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GENERATING ELECTRICITY IN A DRY COUNTRY: GOVERNANCE OF WATER AND ENERGY IN SOUTH AFRICA

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His recent consulting assignments include a report for Business Leadership South Africa in mid-2009 entitled *Does South Africa face a water crisis?*, which formed the basis of the ILAR study.

He has published widely, the best known being the 1985 study *The Cambridge Phenomenon: The Growth of High-Technology Industry in a University Town* and the 2007 monograph *Breaking the Mould: The Role of Scenarios in Shaping South Africa's Future*.

GENERATING ELECTRICITY IN A DRY COUNTRY: GOVERNANCE OF WATER AND ENERGY IN SOUTH AFRICA

A report for the Laboratory on International Law and Regulation,

University of California at San Diego

By Nick Segal

INTRODUCTION

This is a story about how South Africa, historically and contemporarily, plans its electricity-supply system taking into account that it is ranked as one of the driest countries in the world.

The story is in two parts.

The **first** concerns the decision that led to the introduction by Eskom (the national utility responsible for generation and transmission of bulk electricity) of dry-cooling technology[1] for coal-fired power stations in the early 1970s. How and why did this decision come about; what was the subsequent record of adoption of the technology; who was involved in the early decisions; what was necessary for successful implementation? These and related questions are the subject of the first part.

With dry-cooling eventually established by the early 1980s as the appropriate technology wherever circumstances permitted, the **second** part deals with the energy/water nexus in the period from the early 1990s to the present. Here the situation is far more complicated. Because of population growth, increasing stresses in water and other natural resource sectors, the country's political transition – which formally commenced in 1990, with a new administration taking office in 1994[2] – and a growing awareness of the significance of ecological sustainability, decisions about investment in new generating capacity have now to accommodate many factors in addition to the availability of water. Water remains, however, a critical influence on the evolution of the country's energy infrastructure.

While the first part lends itself to reasonably definitive answers to the questions posed, the second necessarily requires a rather more discursive treatment. Indeed, because the story is still unfolding, because of the multiple dimensions involved and because of the limited scope of the study brief, what is presented here must be understood as a first and incomplete shot at describing an exceptionally complex governance process that *de facto* is evolving rather than being planned or even fully anticipated.

The report is based on consultations that commenced in the second half of 2010 and continued into April 2011, supplemented by review of the extensive government and academic literature available and of media coverage. The individuals consulted are listed in Annex B. I express my deep appreciation to them for the time and thought they generously gave to our discussions and, in some cases, follow-up enquiries.

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[1] Three types of cooling systems are used by Eskom at its coal-fired power stations. One is wet-cooling, the standard system used world-wide, which results in heavy water loss. Another is indirect dry-cooling, and the third is direct dry-cooling; both use considerably less water than wet-cooled technology (by a factor of 15 times or even more), although they suffer the disadvantages of higher capital costs and higher consumption of energy for their operation (and hence reduced input into the grid). Annex A describes these different technologies.

[2] This was the so-called Government of National Unity (GNU), led by the African National Congress (ANC) and including two minority parties. The GNU started breaking up in 1996 and ceased to exist in 1999. In effect the ANC has constituted **the** administration since 1994.

Against this background the structure of this report is as follows. The next section tells the story of the introduction of dry-cooling technology. This is followed by a review of developments in the water and electricity sectors over the past two decades (a little longer in the case of the latter). The third section discusses the current situation and outlook for the water/electricity nexus and the final section identifies and explores some of the issues in the evolving governance of the overall system.

Finally, for the reader who is unfamiliar with South Africa, the map below shows the nine provinces and the principal towns and cities as well as the neighboring countries.

The following map is of the provinces (Mpumalanga and Limpopo) where the bulk of the country's power stations are located. Johannesburg, in the province of Gauteng, is the economic heartland of the country, arising out of the discovery of huge deposits of gold in 1886.

The final map is of the location of Eskom's power stations, existing and under construction.

B INTRODUCTION OF DRY-COOLING TECHNOLOGY

There is evidence that as early as the 1930s Eskom, aware of the potential impact of limited water availability on expansion of electricity supply,[3] took an interest in a method for dry-cooling of power stations that had been developed in Germany and Hungary. It was not until the mid-1960s, however, that the chairman of Eskom publicly addressed the issue of scarce water resources – the trigger was a 1965 paper by the country's leading academic hydrologist/civil engineer on water and power in the country's then fast-expanding economy. Well aware that the electricity supply industry was a significant user of water,[4] he committed Eskom to exploring use of dry-cooling technology. The extension in 1970 of Grootvlei power station provided the opportunity to pilot the use of both direct and indirect dry-cooling technology.

Despite the success of this pilot,[5] the next seven power stations (amounting to some 20 000 MW of generating capacity, more than half the total system at the time) were all wet-cooled. This apparently perverse situation arose for three main reasons.

First, the location of these power stations was in the coalfields to the east of the Witwatersrand, an area that had abundant water resources at the time[6]. Thus, while water was increasingly scarce on the Witwatersrand (before construction of the Lesotho Highlands scheme augmented the Vaal River system), the Department of Water Affairs (DWA) was "generous" in its allocation of water to Eskom.[7]

Second, the price of water was low because the DWA was unwilling to include in the price the full costs of supply (let alone any provision for economic value).[8] This was despite arguments made by Eskom engineers themselves for increases in water charges.

Third, because of the lower costs of wet-cooling compared with dry-cooling, it was cheaper for Eskom to install the former, and the prevailing thinking of Eskom's top management at the time was

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[3] It is important to appreciate that it is the **availability and the security of supply,** rather than its cost, that are critical to a power utility – the cost per kwh generated is typically trivially small.

[4] At present Eskom and Sasol (the state-founded but now private sector oil-from-coal producer) are the country's single largest consumers of water, accounting for just over two percent each of total use; the agricultural sector as a whole accounts for a little over 60%.

[5] The van Eck power station in Windhoek (in what is now Namibia) also provided Eskom with operating experience of dry-cooling.

[6] In order to ensure security of water for these stations, Eskom had persuaded the Department of Water Affairs to build two large dams, while Eskom itself built the pipelines to its power stations.

[7] It would be wrong to suggest that the DWA was unaware of the implications for water consumption of the expansion of electricity supply. For instance, in 1966 the State President appointed a Commission of Enquiry into Water Matters (one of whose members was the Eskom chairman); reporting in 1970, the Commission included an important section on the need to reduce water use per kwh produced.

[8] This remains the case today.

strongly influenced by financial considerations. (There were, however, a number of senior staff, notably on the engineering side, who were unhappy about the long-term consequences of choosing a water-intensive technology.)

Indeed it was not until the 1980s, when it became apparent that there was insufficient assured water to allow wet-cooling of stations sited on the coalfields, that there emerged a commitment on the part of both Eskom and the DWA to the use of dry-cooling. In the period 1982-1994 the next three stations – known as Matimba (near Lephalale in the Waterberg in the north-west of the country), and Kendal and Majuba (in Mpumalanga to the east of Johannesburg), each consisting of six generating sets of 660 MW or greater– were all designed for dry-cooling.[9]

Eskom used the decade of experience gained at Grootvlei in particular to shape the design of the three stations and to optimise their performance. This practical experience was underpinned by the establishment of a long-term engineering research programme, led by Eskom but also involving the national Council for Scientific and Industrial Research and the Department of Mechanical Engineering at the University of Stellenbosch. The research, funded largely by the national Water Research Commission out of a levy paid by all bulk water consumers, had several key components, including analysis of heat transfer dynamics in relation to ambient weather conditions, examination of the mechanical performance of heat exchange and other plant and investigation of the re-use of effluent water in order to minimise water losses.

The combination of Eskom's extensive practical experience and the R&D programme initiated in the 1980s (but discontinued in the following decade) has made Eskom, at this juncture, probably the leading operator of dry-cooling systems in the world. (This position will not be maintained, however, as other countries, notably China, invest massively in the technology.)

