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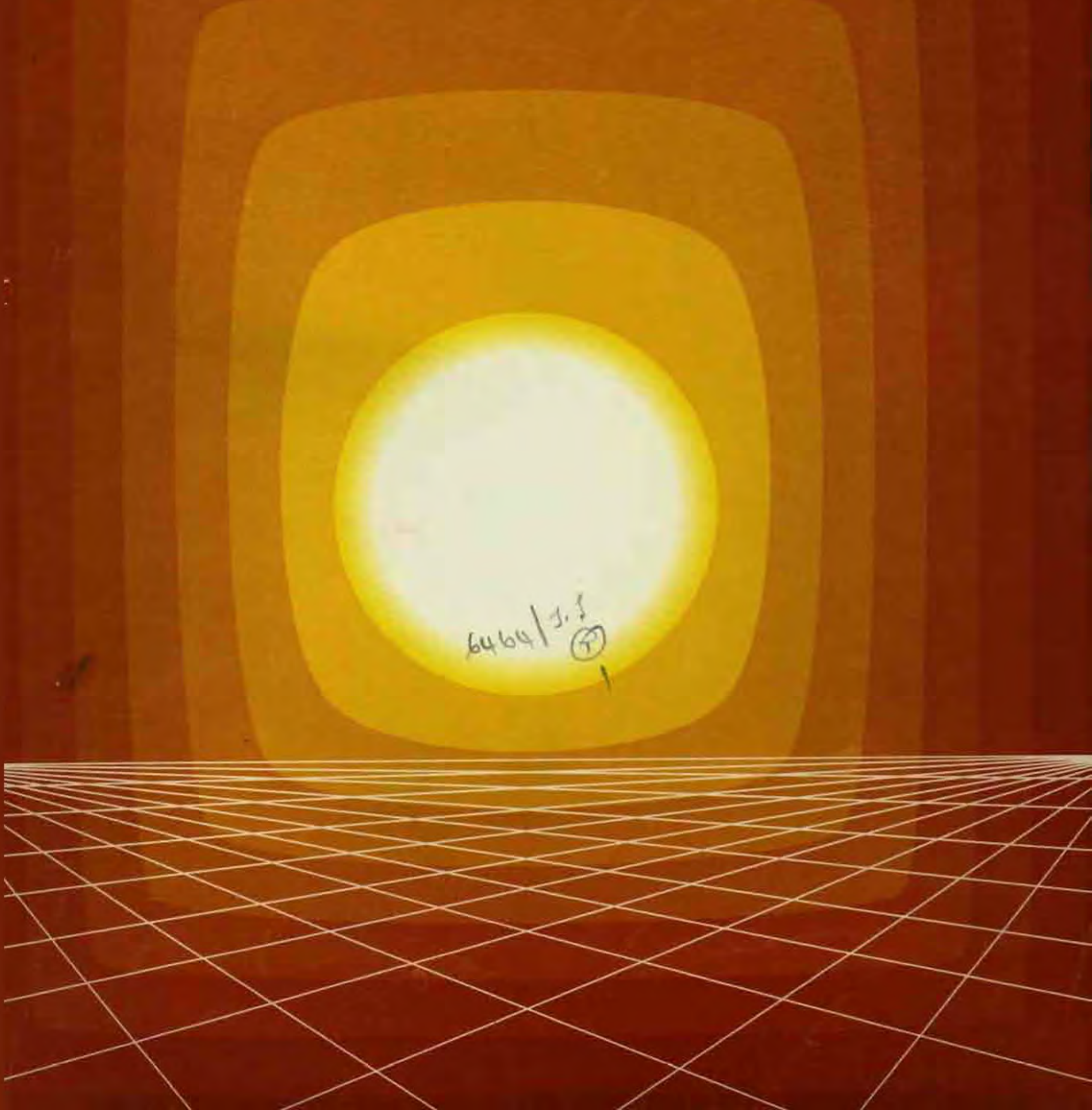

# Journal of Energy in Southern Africa

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It is the policy of the Journal to publish, as far as possible, original papers covering the technical, economic, political, environmental and techno-social aspects of energy. Only previously unpublished work will be accepted. However, conference papers delivered but not published elsewhere are also welcomed. Short comments, not exceeding 500 words, on articles published in the Journal are also invited. Items of general interest, news, technical notes, reviews and research results applicable to the Southern African context will also be included. Announcements of relevant publications, reviews, conferences, seminars and meetings will be included.

Those wishing to submit contributions for publication should refer to the guidelines set out in *Information for Authors* printed on the inside back cover of the Journal. All papers are refereed by knowledgeable persons before publication.

The Editorial Committee does not accept responsibility for viewpoints or opinions expressed, nor the correctness of facts or figures.

## Contents




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# Editorial

## B H A WINTER

This, the first issue of Volume 4 of the Journal contains a number of "firsts".

(i) As promised in the Editorial of our last issue, we have a new cover which depicts, in a dramatic way, the focus of the Journal.

(ii) The new title of the Journal widens its scope by allowing a variety of items of interest in the Southern African energy field over and above its primary mission to highlight important research and development activities in this area.

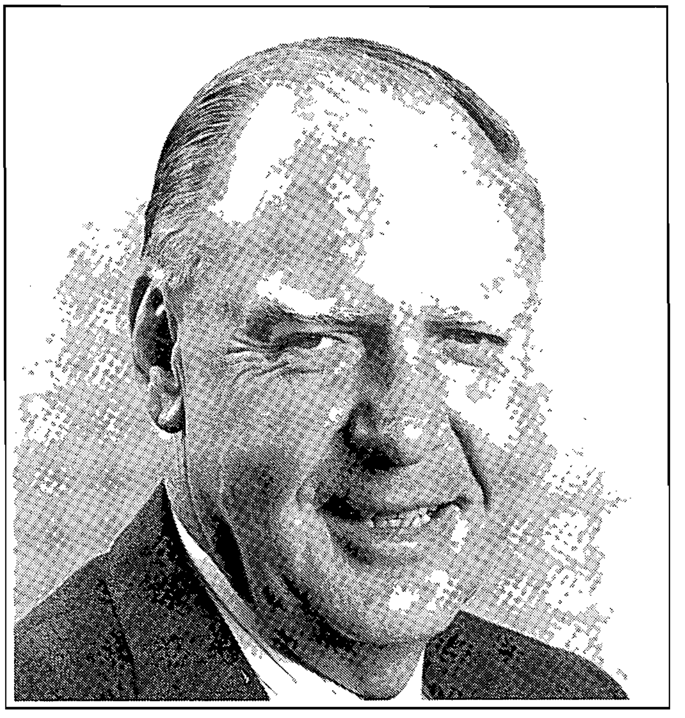
(iii) For the first time, we feature contributions from eminent scientists outside Southern Africa, and in welcoming these contributions from Miguel Schloss of the World Bank and Dr R K Pachauri of the Tata Energy Research Institute, we are encouraged by this evidence that the Journal is beginning to receive international recognition. These papers discuss the relationship between energy and development in developing countries from different perspectives.

