Increased integration and co-operation within the Southern African power sector has opened up significant opportunities for reducing the economic and environmental costs of meeting increasing electricity demand in Southern Africa. This paper applies a linear programming model to investigate the economic and environmental benefits of regional integrated planning for electricity, and the impact of including environmental costs in the decision-making process. We find that, from a financial perspective, optimising generation and transmission investments in the region would result in savings of $2–4 billion over 20 years, or 5% of total system costs. Introducing a tax based on the external damage costs of carbon dioxide as part of the decision-making process would result in moderate increases in financial costs (15–20%), but would reduce regional carbon emissions by up to 55% at a mitigation cost of $11 per tonne of carbon dioxide. This raises the possibility of financing regional power projects with Clean Development Mechanism funding, which we explore with an example.

Keywords: Southern Africa; Integrated resource planning; Clean development mechanism

1. Introduction

The end of civil wars in Mozambique and Angola and of apartheid in South Africa opened up the possibility for greater electricity co-operation in Southern Africa. The enlargement of the Southern African Development Community (SADC) to include South Africa in 1994 increased the opportunities for energy resources from throughout the region to be developed to the benefit of all countries. The scope for such regional development is vast, obvious examples being the Pande and Kudu gas fields in Mozambique and Namibia, respectively, the hydroelectric potential of Mozambique, Zambia, Zimbabwe and the Democratic Republic of Congo (DRC), and the oil and hydroelectric potential of Angola. For the electricity sector, particularly in South Africa, there is an opportunity to source electricity from less expensive and more environmentally benign sources instead of utilising local generation. Further benefits are a reduction in total reserve capacity required for supply security because of different peak demand times in different countries.

Numerous studies have shown that greater regional trading and cooperation within SADC on power development could substantially reduce investment and operational costs, as well as carbon emissions (Rowlands, 1998; SADC, 1993; Sparrow et al., 1999). The need for a regional power trading pool, however, grew out of the power utilities' recognition of the vulnerability of individual countries if each continued to pursue a policy of self-sufficiency, rather than out of a desire to minimise the social or financial costs of the region's power. The 1995 SADC Protocol on Energy, 1996 Energy Co-operation Strategy, and Energy Action Plan all place a high priority on regional co-operation in

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energy investment and trade, particularly in electricity. The creation of the Southern African Power Pool (SAPP) in 1995 from the region's national utilities marked the most important step toward realising the benefits of regional electricity planning (SAPP, 1997). The SAPP Planning Sub-committee has completed a Pool Plan for future co-ordinated expansion; while the Operations Sub-committee is managing the Co-ordination Centre in Harare that administers short term trades in surplus electricity and has finalised a 'wheeling formula' that will standardise the charges for electricity trading across third parties (Mokgatle and Pabot, 2002; SAPP, 1999).

Despite this progress toward regional integration, one of the major challenges is that, in view of the broad range of alternative new generation projects and huge geographical distances in the SADC region, long-term system expansion planning has to be based on a suitable planning methodology, which includes generation *and* transmission investments. In addition, other non-technical aspects like national security requirements and external costs of electricity production also must be integrated into the planning approach. This paper describes the application of a planning approach based on mixed integer linear programming, called the regional integrated electricity planning (RIEP) model, which integrates all these different aspects of regional electricity planning to quantify the benefits of regional integrated planning for electricity. Section 2 introduces the important concepts behind regional integrate planning. Section 3 lays out the model structure and functionality. Section 4 presents the results of applying the model to current policy questions of regional integration, self-sufficiency requirements, including external costs into the decision making process, and using regional projects as potential Clean Development Mechanism projects under the Kyoto Protocol to the United Nations Framework Convention on Climate Change (UNFCCC). Conclusions follow in Section 5.

2. Regional integrated resource planning as a decision making tool

2.1. Integrated resource planning and its relevance in a trans-national context

Integrated resource planning (IRP) is an electricity planning methodology that integrates supply- and demand-side options for providing energy services at a cost that appropriately balances the interests of all stakeholders (Swisher et al., 1997). In contrast to traditional supply-planning that took demand growth as a given, IRP incorporates the potential for reducing or shaping electricity demand—that is, demand-side management (DSM)—and the social and environmental aspects of electricity production. With the liberalisation of energy markets, IRP is no longer a priority for most utilities in the United States, where it had formerly been the strongest (Bakken and Lucas, 1996). But the basic concept of IRP—to optimise the electricity system from a social perspective and to provide energy services at least social costs—remains valid. From a policy perspective, government and utilities still want to achieve the best outcome for society through integrating demand and supply options for energy services. In developing regions such as Southern Africa, this broader concept of IRP is an appropriate tool to guide political and financial decisions in the electricity sector. Rapidly growing electricity demand and a great potential for efficiency improvements and DSM mean that a rational basis for decision-making can facilitate economic development in these and other developing countries.

IRP was generally implemented on a national or utility level, but there are several reasons for expanding the fundamentals of IRP to a trans-national or regional level:

- taking advantage of different resources in different parts of the region;
- taking advantage of different peak demand times in different parts of the region;
- sharing generation reserve margins among several utilities or countries;
- increasing supply-security;
- decreasing electricity prices; and
- reducing environmental degradation.

For planning in Southern Africa, the key question is where and when to build a new large-scale power station or high voltage transmission lines, considering an integrated generation expansion plan and the associated new transmission lines. Regional planning is not an attempt to replace national or local electricity planning. The planning process concentrates on elements of the system for which rational decisions are best made on a regional level and it builds upon national and local planning (Graeber and Spalding-Fecher, 2000). To implement a regional, social planning approach within the SADC, appropriate institutional and regulatory frameworks would have to be developed, which is already starting with the regional electricity regulators association.

2.2. Multi-criteria decision-making and regional IRP modelling

The use of multi-criteria analysis (also known as multi-attribute analysis) for decision-making is one way in which analysts are able to address the limitations of appraising projects exclusively on the basis of cost criteria (Martinez-Aliers et al., 1999). Multi-criteria