Dry-cooling is now well established in South Africa. The two large coal-fired power stations currently under construction (Medupi in the Waterberg and Kusile in Mpumalanga) are both being designed for dry-cooling, and current energy planning is predicated on the use of this technology for any future coal-fired plant and, where feasible, for concentrating solar and nuclear power.[10] The National Water Resource Strategy of 2004 (currently being updated) is emphatic that dry-cooling is the

[9] There is an unfortunate wrinkle to this story. In the mid-1990s the last three sets at the third power station Majuba were re-designed for wet-cooling. While a number of factors were involved, there appears little doubt that the principal reason for this switch was that the water authorities needed additional revenues to be able to service the debt incurred for construction of the Lesotho Highlands scheme aimed at augmenting water supplies to the Witwatersrand. The decision – resulting from the personal intervention of the Minister of Water Affairs and evidently with the support of the chairman of Eskom, because wet-cooling was less costly than dry-cooling – was never publicly debated.

[10] There is an important qualification to these statements. This is that in conditions of very high ambient temperatures – which can occur at the likely location of a new coal-fired station, and also at the favoured site of a large-scale concentrating solar generator – dry-cooling loses efficiency, and so it may be necessary to use a hybrid wet/dry system.

required technology wherever feasible. The Department of Water Affairs' 2010 situation analysis of integrated water resource planning for the country reiterates this view, while drawing attention to the critical relationship between long-term energy and water planning.

It is clear from the above that Eskom has been a pioneer of dry-cooling for over four decades. Given the technology's much lower water consumption than that of conventional cooling, and given the widespread awareness of the country's dryness, it can now only be regretted that there was an extended period, roughly from 1970 to 1985, when all the new power stations were designed for wet-cooling. The problem was compounded by the decision in the mid-1990s to use wet-cooling for the final three generating sets at Majuba (see footnote 12).[11]

Further, while as noted above, it is currently axiomatic that dry-cooling will be the chosen technology wherever feasible, after the 1980s there was an extended period when the fact that water availability was a constraint on electricity generation was not on the national agenda. My interviews with very senior individuals involved in water and energy policy in the 1990s and early 2000s clearly indicate this. It is only in the past five years or so that water has been recognised as a critical constraint that importantly influences the choice of fuel, technology, size and location of new power stations.

C RECENT AND CURRENT DEVELOPMENTS IN THE WATER/ELECTRICITY NEXUS

It was remarked in the introduction that the water/energy nexus in South Africa has become vastly complicated since around 1990. In order to understand this and to lay the foundation for analysis of the contemporary planning/policy scene, it is necessary to present an overview of developments in each of the water and electricity sectors, going back beyond 1990 in the case of electricity in particular.

1 DEVELOPMENTS IN THE WATER SECTOR

The accelerating deterioration in South Africa's water sector is well documented.[12]

[11] It is instructive to explore the implications of these decisions for water consumption. On the assumptions that the power stations concerned use an average of 40 million cubic metres of water per year and that dry-cooling uses 10% of that, an **annual** saving of some 270 million cubic metres (around 1% of current national consumption) would have been achieved. This corresponds in current monetary terms to a saving of at least R1.6 billion per year (which, coincidentally, is the current size of DWA's annual budget). Apart from these savings, there would have been benefits from deferred investment in new supply capacity, notably in the Lesotho Highlands project.

[12] Numerous specialist studies and media reports are available. This section draws heavily on the author's report, prepared for Business Leadership South Africa in mid-2009, updated where necessary.

South Africa is, on several indicators, one of the driest countries in the world; it also has an unusually high intensity of water usage. The problem of water scarcity is compounded by the spatial pattern of economic activity and settlement, which is out of line with the natural availability of water. To deal with this situation, over the course of the last century the country developed an internationally recognised competence in building and operating large dams, tunnels and pipelines for storing water and for transferring it from areas of surplus to areas of shortage. (An equivalent competence was developed in waste water treatment.) The full significance of scarcity was masked by the highly uneven racial distribution, congruent with the distribution of political power of access to water and sanitation, with the bulk of the population being very poorly served.

The political transition of the 1990s introduced fresh thinking into water management. Water was defined as an "indivisible natural resource",[13] managed by the national government for the benefit of all South African residents. The prevailing system of riparian rights was abolished and people's rights to water were changed to temporary use rights from having been, where applicable, permanent property rights. The stated intention, driven in large part by considerations of basic human rights, was that the policy emphasis would shift from large-scale infrastructure development to issues of access, with a strong component of social equity, of ecological and financial sustainability, of water services regulation, of water conservation and demand management and of decentralisation in service delivery.

After a thorough and well managed, though not uncontested, consultation process, the legislative bills to achieve the above goals started being taken through Parliament in 1997. The resulting Acts were underpinned and reinforced, both at the time and in the ensuing years, by a plethora of policy and discussion papers on such matters as pricing, water allocation methods, water services regulation and institutional development.

The agenda was both extensive and deep. And while the principles underlying the policies and also the overall objectives were widely understood and applauded, the targets set were extremely ambitious. So much so that, some 13 years after the principal Act was legislated, not one of the institutional and policy proposals has been taken through to completion, and there has been little if any progress in reducing water losses (thought to be well in excess of 30% of total supplies) and in managing demand.

Further, over this same period there has been a marked deterioration in water quality in several of the country's main catchment areas. There are three main causes of this deterioration:

- Continuing sub-standard discharge of urban, industrial and agricultural effluent to rivers, exacerbated by the sanitation problems associated with informal settlements

[13] The distinction is made between *water resources* (bulk water in rivers and dams, underground and being transferred between catchment areas) and *water services* (water in pipes, for final consumption or for treatment).

- Wash-off and leachate from mining operations (so-called acid mine drainage). Until recently[14] it was thought this problem, which is of serious proportions, was limited chiefly to the Witwatersrand goldfields; it is now evident that the problem might be present on an even larger scale on the Mpumalanga coalfields[15]
- Wash-off from areas with overloaded or simply broken waste water treatment plants and sewage systems.

Why is the water sector in such disarray, to the point that many commentators believe a crisis is looming? There have been three main factors.

The **first** arises out of the extreme ambition, already remarked upon, of the objectives and instruments formulated in the 1990s, in terms of for example:

- The operationalisation of apparently simple but, in practice, complicated concepts such as the ecological reserve and the polluter pays principle

- Establishing new institutions on the supply and demand sides of the industry. This called for coordination horizontally across some 20 national government departments and agencies and vertically between the three tiers of national, provincial government. It required too establishing governance and management arrangements to ensure clear designation of responsibility, authority and accountability for each institution as well as effective interfaces between the institutions[16]

[14] The problem has long been known about. Especially on the Witwatersrand, the technical parameters are reasonably well understood and there are proven technologies for treating the water to potable standard. Nevertheless, until very recently the government has been unwilling to recognise that the problem arises in large measure because of the existence of a very large number of disused mines without owners, so that it (the government) has no option but to contribute financially along with the still-working mines to a sustainable solution.

[15] This is because of, over and above the legacy of large-scale mining (which continues), the liberal granting of mining licences to small (black-owned) mining companies. This is part of the thrust to broaden the racial ownership pattern of the industry. But it has been done without ensuring that the companies have the resources to manage their short- and long-term environmental impacts responsibly. The situation is not helped by a fundamental conflict of interest on the part of the Department of Mineral Resources: DMR is both promoter and policy-maker for mining and also its environmental regulator.

[16] One example of the apparent naiveté with respect to institutional matters has been the approach to establishment, as provided by the 1998 National Water Act, of 19 Catchment Management Agencies (CMAs) to manage bulk supplies across the country and to engage with counterpart bodies on the users' side. Little if any thought was given to the feasibility of staffing the CMAs, the relationship of each with DWA which had previously played the

- Devolving functions to local authorities that many were not equipped to perform, and not investing in development of their capacity to do so.