(iv) We have started a planned series of profiles on important people in Southern African energy scene and could think of no more appropriate person than Ian McRae with whom to begin this series.

(v) Short items of Southern African and African energy news have also been included, as well as a comment on a paper published in the previous issue.

We would appreciate any comments from our subscribers and contributors on the changes we have made, and we hope that these will result in a renewed interest in what we believe to be an important journal in the development of the Southern African region.

# Profile: Ian C McRae



The names of Ian Campbell McRae and Eskom are practically synonymous. Starting as an apprentice he has risen to the top position of Chief Executive Officer, proving that dedication, hard work and ability are the only characteristics necessary to achieve success.

Ian McRae started with Eskom as an apprentice in 1947 where his obvious ability resulted in him being sent to the University of the Witwatersrand where he obtained his BSc (Eng) degree in Mechanical Engineering. He was, in fact, one of Eskom's first bursars. He was then allocated to the generation side of Eskom's activities with periods at Taaibos, Highveld and Komati Power Stations. Promotion saw him transferred to Eskom's Head Office. In 1980 he became General Manager of Operations and in 1984 he was promoted to General Manager of Engineering. In 1985 he was designated Chief Executive Officer and Chairman of the Management Board. At the end of 1992, the Chairman of Eskom's Electricity Council, Dr John Maree, announced that Dr McRae, who is 63, will only retire in 1 March 1994, which is three years' beyond the normal retirement date for Eskom's top executives.

His success in Eskom has also been recognized outside the organization. He has been awarded an Honorary Doctorate in Engineering by his Alma Mater - the University of the Witwatersrand - in recognition of his efforts in the economic upliftment of South Africa and of the neighbouring states, and for his attempts to improve the quality of life for the developing sector of the country. Other awards include Honorary Fellowship of the South African Institute of Measurement and Control, Fellowship of the College of Engineers of the Society of Professional Engineers, Honorary Fellowship of the Institution of Nuclear Engineers, the Engineer of the Year Award, and the Gold Medal Award of the Institution of Mechanical Engineers.

On the technical side, Dr McRae has always set high standards, resulting in Eskom being known for its quality of technological expertise. He has always supported the need for research and development, despite serious financial constraints. Apart from his technical knowledge, he has always been popular at all levels as a leading businessman.

Dr McRae has been described as a person with a rare combination of traits which allows him to be equally at home in a highly technical environment and yet able to relate to people at all levels and from all walks of life. This has enabled him to bring closer to fruition his vision of an interconnected African Grid which he first described in 1987. At that time, however, South Africa's political isolation made it seem like a dream. He continued to propagate this idea by talking to politicians, other utilities and people of influence, so that today the idea has the possibility of becoming a reality. Under the slogan, "Electricity for All", he sees Eskom as the catalyst in bringing electricity to the millions of South Africans presently without it.

Ian McRae is known and respected worldwide in electricity circles. In 1989, he was a signatory to the World Association of Nuclear Operators (WANO) Charter in Moscow.

Experienced in all facets of the business he heads, Ian McRae has been described best in the words taken from the citation of his latest award, the Servant Leadership Award from Samford University Business School, Birmingham, U.S.A.:

> Listening to people, serving real needs, empowering employees, developing communities, thinking globally, acting ethically and affirming individual dignity and worth - these are the hallmarks of leadership in the 21st century. ...The Servant Leadership Award stands as a testament to the philosophy that in order to lead, one must also serve.

Dr McRae is married to Jessie and they have two children, Heather and Donald, neither of whom have followed in their father's footsteps. Heather is in finance and Donald in publishing - he has recently had a book published. Both live overseas. When he not dealing with the problems of Eskom, Ian McRae enjoys a keen and regular game of bowls, and jogs. He also enjoys gardening, the theatre and watching sport.

# Sub-Saharan energy financing: The need for a new game plan

* M SCHLOSS

Since the beginning of the 1990s, there has been a growing realisation that the energy sector is pivotal to development and constitutes one of the largest development expenditures in the Sub-Saharan region – with a sizeable portion of capital and recurrent costs being in foreign exchange. This sector is thus becoming an important element in national debt strategy and macro-economic management, and needs a reassessment of strategic thinking. This paper sketches the financial and institutional implications of future energy investments in the region from the World Bank's view.

**KEYWORDS:** energy financing; Sub-Saharan Africa; development

## The setting

Africa can take heart from its rich energy resource endowment: 300 GWh of hydropower, 250 GWh equivalent of identified natural gas, and known petroleum reserves which are equivalent to 120 years of supply, at the present rate of Sub-Saharan Africa's petroleum product consumption. Important strides have been made in setting up impressive institutions, such as, Compagnie Electrique du Benin and the Volta River Authority, with significant impact in power and associated development in all the countries concerned. Sub-Saharan Africa also has substantial reserves of coal and biomass. But despite these accomplishments, we are barely scratching the surface of Africa's resource potential. These resources are far from being the cornerstone of sustained economic growth they could be and should be across the continent.

One does not have to look far within this region to see examples of economies with enormous growth potential, an emerging private sector, markets hungry for manufactured goods which can be made locally, but which are constrained by power outages while natural gas is being flared, and hydropower dams are spilling energy. Indeed, in the final analysis, the essence of energy and development is indistinguishable – to make the human condition more bearable. No matter what path of development is chosen by a country, ultimately development depends on the effective substitution of other means of energy for human labour. If

"One does not have to look far within this region to see examples of economies with enormous growth potential . . ."

Africa is to grow, it will inevitably have to expand the use of energy.

Few parts of the world have such an imbalance between resource endowment and commercial utilisation. But in the 1990s, exploiting this endowment in the quest for growth poses two special constraints.