Second, insufficient attention was, and continues, to be paid to implementation as opposed to formulation of policy, and consequently also to investing in the human capital essential for effective functioning of the key institutions serving the industry. Indeed, there has probably been a reduction in both the quantity and the quality of professional, technical and managerial skills in the public sector organisations, because of a policy of allowing if not encouraging the retirement or premature departure of highly experienced officials, which has resulted in a serious loss of institutional memory.

Third, there has been a failure politically to recognise and to confront head-on the numerous problems encountered. Instead of acknowledging, in the light of on-going experience, the over-ambition of the policy goals as well as the capacity constraints, the practice has been to proceed on all fronts as if the constraints did not exist. This failure is the consequence of many factors; undoubtedly one is the practice of assigning to the same Minister the two portfolios of Water and Environmental Affairs, an impossibly large job.

In short, the problems besetting the sector are problems fundamentally of governance and management and not of policy and the principles underlying policy.

2 DEVELOPMENTS IN THE ELECTRICITY SUPPLY INDUSTRY

Eskom[17] has, from virtually the time of its establishment by Parliamentary Act in 1922, been the dominant player on the country's electricity and indeed energy scene. It is only in the last few years that this dominance has been institutionally challenged, with potentially profound consequences for the energy sector and indeed the country as a whole; this will be discussed in a later section.

Eskom was given statutory powers to generate and distribute electricity at the lowest possible cost[18]. Its means of raising capital was through issuing of bonds plus, in its early years, receipt of loans from government. It was mandated to operate at break-even and was exempt from corporate income tax.

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equivalent role, the governance arrangements for the CMAs, and so on. Fewer than a handful have been set up and none is fully operational. Proposals are currently being developed to reduce the number to nine, to help deal with staffing and other resourcing issues. There is also a fierce debate under way as to whether the CMA boards should comprise stakeholder representatives or genuinely independent individuals with an explicit obligation to consult extensively.

[17] It was originally called ESCOM (Electricity Supply Commission). The name was changed to Eskom in the mid-1980s; for simplicity, this is the name used in this paper.

[18] The paragraphs on the history of electricity supply and of Eskom draw heavily on Anton Eberhard, *The Political Economy of Power Sector Reform in South Africa*, chapter 6 in *The Political Economy of Power Sector Reform in Developing Countries*, Cambridge University Press pp 215-253, 2007.

The 1922 Act also provided for the regulation of electricity supply undertakings as well as the licensing of prospective new suppliers. The way this system was implemented resulted in Eskom's becoming, in 1948, virtually a monopoly generator and also operator of the national transmission grid (which was fully connected in 1973).

From its inception Eskom concentrated on exploiting the vast deposits of low-grade but also low-cost coal in what is now Mpumalanga. The standard practice, which has largely been maintained to the present day, was for the power station to be built next to the privately owned coal mine, with a dedicated railway delivering the coal on a continuous basis within the framework of a long-term supply contract.

The South African economy grew rapidly in the 1960s, as did demand for electricity. Although, because of the structural and other costs associated with apartheid, the economy started to slow down in the 1970s, electricity demand continued to rise because of the 1973 oil crisis and the concomitant switch to electricity. As a consequence Eskom invested heavily in new capacity, with significant increases in power station size in order to capture economies of scale. Because of technical problems – construction delays, scaling-up difficulties as generating sets became larger, use of low-grade coal and the like – Eskom felt the need to increase its investment programme in order to ensure that there would not be power shortages. In the early 1980s Eskom had some 22 000 MW of generating capacity on order, more than twice the size of the system then being operated.

As had been the case since the late 1920s, Eskom was responsible for financing its capital programme through retained earnings, commercial loans and domestic and international bonds guaranteed by the government. In order to boost its retained earnings, Eskom introduced significant price increases starting in the late 1970s, which consumers felt were not justified and complained accordingly. There was also concern about the lack of clarity in Eskom's governance arrangements – how was it held accountable to whom?

The upshot was the appointment in 1983 by the government of a commission of enquiry into all aspects of the utility's governance, structure, finance and operations. The resulting report was highly critical of Eskom, and the consequent legislation changed the governance arrangements in which the executive management team was made accountable to a new council made up of representatives, appointed by the government, of Eskom's principal stakeholders. The requirement to operate at neither a profit nor a loss was amended to satisfying cost-effectively the needs of the consumer subject to the national interest. Despite the vagueness of this new obligation, the effect of the legislation was to introduce an emphasis on the utility's commercial performance. This emphasis was reinforced by the personality of the chairman of the council, an industrial captain narrowly focused on the bottom line and with close connections to the state president.

The new commercial orientation led to a critical review of the capital investment programme, which was leading towards a huge excess in capacity, a consequence both of aggressive planning by Eskom and the economic stagnation in the last decade of apartheid. Despite Eskom's slowing-down of the new-build programme as well as closure and mothballing of older plant, by the early 1990s the reserve margin was around 40%, well in excess of standard practice.

To promote consumption, Eskom entered into contracts with energy-intensive users, notably in the export-oriented minerals beneficiation sector including aluminium (though the raw material bauxite has to be imported) and ferro-chrome. Eskom also drove a massive programme to make electricity available to new consumers in both urban and rural areas, with impressive results.

On its assumption of power in 1994[19], the ANC inherited a stagnant economy and an electricity supply system with surplus capacity. Despite the socialist philosophy adopted by the ANC-in-exile, which became the dominant presence in the first administration, the new government came to adopt conservative macroeconomic policies – which quite quickly resulted in significantly faster growth, maintained until the global financial crisis of 2008 – as well as a pragmatic posture towards both the governance of state-owned enterprises (SOEs), of which Eskom was one of the most important) and the potential for participation of private capital in the industries dominated by these enterprises.

In the mid to late 1990s nine of the largest SOEs, including Eskom, were identified as candidates for full or partial privatisation. In preparation for this they were made accountable to a special unit set up inside the National Treasury, which in due course became a separate Department of Public Enterprises (DPE). In 2000 the DPE published a policy framework for the so-called "restructuring" of SOEs that, inter alia, provided for "corporatisation" of Eskom, ie Eskom would be converted into a limited liability company, with government as the sole shareholder, and would pay taxes and dividends; Eskom would also be broken up into a number of generating companies that would, in due course, be the vehicles for attracting private capital for new investment.

These proposals were bitterly contested by Cosatu (the Congress of South African Trade Unions, a political ally of the ANC), which was hostile to the notion of privatisation in part because of its belief in the "developmental role" of SOEs in the core infrastructure industries. To all intents and purposes the outcome was that nationalisation was forced off the government's agenda,[20] although Eskom was formally corporatised in 2001 and became subject to payment of taxes and dividends.

Some of the DPE's thinking echoed ideas that had been expressed in a 1998 White Paper on Energy Policy, issued by the predecessor to the current Department of Energy (DoE)[21], which had called for introducing competition and private capital into (the generating side of) the electricity industry,[22] and that continued to be articulated through speeches, policy papers and workshops.[23] Presciently the

[19] See footnote 2.
[20] Indeed, the post-2009 administration has shifted leftwards in its overall economic philosophy, and there is now not only a strong pro-nationalisation stance but also a conviction that the state through its enterprises, especially though not only limited to the infrastructure industries, should be the leading agent of growth and development.
[21] *Viz* the Department of Minerals and Energy, which in 2009 was separated into the Department of Energy and the Department of Minerals Resources.
[22] Though it was always envisaged by government that it would be the dominant owner of the generating system.
[23] Also prominently on the policy agenda was the issue of restructuring the distribution side of the industry.

White Paper observed that new generating capacity would be needed by around 2007 if Eskom were to be able to meet the expected peak demand at around that time.