Firstly, the investment required is huge by any historical standard, with an annual total investment rising from around US$2 billion in 1990 to US$4,7 billion in 2000. The global pool of investment resources appears to be stagnant if not shrinking, and African countries face stiff competition in mobilising these resources from newly emergent market-oriented economies, such as those countries previously belonging to the Soviet Union, that have been starved of investment for decades.

Secondly, there is increasing concern about the environmental implications of large-scale energy resource development, about the good husbandry of our precious natural resources, and the sustainability of the benefits of their exploitation. It will take longer to plan and develop these natural resources now than before, and there is a growing link between the availability of investment financing and the environmental soundness of resource development.

The real challenge for Africa lies not so much in building more power plants, more transmission lines, or pipelines, but in building the institutional capacity and creating the type of environment that will get the job done. This is particularly important in the inhospitable environment in which African countries in general and capital-intensive sectors, such as, energy in particular, are seeking to work their way out.

Are we ready for this challenge? Frankly, the answer must be, "No"! To know where to go from here, it is important to understand where we are now. This is what this paper explores in the understanding that the World Bank is a partner in this joint enterprise.

## The capacity building challenge

While much has been done to develop human and physical resources, the institutional framework is inadequate to meet the challenges ahead. Included in this catch-all of "institutional framework" are public utilities, civil service administrations, and the regulatory and incentive systems that help create the business environment. The power sub-sector is used as an illustration because it is regarded as arguably the most capital-intensive component of the energy sector in Africa.

Despite repeated efforts for decades, the Bank, and most governments, with a few important exceptions, failed to leave a lasting legacy of strong and capable institutions that can develop and supply

Based on a publication with the same title by this author and published as Division Note No.5, December 1990, by the Industry and Energy Division of the World Bank's Africa Technical Department.

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energy reliably and cost-effectively; institutions that instil confidence in consumers and investors alike; that are not demonstrably subject to political interference; that routinely make a respectable rate of return on investment; that are financially viable and capable of contributing adequately to substantial new investment in the face of rapidly growing demand; and - the "acid test" – that can raise funds for their investment programmes independently of government.

More fundamental yet, the assumption has all too frequently been, explicitly or implicitly, that only governments "do" the power business. Following this assumption, less attention has been given to the institutional framework for promoting private initiative and participation, to a regulatory and incentive framework which ensures that all participants are motivated, in a competitive environment, to expand and improve the quality of consumer services. In the process, the Bank's lending in various sectors, has inadvertently over-extended the State apparatus, forgetting that administrative capabilities are one of the scarcest factors of production. Hence, the need for a re-appraisal. Such a review should not be driven by ideology but rather by pragmatic consideration of the tasks at hand.

In this connection, the question must be asked: How big is the financing challenge facing the sector in the years to come, and what are the institutional implications?

Over this decade, it has been estimated that electric power investments in Sub-Saharan Africa, will require about US$11 billion in foreign resources to finance some 4 300 MW of additional capacity, that is, over US$1 billion per year. While hydropower will continue to play a major role, a substantial increase is planned in investment in gas-fired power plant (30% of planned new capacity or 1 500 MW).

***Can governments and their power utilities mobilise this financing?***

Throughout the continent, many utilities are technically bankrupt. Few earn close to the type of returns required to attract the resources necessary for the 1990s. All depends on government credit, and this can be precarious. Governments across this region face huge demands for the use of scarce public revenues and they are increasingly unwilling to bankroll the large capital requirements of the power sector. Public borrowing on behalf of the energy sector account often for more than 20% of the external debt.

While Africa's needs are only 1,5% of the global total of US$750 billion, most of its financing must be on concessional terms if borrowing is to be affordable. When seen as a proportion of the total availability of concessional funds, Africa's needs are much more significant. Also, international donors and borrowing governments are not as willing as they have been in the past to finance new power sector debts. The Bank has estimated that, under the most optimistic of scenarios, external aid flows can finance only about half of the required total.

## The Bank's contribution: Past and future

The question may be asked what role the World Bank will play in mobilising energy sector financing in Africa, and what it has done so far. For the whole of Sub-Saharan Africa, from 1980 to the present,

**"Outright sale of utilities would not be a popular, or perhaps even a useful, option in Africa . . ."**

the Bank will have contributed about US$2,1 billion to energy sector development, amounting to 7% of total Bank lending to these countries in that period. The flow of Bank resources to Africa's energy sector has fluctuated substantially during this period. In the early 1980s, it averaged US$150 million per year, in the mid-to-late 1980s, US$100 million per year, and in the last three years, over US$300 million per year. Even in inflation-adjusted terms the Bank's present lending has increased compared with ten years ago. The Bank's present business plans for the next three years (FY92-FY94) suggest a 25% increase in sector lending in nominal terms, averaging about US$377 million over this period - without counting the financing indirectly available through policy lending planned in the region.

Why cannot the Bank and bilaterals do more? Of course, by rearranging the sectoral allocation of lending, the energy sector could be a greater beneficiary than at present. But even a substantial reallocation will not make that much of a dent in the problem. Given the projected levels of financial requirements, the entire World Bank lending to the region would have to be oriented to the power sector alone if the foreseen gap is to be closed - a clearly unrealistic assumption -, since it implies subordinating macroeconomic and other sectors' requirements to the needs of the power sector.

Part of the value of Bank involvement is to allow for the leverage of the flow of substantial additional resources in co-financing of projects by other multilateral development banks and bilateral donors, amounting often to double or more the Bank's contribution. This can be more easily achieved in the energy sector than in other sectors.

## Alternative financing sources

If the government's contribution is restrained by competition for scarce public resources and donor funding is at best half of total sector foreign exchange financing requirements, what alternatives are there? There appears to be two: private domestic and foreign capital.

For the most part, African capital markets are non-existent. Those few countries with an active capital market trade very small volumes of equity and debt issues, and none of the Bank's power utility clients have gone to capital markets successfully to raise substantial new debt financing. Constrained capital markets are also the product of historical reliance on taxes to finance most public infrastructures, rather than utilising private savings. And since, in the earlier stages of economic development, public infrastructure dominates total investment needs, limited capital markets are an inevitability.

It is interesting to note that this is exactly the reverse of the process that took place in today's developed countries. Most public infrastructure was financed from private savings and it was the need to mobilise the savings of thousands of small savers that led to the development of the capital markets in these countries. The ability to mobilise private savings for the financing of electric power will be a critical factor in this decade. Yet few African utilities are today in a position to tap into those markets. This fact adds just one more justification for sweeping financial sector reform, and the development of healthy African capital markets. However, in the short term, resorting to domestic capital markets offers no solution to the energy sector financing problem.