The early-mid 2000s were marked by continuing indecision on the part of government with respect to energy/electricity policy, and consequently a climate of uncertainty. There were several principal dimensions to this, including:

- The absence of a clear policy, regulatory and pricing framework for the involvement of private capital in investment in generating capacity. Associated with this was, critically, the lack of recognition by the authorities that, although it was claimed that South Africa had the lowest-priced electricity in the world, the price was well below the long-term marginal cost of generation.[24] The authorities, unlike other stakeholders, seemed genuinely surprised that in these circumstances the country's electricity supply industry was not an attractive investment opportunity
- Given its stated commitment to facilitating investment by the private sector in generating plant, the government held Eskom back from formulating and implementing its own investment plans
- The emergence on the scene in 1995 of the National Electricity Regulator,[25] which introduced a fresh and independent perspective into the whole energy environment
- The complex and lengthy environmental impact assessment and other regulatory processes required compounded the above difficulties
- The problems being experienced – and today still not resolved – in structuring the distribution side of the industry
- Consequently there was a hiatus in planning for the future of the industry.

In these circumstances, inevitably there was a rising nervousness that the quality and security of supply were at risk, not only in the long term but imminently. This was acknowledged by the government, and by 2004 the strategic priorities had explicitly shifted away from notions of restructuring and competitiveness to that of supply security. The new imperative had a degree of urgency about it, in part because the government was embarking upon a fresh programme (the Accelerated and Shared Growth Initiative for South Africa – AsgiSA) in an attempt to significantly raise the rate of economic growth.

The consequence of this shift was to reinstate Eskom as the preferred investor/operator on the generating side (and, for the time being at least, to entrench its monopoly position[26]). Not only were

[24] Eskom's prices were based on an asset portfolio much of which had long since been amortised. They did not reflect the costs of investing in much more expensive (in real terms) new capacity; and there was, and remains, a lack of clarity about the funding model for Eskom and in particular what the relative contributions towards capital formation should be of the tariff, debt, bonds and government support.

[25] In 2005 expanded to form the National Energy Regulator of South Africa (NERSA).

old coal-fired power stations brought back into operation; Eskom was given permission to invest urgently in two new coal-fired stations each with a capacity of some 4 000 MW: Medupi in the Waterberg and Kusile in Mpumalanga. From a procurement perspective the timing could not have been worse; worldwide there was over-demand for generating plants and, though only partly for this reason,[27]the capital costs of these stations are now widely held to be turning out to be well above normal international prices.[28]

The nervousness about supply security, referred to above, came to be justified. Partly for the reasons given earlier, and partly because of immediate logistical and operational problems in the supply system, in early 2008 supply was suddenly unable to satisfy demand. There were unplanned and hence disruptive power outages and, in addition, Eskom had no option but to put in place a programme for reduced off-take by (selected) consumers, with seriously adverse economic consequences.

These outages, unprecedented in Eskom's history, did great damage to the utility's reputation. This damage was reinforced by the financial difficulties that Eskom was beginning to experience – the utility incurred, for the first time in its history, a large financial loss in the year ended March 2009 (and a smaller loss in the following year).

At around the same time, but reflecting the long- and widely-held view that Eskom was altogether too dominant a player in the energy and not just the electricity sector, several developments were taking place that started challenging Eskom in the policy and planning domain and consequently also its previously uncontested authority. Four factors stand out.[29]

First, an inter-Ministerial Committee on Energy (IMCE) was set up in 2008, initially to look at issues of electricity pricing but later to become the Cabinet's mechanism for formulating a long-term strategy for investment in the electricity supply industry. Serviced by the Inter-Departmental Task Team on

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[26] Eskom generates some 96% of the country's electricity; the residual is produced by a small number of companies and municipalities.

[27] There was a raft of other reasons. These included several changes in the overall approach to procurement of the generating sets; reduced capacity in Eskom's project management team to undertake the commercial negotiations; innumerable design modifications both by Eskom and the boiler and turbine manufacturers; poor scheduling of civil and engineering works; delays in securing funding, because of which the Eskom board, in terms of the Public Finance Management Act, could not allow the contracts to proceed until there was certainty; the Black Economic Empowerment (BEE) requirements imposed on the bidders, which added a premium to the price; these delays plus a rise in the cost of capital to Eskom have had a material impact on the interest costs incurred during construction; and a decision by Eskom not to use a full turnkey contracting arrangement but to enter into multiple contracts which it did not really have the capacity to manage.

[28] There are estimates that Kusile will turn out to cost roughly double an equivalent power station elsewhere in the world.

[29] Formation of the NER in 1995, subsequently widened in scope to NERSA in 2005, was an early indication of this sentiment.

Energy (IDTTE) convened by the Department of Energy, the IMCE published in 2010 a draft of the so-called Integrated Resource Plan (IRP2) for development of the industry up to 2030. Following extensive public consultations, the final version was approved by Cabinet in March 2011 and now stands as government's definitive strategy for the industry.[30] IRP 2010-2030, as the document is known, places a fresh emphasis on the use of renewables – wind and solar – in the country's generating mix[31]; the implications for water use will be discussed later.

Second, the New Generation Capacity Regulation Act of 2009 decisively transferred responsibility for electricity planning to the Minister of Energy. This Act stipulates that the Minister, on behalf of government as a whole, has the final authority with respect to investment in the electricity supply industry, subject to consultation with the Regulator and crucially also to approval by the National Treasury. The Minister's authority extends over such strategic matters as the size, technology and location of new power stations and whether Eskom or an "independent power producer" should be the investor/operator.

Third, because of its poor financial performance and consequently weak standing in capital markets (an entirely novel experience), Eskom faced problems in securing funding for its massive capital programme – some R625 billion in the period 2010-17.

The difficulties were compounded by uncertainties and controversies with respect to its tariffs. For the reason suggested earlier, even in the absence of an agreed funding model, it was clear to all that Eskom had to raise its prices. In 2009 Eskom applied to the National Energy Regulator for a 46% increase in tariff in each of the three years 2011-13. The public outcry was huge, not least because of the general perception that the proposed hikes arose from Eskom's incompetence – *vide* the power outages in 2008 and the financial losses in two successive years after that. In the event, NERSA awarded annual increases of some 25%, and there currently persists a widespread nervousness that the next tariff award will be of the same order of magnitude if not larger.

Fourth, after a lengthy gestation period a parliamentary bill was published in April 2011 to enable establishment of an Independent System and Market Operator (ISMO). Its ultimate purpose is to remove from Eskom the responsibility for investment in and operation of the national transmission network and to place it in an independent state-owned institution accountable to the Minister of Energy. The rationale is to facilitate and expedite the establishment of independent power producers (IPPs), *viz* private sector investors in and operators of new generating capacity that would alongside Eskom – on this model, confined to being a state-owned investor/operator of power stations – sell its output to the ISMO. Underlying this is the need to foster a more "disciplined, open and transparent electricity sector" as a pre-condition for introducing private capital into the industry in order to reduce the financial burden on the state and also to spread the risk burden.

[30] This has clarified what had been a confusing situation in which Eskom, the Regulator and DOE/DMR each had its own long-term investment plan for the industry.

[31] The contribution of renewables is targeted at 42% of the yet-to-be-developed generation mix by 2030.

In addition, early in 2010 Eskom was able to raise a loan for construction of Medupi[32] from the World Bank of some US$3 billion (around R21 billion at current exchange rates), plus US$700 million for other capital expenditure. Later in the same year, the South African government doubled to R350 billion its loan guarantee for Eskom's capital programme to 2017, thus enabling Eskom to proceed with its immediate procurement needs.