Direct private sector financing is a more promising option. Private sector participation offers the double benefit of an injection of new technical and management skills as well as capital, and can take two generic forms: transfer of ownership of an entire public entity, such as, the power utility, or private sector ownership and operation of parts of power systems under arrangements agreed with the public utility. For example, generating power for sale to the public grid, or owning and operating parts or all of the distribution system with power being supplied by the public utility. If private sector participation were to involve transfer of ownership of existing assets, the resulting short-term cash generation would be the least important outcome from a financing perspective. The real benefit is that the government would no longer be responsible for raising funds for, or underwriting power sector investment.

Outright sale of utilities would not be a popular, or perhaps even a useful, option in Africa, whereas private sector investment in generation, transmission or distribution within the framework of a public utility will be an increasingly important source of sector financing during the next decade. Such opportunities are commonly referred to as BOO (Build, Own and Operate) or BOOT (Build, Own, Operate and Transfer) projects, for the power infrastructure, more commonly of power generation capacity.

## Institutional capacity and sector management

If it is acknowledged that there is a need for substantial private sector financing to meet the emerging financing gap and to sustain economic growth in this region, then the question must be asked as to whether the institutional framework is up to the task. Is the business environment in the sector conducive to private sector participation? Can power utilities readily establish cooperative arrangements with private capital to the benefit of the economy and individual consumers? Will they be judged by the private sector as competent and reliable partners? What sort of performance record is available?

## Performance

In connection with the power sector, the question is whether it is the power utilities' performance or the government which is to blame.

At this point, it is fashionable to blame governments for this state of affairs. If only the government would stop interfering in the sector; if only the government would grant the requested tariff increases; if only the government would stop inflating the currency and restricting foreign exchange; if only the government would authorise reasonable salary levels, and so on, with a long list of complaints. But to be realistic, governments have always done these things. If governments own the utilities, they will govern them through the political process. That is a fact of life.

> **"Electricity is not being produced at costs that reflect the abundance of natural resources."**

By confusing the role of shareholder and manager, by refusing to provide real autonomy in exchange for real accountability, by interfering at will in critical business decisions, such as pricing, investment planning, manpower planning and remuneration policies, and by burdening utilities with social and political objectives in addition to commercial and service objectives, instead of being part of the solution, government interventions have become part of the problem. This is reflected in a number of ways:

(i) First and foremost, in financial performance, where few, if any, utilities earn a respectable rate of return. Electric power tariffs are frequently a fraction of what they should be to meet the average incremental cost of power system development. The average power tariff on non-CFA countries in Africa in 1987 was about 5,6 cents/kWh compared with the average for OECD countries of 8,2 cents/kWh. Does that mean that African countries are 50% more efficient than OECD countries in supplying electric power? The implied subsidies are substantial, and the pricing structure is not going to inspire investors to put their money into power system expansion.

(ii) Working with a number of bilateral agencies, the Bank has recently made a detailed review of electric power utility efficiency in 22 African countries, as well as others elsewhere. For the African utilities, the average age of accounts receivable is almost seven months, comprising about four months for private sector accounts and 12 months for public sector accounts.

(iii) Non-technical losses, a euphemism for any number of sins, are about 11% of power sent-out for a smaller group of utilities, and total system losses (technical and non-technical losses combined) average 19,3%. In a well-managed power system these should not greatly exceed 10%.

(iv) Have the right investment decisions always been made? Leaving aside the list of white elephants on which there could be general agreement, it is interesting to note that average capacity utilisation in Africa is about 50% compared with 70-75% in Latin America and Asia. As a result, a few large countries in Africa have more than 135% reserve capacity!

(v) Predominantly hydro systems should have low labour costs. African utilities typically have 50-100 customers per employee. In Korea, this figure is close to 300.

On over-investment, with the benefit of hindsight, there is an uncomfortable feeling that the Bank may have been party to some unwise, or more precisely, untimely decisions. The Bank has asked itself how many times has it been sufficiently uncritical of power demand forecasts during project identification and preparation, ending up supporting capacity expansion when forecast demand was largely illusory, only to turn around under a later lending operation and insist on sharp tariff increases, or utility debt reduction measures, to compensate for expensive unused assets. In a recent retrospective comparing the Bank's own power demand forecasts with eventual demand, it has been found that in more than 80% of cases the forecast was much higher than the final result.

The early focus on hydro has led to a neglect of the region's substantial thermal resources, particularly natural gas, and the development of inflexible investment programmes. Changes in technology are increasingly making this the fuel of choice for electric power generation. Yet few utilities are prepared for the task or even fully recognise its potential.

More generally, most performance measures in African utilities fall far short of what is needed. Electricity is not being produced at costs that reflect the abundance of natural resources. Utilities over-invest to compensate for large inefficiencies. Power is then being sold at subsidised prices so that there is little incentive for consumers to use expensive resources efficiently. It is no wonder that the financial situation of most utilities has deteriorated as foreign capital and government subsidies have declined.

The blame for this poor performance cannot be placed on the management of these utilities. They have merely played their part. So too, have the consumers. They have seen that supplying electricity is part of the political process. They have, as individuals and as groups, tried to capture their "share" of the public purse. In the end, efficiency has suffered. And what is the solution?

Some would argue that the game must be played in a more "honest" or more "fair" manner. If only governments would behave better, if only management would be more efficient, and if only consumers would be more understanding and less selfish. The World Bank has tried to work with these "if only's" for many years. The results are discouraging. Real life shows that such political realities cannot be wished away. Problems are not solved, they merely get bigger. As the old Lao Tse's proverb reminds us, "The biggest problems of the world could have been solved when they were small". And in the process, performance is not improving despite massive attempts to inject training and technical assistance. New problems, such as those associated with environmental and social relocation continue to elude solutions. Yet, solutions are needed. The impact of inadequate energy supplies on the process of economic growth is no longer just a threat, it is a reality.

## A new game plan

There is no alternative but to rewrite the rules of the game, to alter the present roles and responsibilities of the major players: between government, the energy institutions and the consumer. Indeed, to open the game up to a new player - the private investor. It will not be an easy task. The present system has been in place long enough to have strong vested interests in its continued existence, and ways will have to be devised to bring in elements of competition that can help reduce the grip of organised vested interests on the machinery of state and the utilities. The pace of institutional change will be determined by government, by individual country circumstances. One cannot, however, be complacent. Time is not on the side of those who would see an orderly process.

What are some of the elements of this new game plan? What will be the roles of the major actors?

Firstly, the role of the government. Government ownership has carried with it the implied obligation of the public sector to provide the necessary funding. In return, energy supply institutions have had to subject themselves to the political agenda of governments. This link needs to be broken. New means must be found for governments to exercise their necessary public responsibilities for the sector. These new means inevitably will require a more arm's length relationship between the government and the energy enterprises, where government exercises its controls through a more open system of regulation rather than through ownership. Public ownership, as experience has shown, does not necessarily mean public accountability.

Secondly, for their part, the energy enterprises need to be subject to the demands of less forgiving shareholders. If they are to earn the trust of those who lend them their savings, they will have to demonstrate that they can use these resources wisely.

There appears to be no alternative but to make the sector more competitive. Governments have neither the experience nor the resources for heavy administrative systems. They will have to rely on market forces, as much as possible, to complement limited regulatory systems. There appears to be no alternative to competition for improving the performance of the energy enterprises themselves. For too long, it has been assumed that the efficient production of energy requires conditions of monopoly. In country after country, this assumption is being challenged. The present monopolies need to feel the pressures of this competition.

What is meant by competition in the energy sector? Downstream petroleum product supply is already a hotly competitive business in many African countries. In Nigeria, the country with the biggest energy economy, up to eight foreign and local private companies compete aggressively in certain product lines. There is competition in the upstream petroleum area too, with multi-national oil companies vying for petroleum exploration and development concessions.

In the power industry, competition may take a different form. Eventually, a public utility should face the discipline of the financial markets in raising finance for development. In the short term, the regulatory framework in each country should make it possible for the private sector to compete for the right to provide, own and operate incremental sources of power, operate service functions, and even to supply power to regions of countries.

There are inherent problems of scale in Sub-Saharan African economies which virtually eliminate competition from bulk power supply, and capital limitations restrict most domestic private sector entrepreneurs to participation in concession arrangements for managing billing, collection and distribution systems, where the entry price is modest in comparison to major new power plant. Governments wishing to mobilise major new foreign capital for BOO- and BOOT-type investments must re-assure themselves that they have the sustained technical capacity to frame, negotiate, monitor and evaluate such supply contracts or major long-term concession agreements. To avoid being worse off than when they started, they must also go all out for competitive bidding internationally using creditable and transparent procedures. Only in this way will they attract credit-worthy, reliable bidders who can be the conduit for fresh capital, technical skills and business management know-how of lasting value to the economy.

The region should not become fixated by large-scale projects and extending centralised grids. There can be useful competition between expanding networks and local power supply options in private hands. In the Pacific Islands, there is the emergence of commercially viable solar photovoltaic utilities for as few as 500 households and other end-users, each of which owns the end-use equipment of lights, pumps, refrigerators. However, the utility owns and maintains the "power system" - the panels, controllers and batteries.

The alternatives aside, the message is clear: public monopolies need to have their monopoly rights challenged! If an alternative supplier can do a better job, they ought to be given the chance.

Thirdly, the consumer or general public and the regulatory implications should not be forgotton. If the consumer is expected to pay all the costs, he must be a party of the "deal". If he is expected to lend savings to this effort, he must be assured that his money is being used productively, and that it will earn him a return for his savings. The consumer will have to become a central part of the regulatory process. Regulatory boards, independent commissions and similar bodies must reflect consumer as well as government interests. Meaningful public hearings will have to be held.

Competition rather than ownership is the key. It is in this context that the often misrepresented option of "privatisation" is examined. Privatisation does not necessarily mean the outright sale of a power utility, including all its assets. Nor would the wholesale transfer of assets to the private sector necessarily solve the problems of institutional weakness and poor performance. What is required is to restore to all levels in the enterprise a balance of reward and responsibility that motivates individuals to contribute at their highest level. Without changes in management autonomy, improvements in accountability, and the discipline of increased competition, privatisation can be a sham. In fact, one of the most useful forms of privatisation is to establish a long-term concession arrangement whereby for a power company, a long-term management contract is bid competitively, and results in a contract with a significant part of the payment driven by clearly defined performance criteria, in other words, a kind of gain-sharing arrangement. Leasing of government assets is also an option that deserves exploring. Beyond that, the prospects for contracting out power sector services to private bidders are more promising in the case of auxiliary services that do not entail the need to sink a large amount of costs, such as, billing, revenue collection, or maintenance.

Finally, another element in the new game plan must be greater *economic integration* through much enhanced regional cooperation in energy development and trade. Most African economies are too small, and natural energy endowments too varied to expect anything like equal prospects for development of the low-cost energy sources so fundamental to growth. In this region there are great opportunities for expanding power interconnections throughout Southern Africa, including Angola, Botswana, Zimbabwe, Zambia, and Mozambique, feeding to and being supplied from South Africa as welcome political reform and outward orientation in trade and economic relations matures. There are excellent prospects for interconnection of Sudan, Ethiopia and Djibouti, of Tanzania and Kenya, and for enhancement of the existing Kenya-Uganda power interconnection. The Bank is already working with some of these countries to assist with the development of regional power trade, and stands ready to upgrade its efforts whenever requested.

There are important strides that have already been made towards sharing these resources on a commercial basis. Power system interconnections are already numerous, providing a firm foundation for distributing low-cost energy from resource-rich to resource-poor countries. An example the region can be proud of is the Togo-Benin-Ghana-Ivory Coast interconnection, and the role of the bi-national power utility, Compagnie Electrique du Benin (CEB), established in 1968, to provide low-cost power to these economies. To mention an exciting local development, the Bank has been invited by the government of Mozambique to assist in the rehabilitation and restoration of high voltage transmission links from Mozambique's Cahora Bassa hydropower plant to neighbouring countries, to reinstate energy exports from this valuable resource.

**"There is no alternative but to rewrite the rules of the game . . . . . . to open the game up to a new player – the private investor."**

Beyond that, to provide the underpinnings for further efforts in this direction, the Bank is about to embark on regional studies to identify options as a means of reducing the cost of petroleum supply through a range of region-wide and sub-regional cooperation and investments. The Kenya-Tanzania and inland supply sub-region, and the Zimbabwe-Zambia-Mozambique and inland supply sub-region are highly ranked to receive detailed options analysis under this regional study which is now fully funded and was scheduled to begin in January, 1991. Closely related to this study is a survey of the West Africa gas-based energy supply to evaluate the feasibility of exporting abundant Nigerian natural gas to up to ten energy-poor countries to the west of Nigeria.