Despite Eskom's "vulnerability" over this period, such was the quantity and the quality of technical resources that it could mobilise, compared with all the other players, that Eskom was appointed as the secretariat for preparation of the strategy IRP 2010-2030 and its predecessor drafts. In this capacity, Eskom was responsible for assembling the key data, and it was Eskom's planning model that was used. While the inter-Ministerial Committee, acting as the steering committee for the process and the recommending body to Cabinet, underpinned by officials from the concerned departments, undoubtedly has been an important counter to Eskom, the fact of "information asymmetry" between Eskom and the others meant that the utility has continued to exercise huge influence on the future of the industry.

Further, now that its immediate capital funding is in place,[33] and because of the priority that has been attached since 2004 to supply security (ironically strengthened by the 2008 power failures), Eskom is once again in a powerful position. The fact that the proposed Independent System and market Operator is to be phased in, with Eskom continuing to play a role in management of the grid over an as yet unknown but presumably extended period, reinforces this view. This conclusion can be inferred too from the fact that, despite IRP 2020-2030's emphasis on Eskom's future focus on meeting the base load using coal and nuclear fuels, two of the initial renewable energy projects are already being pursued by Eskom.

In addition, both solar and wind power are new technologies, unproven at scale. The operator of the national grid – whether Eskom or ISMO, or some transitional combination – would likely be nervous about being required to run a system whose stability could be compromised by premature or over-ambitious adoption of new technologies. This is despite IRP 2010-2030s having built in a learning factor for adoption of the new technologies.

3 CONCLUDING COMMENTS

The two preceding sections highlight the current state of flux in both the water and electricity sectors. It would be trite to suggest that this state comes about only because of the country's political transition and the emergence of major interests that had, prior to 1990, been denied effective participation in the political economy. Deep-seated changes were already underway in the 1980s, driven by an inexorable trend towards increasing involvement of the state in the economy and by a rising concern about responsible management of the country's natural resources.

[32] In the context of the present report it is worth noting that one of the conditions of the loan was that sulphur dioxide in the flue gases be scrubbed, the consequence of which will increase three-fold the station's water requirements.

[33] Though full funding of Kusile is not yet secured.

But that the political transition has both accelerated and indeed radicalised some of these changes is undeniable. The governance arrangements and the associated institutional architecture have been and still are being altered, and in the process there is abundant evidence that existing institutions have been, and perhaps are continuing to be, weakened. These are not necessarily untoward developments – after all, what worked yesterday does not necessarily work tomorrow, and a new political order cannot but herald governance and institutional change. The *caveats* are that numerous proposals for new institutions have yet to be effectively implemented,[34] even where legislatively authorised, and that ostensibly sensible proposals have been politically defeated[35].

The next section will further explore these changes as well as their implications.

D THE WATER-ELECTRICITY NEXUS: CURRENT AND PROSPECTIVE SITUATION

Within the complex context sketched in the preceding sections, the starting-point for analysis of the inter-related policy choices with respect to the water and electricity sectors is necessarily IRP 2010-2030, approved by Cabinet in March 2011.This document represents, despite all the many conflicting views about both process and content, as robust and widely consultative an approach as could be realistically achieved. So, it is important to look at it more closely.

IRP 2010-2030, as the national strategy for investment in electricity supply, is presented as a "living" plan – hence subject to on-going revision as circumstances change – that, while ensuring security of supply, seeks to find a balance between competing objectives *inter alia* of:

- Affordability (implicitly in both investment and consumption terms, though steep increases are projected for the price of electricity per kwh)
- Reduction of carbon emissions (in the light of the government's Copenhagen commitments)
- Water conservation
- Local industrial development and job creation
- Development of the southern African region.

Starting in 2009 under the aegis of ICME as set out earlier, a methodology was developed that entailed formulation of scenarios for investment in new generating capacity up to 2030 across the mix of available technologies, using different assumptions about demand growth, operational

[34] Eg, the many new institutions proposed for the water sector.

[35] Eg, the establishment of the National Water Resources Infrastructure Agency as a state-owned holding body to ensure effective management of the massive assets in the water resources sector.

efficiencies, risk aversion and other parameters. Each scenario was critically scrutinised with respect to its contribution to the above objectives. The focus of the present report is only on water.

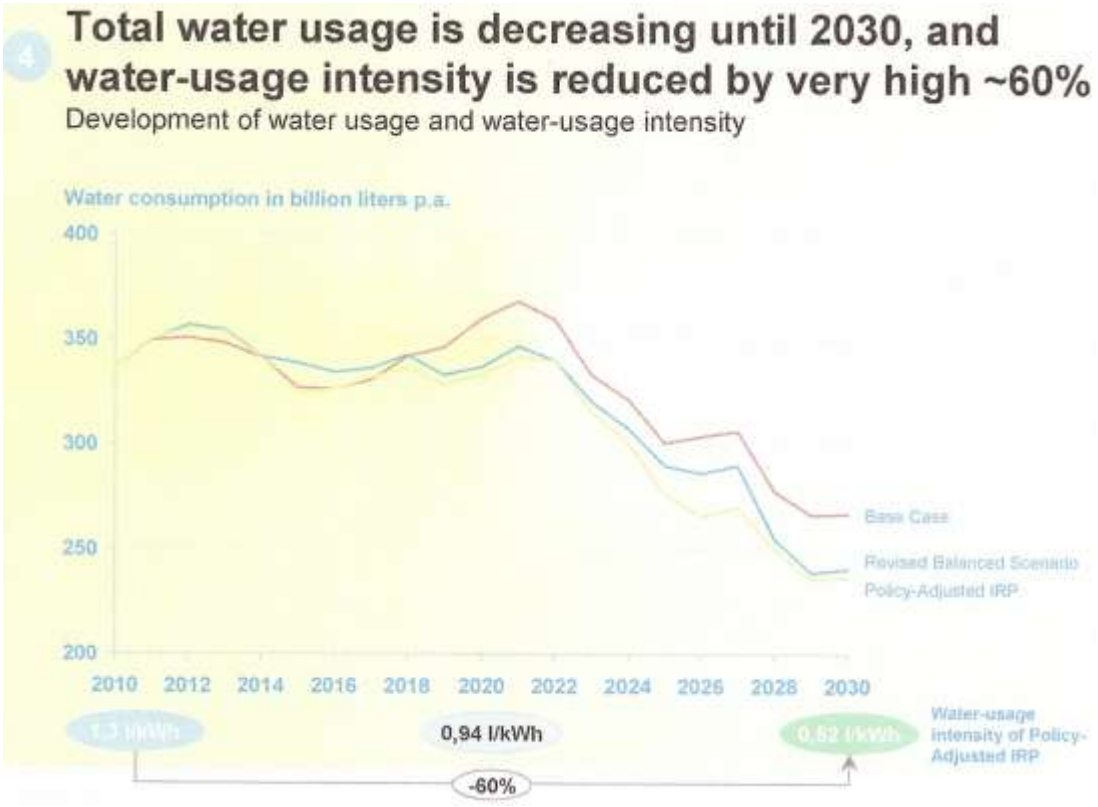
The strategy ultimately adopted provides for additional capacity of 42 500 MW, effectively doubling the size of the present system.

The table below shows the key components of the strategy, indicating a significant reduction in the reliance on coal and significant increases in reliance on nuclear and renewables (of which just over half is solar, both photovoltaic and concentrated, and the balance wind).