The Bank also has, at various stages of preparation and implementation, and with various donor, multi-lateral agency and country partners, a range of petroleum resources development initiatives designed to accelerate private sector investment in exploration and development for export and local use.

These include the Red Sea Basin study now at mid-point, the East Africa Passive Margin study, and the Gas Development Strategies programme for Africa. The Red Sea and Passive Margin studies are designed to give countries and the oil industry a comprehensive picture of underlying petrogeological structures crossing many country borders, stimulating greater interest in under-explored yet high potential areas. Already, the Red Sea Basin study has played a role in moving exploration from nearly zero to contracts in excess of US$100 million dollars in the last two years.

The Bank has also prepared for donor funding a regional study on natural gas utilisation designed to shed light on, and devise ways to alleviate, constraints to private sector investment in development and local utilisation of existing gas resources, both domestically and for regional trade. There are several important known gas finds, such as, Pandi in Mozambique, and Calub in Ethiopia, which have been regarded to date as too small for commercial exploitation and unsuitable for domestic use. The Bank is convinced that these resources have good commercial potential and wants to assist countries in their early development.

Each of these studies is designed to mobilise foreign and local private investment in the development of Africa's rich resource endowment or improve utilisation of existing petroleum supply.

These initiatives are all very well, but the question is, is it all too idealistic? All changes around the world have started with dreams. In fact, there are already signs of change in many countries in the region, and the pace of change is exciting. The following are some examples:

(i) In the *Ivory Coast,* the government is paving the way for private sector participation in its power utility, EECI, with the establishment of a new majority private sector-owned and managed holding company, CIE, to operate the State-owned assets of EECI.

(ii) In the *Gambia,* having had the efficiency of the government's water utility dramatically improve when leased to the private sector, the government has now asked the World Bank for assistance in privatising its power utility, probably using similar long-term concession arrangements.

(iii) In *Kenya,* the government has sought USAID assistance to design the regulatory and incentive framework to enable private sector development of geothermal resources for sale of power to the public grid.

(iv) In *Nigeria*, the government is examining privatisation of power distribution as part of a larger privatisation programme, and is embarking on a programme of power utility "commercialisation".

(v) Both in the *Ivory Coast and Cameroon* options are being reviewed by these governments for the development of natural gas by the private sector for power generation to the public grid.

(vi) In the *Congo*, the government has expressed interest in workable privatisation options for its power utility.

(vii) In *Mauritius,* the government's power company has for a long time bought substantial power from private sector sugar producers, and since 1986, the largest single thermal plant in the power system, a coal- and bagasse- fired unit, has been privately owned and operated.

Each of the above initiatives provides, or offers, the chance to add private sector capital to the traditional sources of energy sector financing, or to increase the level of technical and management skills for the improvement of power sector efficiency, or both.

The crisis in finance has been used in this paper to highlight the need for change. The type of institutional structure outlined here, with its clearer delineation of responsibilities and greater accountability, is a necessary ingredient for improving performance in this area.

## Conclusion

To sum up, the concept of "business as usual" cannot be relied on to meet the challenges of the 1990s. The evidence is, unfortunately, overwhelming and the visible gaps in performance such that the problems cannot be dismissed as purely an expression of ideological bias. The events of the 1980s have assailed our optimism, and we now must be prepared to bite the bullet and thus rewrite the rules of the game. Institutions will have to rethink their roles and respond to changing conditions, and we all have to be prepared to shed approaches that have outlived their usefulness. There is nothing wrong with having been wrong in the past, provided that we adapt to the changing circumstances. The approach outlined here is aimed precisely at the introduction of elements of market-oriented behavior with a view to providing greater scope for, and stimuli to, better performance and improvements in production efficiency. There is no doubt that, given appropriate incentives, the sector can meet the needs for efficient, equitable and environmentally acceptable energy supplies.

The World Bank plans to be part of this process of change, just as it has been part of the solutions and the problems of the past. It is actively engaged in trying to help countries to break out of the circle in which they find themselves or, as stated earlier, to design a new game plan. The Bank plans to make a greater share of its financing available for this task – both to the public and to the private sectors. There is little doubt that funds will flow to those that are willing to change by creating conditions that attract resources, to meet the goals of the 1990s for efficient and safe energy.

# Energy and development

* R K PACHAURI

The paper examines the relationship between energy and development. It stresses that the concept of development needs to be revisited because of the change over the last 150 years in human desire which has been driven by a growing longing for the consumption and production of more and more goods and services, regardless of the impacts on the environment and human behaviour. In fact, certain countries could be described as having reached a level of "maldevelopment", where blind economic growth has been pursued while being detrimental to the environment and society as a whole. With regard to the developing countries, the author points out that energy efficiency improves only when overall economic efficiency has reached a certain level. Also, even with improved efficiency, the developing nations would require substantial increases in energy consumption. The paper highlights a big problem in the developing world, namely, that of biomass energy which is used mainly by rural populations, and the impact this has on the environment and the society. He emphasises that the developing countries have neither the money nor the expertise to improve their energy efficiency and are therefore reliant on the developed countries for assistance. The author stresses that it is essential for the local institutions and organisations to be involved in the technological developments which the developed countries offer to the developing countries. For example, a network of institutions should be set up in the developing world and provided with adequate resources for research and development on renewable energy technologies, devices and their dissemination, which are within the capabilities of the developing countries.

**KEYWORDS:** development; economics; developing countries; technology transfer; biomass; energy efficiency; energy consumption

Studying the relationship between energy and development is important today, because with the growing concern worldwide on the environmental effects of energy production and use, the subject of development and its dependence on energy appears to have lost its conventional significance. It hardly needs to be emphasised that at various stages of the evolution of human civilisation specific technologies or innovations for harnessing energy in some form or the other have had a profound impact on the manner in which human activities and welfare have progressed. For instance, the invention of the wheel was the first step in harnessing muscle power, both animal and human, an invention which has proved over time to be the most revolutionary of all in shaping the path of human development. Subsequent inventions, such as, James Watt's steam engine, Thomas Edison's electric lamp and the mass production of the internal combustion engine, have all marked turning-points in the way human beings live and work, and these have impacted directly on the manner in which energy came to be utilised for specific end-uses. It is necessary to remember that the industrial revolution which ushered in an era of rapid prosperity in several parts of the globe was accompanied by a major expansion in the use of energy, made possible through a series of technological breakthroughs involving both the supply and use of energy. The second point that should be put forward as a fact, often ignored or forgotten, is the reality that a large part of the human race is today gripped by widespread poverty, which can only be improved through an absolute minimum level of energy use as an input to a range of activities that provide the very basic of services for a secure and stable human existence.

> **"... gains in energy efficiency will not in the foreseeable future, at least, prevent increases in energy consumption in the Third World if development is to take place."**

The concept of development itself, of course, requires to be revisited, because somewhere during the past 150 years or so, a large proportion of the human race has been propelled by a growing desire for the consumption and production of more and more goods and services, oblivious of the impacts that these may be imposing on the environment and on human behaviour itself. The atomisation of individual existence that one sees growing evidence of, and the breakdown of social structures, family life and strong human relationships undoubtedly flow, at least in part, from a preoccupation and obsession with the acquisition and use of more and more consumer goods and devices, which can hardly be substitutes for the social values and relationships that have supported human civilisation for thousands of years. Never in the history of the human race has there been such a rapid increase in the use of man-made goods and services, in the use of "exosomatic limbs" by human beings, in the words of Nicholas Georgescu-Roegen[2]. It is, therefore, necessary to understand, first and foremost, the concept of development itself before one can step further into the pathways linking energy with development.

In this regard the United Nations Development Programme (UNDP) has made a pioneering effort in conceptualising and measuring the variable called human development. Its annual publication, the Human Development Report[5], attempts to explore the concept of human development for all the countries of the world, establishing the difference between an assessment purely of economic output and an index of measures of human development which comprises a number of variables more directly linked with human welfare. This measure will be examined later, but at this stage it would be worth referring to the term aptly used by Paul Ehrlich[1] in describing certain countries as having reached a level of "maldevelopment". In other words, a blind pursuit of economic growth does not necessarily result in increased development because, beyond a certain range, society may

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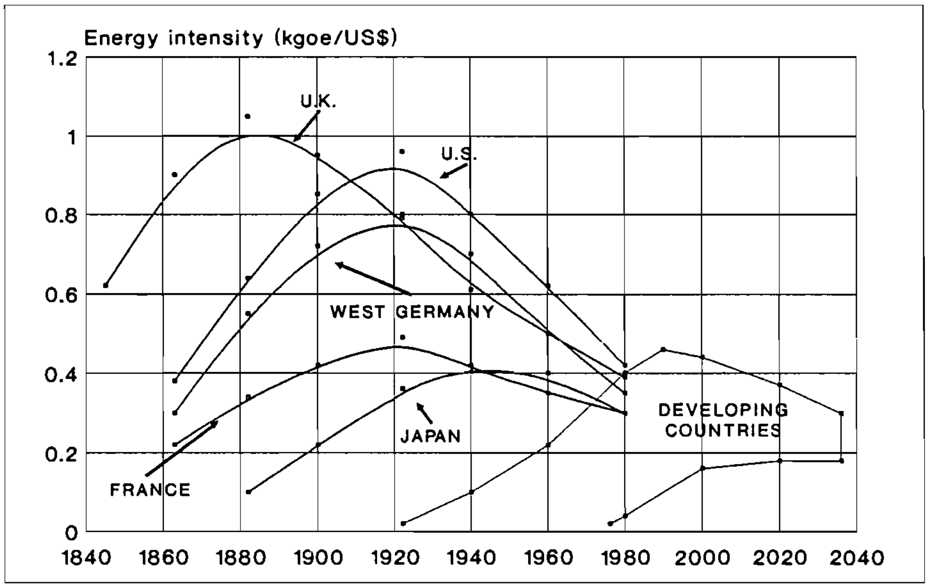


*Figure 1:* *Energy intensity of commercial fuels*

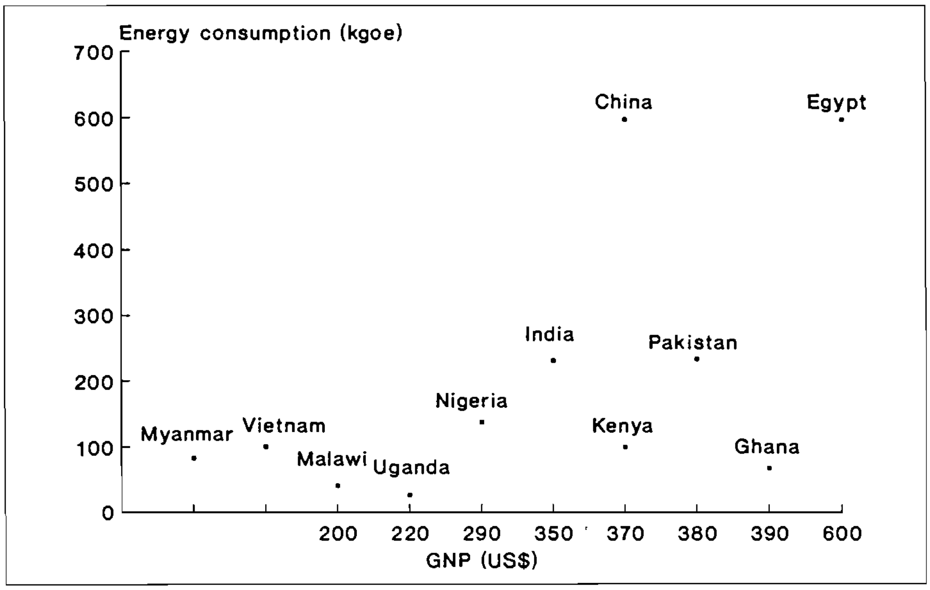


*Figure 2a:* *GNP and energy consumption per capita in selected low income countries*