Table: Proposed growth in national electricity supply up to 2030

	Existing capacity 2010, GW	Already committed capacity, GW	Additional capacity by 2030, GW	Energy share 2010, %	Energy share 2030, %
Coal	35.5	10.1	6.3	90	65
Nuclear	1.8	0	9.6	5	20
Hydro	2.1	0.05	2.6	5	5
Gas CCGT	0	0	2.4	0	1
Gas OCGT	2.4	1.0	3.9	<0.1	<0.1
Renewables	0	1.0	17.8	0	9

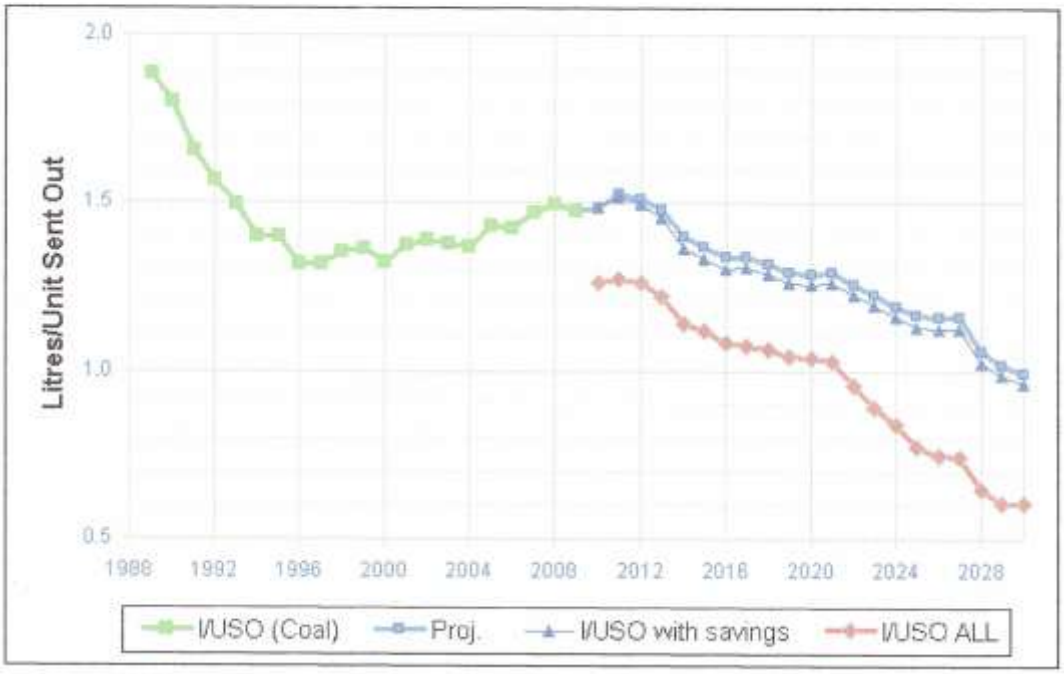
More important in the present context is the implication of the above strategy for water consumption. This is shown graphically in the following figure, where it is evident that a reduction of 60% in water consumption per kwh is projected which results in an **absolute** reduction of some 33% between 2010 and 2030.



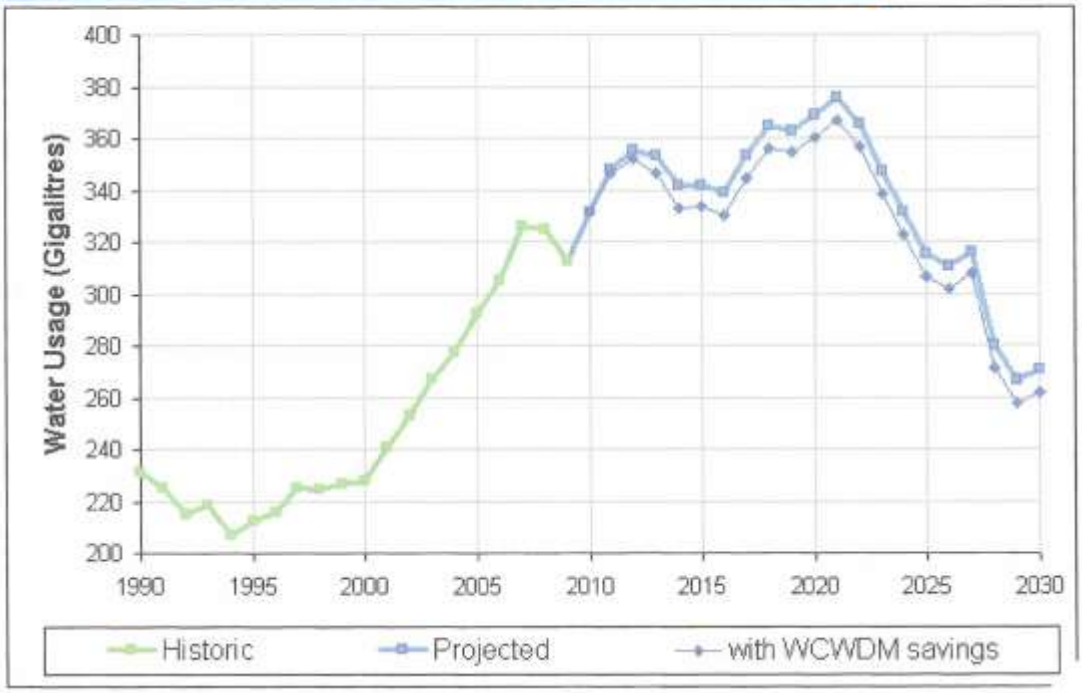
Further evidence of the favourable trend in water usage is provided in the following two figures (which are for Eskom only, based on its interpretation of an earlier version of the IRP 2010-2030). These show:

- An improvement in the efficiency of Eskom's use of water, from 1.9 litres per kwh sent out in 1988 to a projected figure of 0.6 litres per kwh sent out in 2030
- A steep increase in Eskom's water consumption from the mid-1990s to the present with continuing but slower increases until the early 2020s, after which there will be a sharp reduction because of the decommissioning of wet-cooled power stations and the increasing use of less water-intensive technologies.

Eskom's water use consumption improves significantly over the IRP 2010 period



Eskom's water usage will reduce considerably with the decommissioning of its older coal fleet



It must be recognised that the strategy is indicative only. Exactly how implementation of the strategy proceeds and consequently what actually happens by way of water consumption will depend on many factors. Over and above growth in demand, as well as trends in the capital costs of the various technologies, these will be determined only when detailed feasibility studies are undertaken for each proposed new investment. For example, in the case of coal-fired power stations in particular, these factors will critically include the location of the power stations, which will be influenced by the availability and costs of water, the costs of coal and the costs of connecting the station to the grid, taking into account both operating and capital costs. Given the long lead-times for such infrastructure projects, and also the longevity of the assets created, these are profoundly important questions that go beyond water consumption alone and bear upon such matters as evolution of the spatial development of the economy.

As remarked earlier, the strategy is deliberately silent about which investments will be made by Eskom and which by other parties. In principle the government is committed to introducing private capital into the supply system, in practice the pricing[36], regulatory and other essential frameworks are not yet in place for the opportunities to be attractive to private investors.

CONCLUDING COMMENTS

This section has clearly demonstrated the current deep awareness among the water and energy planning authorities of the importance of the availability of water in long-term electricity supply planning.[37] Encouragingly, this awareness is not confined to these authorities only. This certainly applies at national level to all government departments and agencies concerned with planning and resource allocation in general. It can safely be said that the governance arrangements are now firmly in place to ensure that water will always be a key consideration in electricity supply planning.

Earlier sections, however, demonstrated that this was not always the case. After a promising start, initiated by Eskom in the late 1960s, there was a period of some 15 years when water as a constraint was disregarded. In the mid-1980s this situation changed, but only temporarily, and it has been only in the last decade that a robust consensus has emerged that surely is irreversible.

[36] Until very recently it seemed that the pricing regime set by the National Energy Regulator to incentivise private investment was established, but new and less attractive arrangements have now been announced.

[37] As observed earlier, it is the **availability** not the cost of water that matters to the power utility. However, from a national perspective it is the total "system" costs that are relevant, as argued in the previous paragraph.

E OUTSTANDING ISSUES IN THE GOVERNANCE OF WATER AND ELECTRICITY

This has been a wide-ranging study, in the course of which many issues of governance have been encountered. While they do not bear directly on the governance of both water and electricity, all of them influence indirectly the overall water-electricity system. They are briefly discussed here, both for their intrinsic interest and because they illuminate the political, institutional, policy and hence governance flux in contemporary South Africa.

GOVERNANCE OF STATE-OWNED ENTERPRISES (SOEs)

There are some 260 SOEs in South Africa. Nine of them – comprising essentially the largest and those considered the most "strategic", among them Eskom – are subject directly to two ministries/departments.[38] In the case of Eskom, the departments are:

- Department of Public Enterprises (DPE), the so-called "shareholder department" to which Eskom is accountable for its performance. The current practice is that DPE agrees annually a "shareholder compact" with Eskom, which sets financial and operational performance targets. DPE (through the minister) appoints the (nominally independent) board of Eskom, explicitly including the chairman. In principle the board appoints the chief executive, subject to DPE's approval; in practice the minister plays a direct role in this
- Department of Energy (DoE), which serves as the policy department, shaping the policy and regulatory framework with which Eskom operates. Section C above traced the trend towards increasing authority, exercised by the DoE, on the part of government in determining the investment strategy for the electricity supply industry.

Two other departments play significant roles. One is the National Treasury (NT) which, under the strict disciplines of the Public Finance Management Act, exercises control of capital spending by Eskom and also has to deal with the consequences of any financial losses made by the utility. The other is the (new) Department of Performance Monitoring and Evaluation (DPME) which, on behalf of the President, sets outcomes-based performance targets for all Cabinet ministers.[39]

There is, in addition, the role played by the independent National Energy Regulator.

It need hardly be said that many tensions and other problems arise in these circumstances. The various institutions have different capacities – a mix of technical expertise, resource availability and

[38] The distinction is made between the "ministry", headed by the (Cabinet) minister and comprising his/her advisors, and the "department", headed by the director general and comprising civil servants. Past practice was that policy would be formulated by the ministry and executed by the department but, with the trend under the ANC for the top officials to be political appointees, the situation is now blurred.

[39] The (new) Planning Commission, located (like the DPME) in the Presidency, could also come to play a material role in the future.

experience – to deal with problems as complex as those of long-term electricity supply. As observed earlier, the difficulties are compounded by the dominance of Eskom, arising out of the sheer quality and quantity of expertise it can mobilise; the other institutions, even collectively, cannot "compete" with Eskom in this respect. The difficulties are compounded further by the inevitable tendency for ministers to override the board and to interfere in operational matters, as well as by the lack of clarity of what ultimately is expected Eskom as a "strategic" SOE.[40]

There is widespread acceptance of government's overall responsibility for the electricity and associated sectors, and hence of the fact of government's growing involvement over the past three decades, albeit at an increasing pace in recent years.

But several worries remain: the time-frames for the huge investments involved are way beyond those of the average politician; increasing interventionism is often (though by no means always) accompanied by diminishing not rising capacity in the civil service and parastatal agencies; and the technical complexities of the sectors seem continuously to become greater.

The question must be asked whether government, in a practical sense, is not over-reaching – would it not be more effective and efficient for government to set the strategic goals and parameters for the different parts of the system, to give the bodies concerned the authority and responsibility for the required delivery and to devise the necessary mechanisms to hold those bodies accountable?

GOVERNANCE FOR IMPLEMENTATION OF IRP 2010-2030

Formulation of IRP 2010-2030 was a highly consultative process. But, as observed, the strategy is no more than indicative – innumerable questions remain as the individual projects come under detailed scrutiny. While the decision authority now unambiguously lies with the Minister of Energy, the question remains as to how the many contending stakeholders are kept informed and involved as the planning/implementation process evolves.

As noted before, the concept of (good) governance is not widely understood and agreed in South Africa. The critical issues, derived from the country's long history of excluding legitimate stakeholders from participation in the political process, revolve around whether these stakeholders can do more than make inputs or can actually influence decisions and also whether and how stakeholders are "represented" in the decision structures.

The principles of corporate governance clearly exclude the notion of a stakeholder being "represented". The board or equivalent comprises individuals who, even if nominated by stakeholders, are expected to make judgments based on what is in the best interests of the organisation; each individual must wear only the "hat" of the organisation. The balancing constraint is that in reaching their decisions the board must necessarily consult widely in order to ensure that the perspectives of all stakeholders are taken into account.

[40] A Presidential commission is currently considering the roles and performance of SOEs.

Conceptually this is an attractive model even for something as complex as IRP 2010-2030. One can go further and argue that it is the only workable model, for the simple and practical reason that there are too many stakeholders for them all to be represented – far simpler to have an independent board with the obligation to consult as widely as possible.

But the voices arguing for the notion of "representatives" are strong, and the argument is far from over.

LONG-TERM INFRASTRUCTURE PLANNING

Three distinctive features of investment in supply of water and electricity are the large capital sums involved, the long time-frames and the implications for investment in associated infrastructure sectors. The situation is well exemplified by the options for utilising the massive but low-grade and high sulphur-content coal reserves in the Waterberg.

It was earlier noted that the Matimba and Medupi power stations (the latter still under construction) are located on the Waterberg coal field. It was also noted that the decision was taken to strip sulphur and nitrogen from the stations' flue gases. To make all this possible it was necessary to commit to augmenting the locally available water supplies by building a pipeline to enable water to be drawn from another catchment area. Installing high-voltage power-lines to connect the stations to the national grid was also required.

These projects are resulting in physical development of an area that, apart from quite large-scale coal and platinum mining, was previously sparsely settled. The process of urbanisation is already under way, with all the attendant problems of provision of water, sanitation, housing, transport and other services for the "immigrant" population including those on so-called squatter or informal settlements.

The coal reserves are sufficient to fuel a third and probably even a fourth power station. The principal options are:

- Site the station(s) on the coal field and invest in further augmenting the supply of water from elsewhere, as well as the urban infrastructure
- Ship the coal to Mpumalanga where coal reserves are running out and where existing generating and transmission capacity exists or can be renewed. This would require investment in a rail transport system.

These are complex choices, not least because of the dispersed *locus* of the decisions and the many different interests and organisations, both public and private, necessarily involved. They are also choices that will have long-term impacts on, for instance, the spatial organisation of the national economy and, more directly and locally, on the quality and costs of service provision.

Only very recently has it become recognised that South Africa does not have in place the institutional structures and processes to address such issues from a national perspective. The Treasury, for instance, has come to appreciate that its approval of a major capital project must be decided in the latter's systems-wide context and not simply as a stand-alone investment; therefore, to exercise its authority responsibly it needs to participate from the outset in the planning processes to ensure that the right options are being explored and sound decisions made. Similarly, Eskom, DPE and others have recognised that if the problems associated with urbanisation in the Waterberg are to be effectively met, the relevant provincial and national authorities must be involved because of the limited capacity of local government in a deep rural area.

The response so far by individual parties has been pragmatic and responsible. Ideally a broader approach is needed, and perhaps the new Planning Commission will bring greater structure and system to these matters.

INSTITUTIONAL MEMORY

In the mid-late 1960s and into the early 1970s, water availability was identified in Eskom and in government more widely as a (future) constraint on investment in electricity supply. Until the mid-1980s, while still recognised as a constraint in some parts of Eskom, water did not feature as a significant factor. In the mid-1980s this changed, resulting in a commitment to dry-cooling technology for the major coal-fired power stations then being commissioned.

But, with the inauguration of the new government in 1994, there was a change again, at least at the political level. Water as a determining factor on the choice of fuel and of location of power stations was evidently not recognised at the political levels of government, including in the Cabinet. Further, from the decade commencing in 1995 water supply was never prominently on the Eskom board's agenda. This was a far cry from the concerns expressed initially in the 1960s, which led to Eskom's pioneering role in the development of dry-cooling technology.

One can only speculate on how and why this happened. At the political level, it is perhaps understandable given the change of administration that took place in 1994, even though the civil service might have been expected to have provided continuity of experience and advice. But that it happened at Eskom is harder to fathom – perhaps simply the consequence of changing personnel.

PRICING

Both electricity and water have been, and remain, seriously under-priced relative to the costs of supplying them. This report notes that electricity prices are being brought into line with long-term marginal costs; water prices are barely on the national agenda.

The simple point to make here is that inappropriate pricing results in hugely inefficient allocation of resources[41]. It also results in highly uncomfortable processes of adjustment for all consumers and producers when the prices inevitably come to be corrected.

AFFORDABILITY

The need for prices to rise substantially obviously raises questions of affordability for consumers, especially given the country's exceptionally high level of unemployment and despite the social grant system.

There is another dimension to affordability, viz the capital costs of the projected investment programme in electricity supply in particular. These are all the higher because of the government's stated intention of reducing dependence on coal as a primary fuel and concomitantly increasing the use of nuclear, solar and wind energy. At this juncture, it seems absolutely essential that an attractive financial and regulatory environment be created to induce the participation of private capital; without this, which will be politically difficult to put in place, it is very hard to see how the required investment programme will be funded.

CONSTITUTIONAL ISSUES

South Africa prides itself on the modernity and comprehensiveness of its rights-based Constitution, which was negotiated some 15 years ago as the foundation of the country's political transition. So, it is with caution that one raises the soundness of some of its provisions.

From the perspective of this study, the weaknesses lie in the lack of clarity/conflicts of interest associated with the allocation of responsibility for service provision across the three tiers of government. This study and the author's previous work on water have identified several such anomalies: while environmental management is designated as a joint national and provincial competence, air pollution and waste disposal are assigned locally (but land contamination is assigned nationally); who is ultimately responsible if contaminated water causes illness is far from clear – the local authority which is constitutionally responsible for provision of water services, the province which is responsible for the effective functioning of its local authorities, the Department of Water Affairs which is responsible for regulation of water services providers, the Department of Cooperative Governance and Traditional Affairs which sets the framework for provincial and local government, the Department of Health, and so on.

Without clarity in such over-arching matters, it is hard to imagine that good governance can take effective root.

[41] There are innumerable examples that could be cited; one of the most telling is the decision to offer South Africa as a cheap source of power for aluminium smelting, for which bauxite had/has to be imported, when the real electricity costs make/made this a highly uncompetitive activity.

CORRUPTION

It is similarly uncomfortable to talk about the corruption that apparently pervades the system.

The key mechanism is through procurement. This goes beyond “conventional” corruption whereby officials take bribes from suppliers in the award of contracts. It also includes, for instance, the award of contracts to companies in which the civil servants concerned have a stake; the insistence that certain firms, in which the officials have an interest, must participate in the supply contract in terms of the government’s black economic empowerment legislation; and, more specifically, the award of major equipment supply contracts to Hitachi, in which locally the African National Congress has, indirectly, a large interest. An earlier section noted that power station capital costs are allegedly far higher than elsewhere, for these and other reasons.

There is abundant evidence, even if mostly anecdotal, to support these concerns. And the legislation exists to address corrupt procurement practices. For instance, there is provision for civil servants to declare their business interests and to have them approved, or otherwise, as the case may be. But the enforcing institutions are evidently lax and also poorly resourced, and the political will to tackle the problems aggressively is absent.

Again, so long as such practices persist, it is difficult to talk of good governance in the water/energy system.

ANNEX A – TECHNOLOGIES FOR COOLING POWER STATIONS

The turbines at coal-fired power stations are driven by steam. The steam is produced using demineralised water, which needs to be recovered both because of its costs and, in South Africa, its scarcity.

When the steam leaves the turbine it is at a very low pressure and high volume, at a temperature of ±40ºC. Steam cannot be compressed, so the only way to recover the spent steam is through condensation, i.e. changing the steam (vapour) into a liquid.

Eskom uses three types of cooling systems at its coal-fired plants.

With wet cooling (the conventional system used world-wide) and direct dry cooling, condensers along with cooling water and cooling towers are used. The cooling water flows through thousands of condenser tubes, with the steam on the outside. As a result of the temperature differential between the water and the steam, the steam condenses. The warmed cooling water flows to a cooling water where an upward draft of air removes the heat from the water, which is then returned to the condenser.

In the wet-cooling system, with this upward movement of air, a substantial amount of water is lost though evaporation. The white plume seen on top of cooling towers at most thermal stations is pure water vapour.

In the indirect dry-cooling method, steam from the last-stage turbine blades is channelled directly into radiator-type heat exchangers (there are no cooling towers). The heat is conducted from the steam to the metal of the exchanger. Air passing through the exchanger is supplied by electrically driven fans. The air removes the heat, thereby condensing the steam back into water for use again in the boiler.

The indirect dry-cooling method also uses a cooling tower and water. The principle of operation is similar to that used in a car radiator. Heat is conducted from the water through
A-frame bundles of cooling elements arranged in concentric rings inside the tower. The cooling water flows through these elements, is cooled as the cold air passes over them and then returns to the condenser. This is a closed system and there is no loss of water through evaporation.

At Koeberg nuclear power station, a different cooling system is used. Sea water is used to condense the steam, after which the warm sea water is discharged into the ocean.

ANNEX B – INDIVIDUALS CONSULTED

Kader Asmal (Minister of Water Affairs, 1994-99)

Thabang Audat (Director, Department of Energy)

Thinus Basson (Consultant)

Brian Bruce (Chief Executive, Murray & Roberts)

Thembani Bukula (Board Member for Electricity, National Energy Regulator)

Rod Crompton (Board Member for Petroleum, National Energy Regulator)

Johan Dempers (Corporate Specialist: Coal, Eskom)

Anton Eberhard (Professor, UCT Graduate School of Business)

Alec Erwin Minister of Public Enterprises, 2004-09)

Nandha Govender (Water Procurement Manager, Eskom)

Ian Hall (Anglo Coal)

Avril Halstead (Chief Director, National Treasury)

Alex Ham (Executive Director: Technology, Eskom 1991-94)

Sarah Haswell (Director, National Treasury)

Mervyn King (Chairman, King III Committee on Corporate Governance)

Detlev Kroger (Emeritus Professor, University of Stellenbosch)

Doug Kuni (Managing Director, Independent Power Producers Association)

Kannan Lakmeeharan (Divisional Executive: System Operation and Planning, Eskom)

Laurraine Lotter (Overall Business Convenor, National Economic Development and Labour Council)

Penuell Maduna (Minister of Minerals & Energy, 1996-99)

Neva Makgetla (Deputy Director General, Economic Development Department)

Lize McCourt (Chief Operating Officer, Department of Environmental Affairs)

Dolly Mokgatle (Executive Director, Eskom 1991-2003)

Smunda Mokoena (CEO, National Electricity Regulator)

Mohammed Valli Moosa (Chairman, Eskom,)

Allen Morgan (CEO, Eskom, 1994-2000)

Helgard Muller (Acting Chief Director, Department of Water Affairs)

Valerie Naidoo (Water Research Commission)

Willem Needham (Senior Manager, Eskom)

Zvi Olsha (Corporate Advisor, Eskom)

Crispian Olver (Director General, Department of Environmental Affairs,)

Gary Pienaar (Senior Researcher, The Institute for Democracy in Africa)

Wendy Poulson (General Manager: Sustainability & Innovation, Eskom)

Jeffrey Quvane (Senior Financial Officer, National Treasury

Barbara Schreiner (Deputy Director General, Department of Water Affairs, 2002-07)

Vuyo Tlale (Director, Department of Public Enterprises)

Theo van Robbroek (Deputy Director General, Department of Water Affairs, 1987-1991)

Johan van Rooyen (Director, Department of Water Affairs)

While it may seem invidious to do so, I wish to record my special gratitude to Messrs Ham, Van Rooyen and Govender for the special effort they each made to assist me in this study.