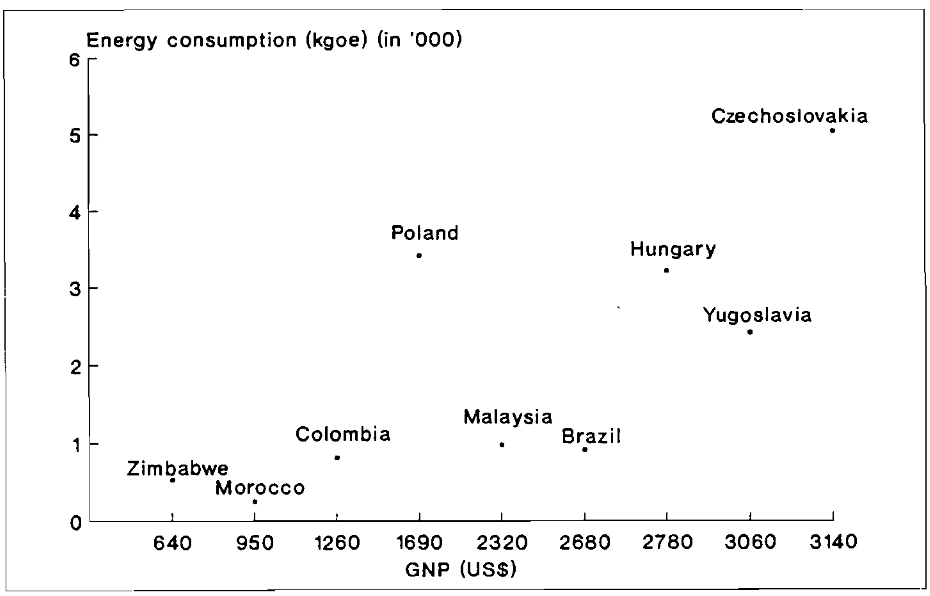


*Figure 2b:* *GNP and energy consumption per capita in selected middle income countries*

suffer from the excesses of economic growth, with an unfavourable impact on the environment and on society in general, which seems to suggest that economic growth should have some definable upper limits. Or else, at least, beyond a certain stage, the structure of economic growth may need to be altered because a large part of the output of goods and services may have to be allocated to countering and mitigating the ill-effects of further increases in the output of goods and services.

It would be useful to review the historical record of energy use in relation to economic growth, which is brought out by the familiar numbers shown in Figure 1, wherein is plotted the use of energy per unit of Gross Domestic Product (GDP) in relation to economic output. Energy intensity is expressed as the amount of energy (in equivalent metric tons of petroleum) consumed to yield US$1 000 of the GDP.

The path of energy intensity in countries that have industrialised in the past exhibits an increase in the initial period of economic development which has been replicated in other cases which industrialised later. However, what has not been repeated by those countries that developed at a later stage in time is the peak that was reached by countries that industrialised earlier. Today there is much concern about the future consumption of energy in those populous nations which are in the process of industrialising. This concern can be partly dispelled by the fact that countries industrialising today are, in any case, on a lower trajectory of energy intensity than those which industrialised earlier. This is brought out in Figures 2a, 2b and 2c which clearly show the cluster of developed countries on a higher energy intensity path, including the nations of the former communist bloc, in contrast with the developing countries who are clearly on a lower trajectory of energy intensity.

The process of economic development would necessarily require a much larger consumption of energy in the developing countries than is currently the case. Undoubtedly, there is significant scope for improvements in energy efficiency that could moderate the rate of growth of energy consumption over the years, but often the case of energy conservation and higher efficiency is overstated and put forward within the unrealistic framework of technological fixes for a variety of end-uses. A sense of realism has to guide the assessment of energy conservation potential and possibilities in the developing countries, as should be the case with

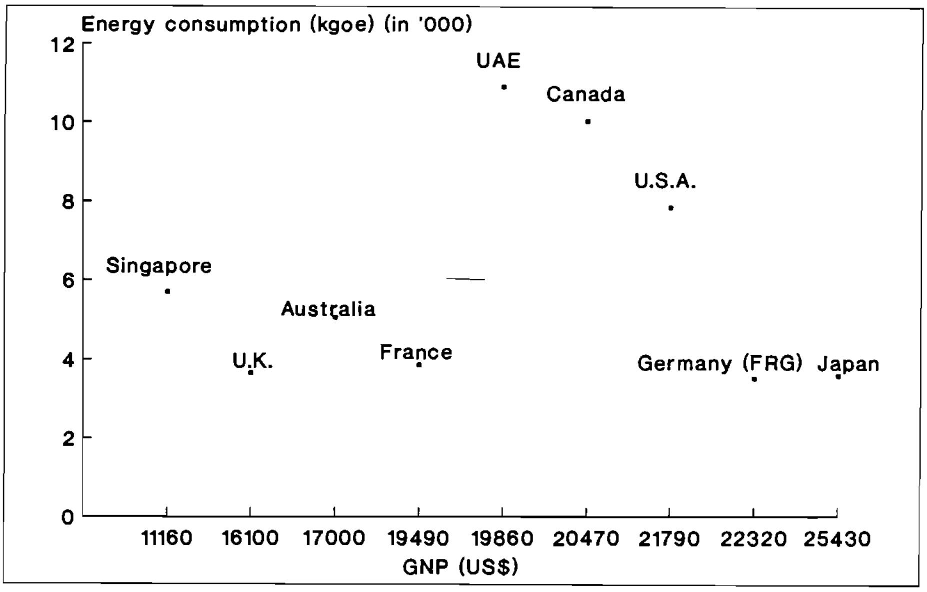


*Figure 2c: GNP and energy consumption per capita in selected high income countries (Source: World Bank[7])*

investments that are designed to bring about an improvement in energy efficiency. Energy efficiency gains cannot be treated in isolation of the efficiency of use of other inputs and resources in an economic system. For instance, a developing society is generally at a stage of lower development only because it has not reached a level of efficiency in the utilisation of its manpower, capital resources and even natural resources. Efficiency gains in respect of any of these inputs for the production of goods and services require the development of institutions, human skills and infrastructure which are created only in the process of development itself. In essence, the leap-frogging of technologies takes place in such societies under a set of severe limitations. It is only a one-legged frog that leaps from one technology to another under the constraints generally operating in a developing country. In recent years, far too much has been made of the wonders of energy conservation based on make-believe scenarios. These scenarios generally rest on an assumed best possible mix of technologies available to a society, as though technology adoption and dissemination could take place in the analyst's world of idealism, totally devoid of economic realities, boundaries and limitations. An assessment of energy efficiency gains programmes in recent years breeds scepticism about the extent to which energy conservation can show results in a developing country. A study of those nations that have had notable success in this respect indicates that energy efficiency improves only when overall economic efficiency has reached a certain level, or when development processes have worked their way through the system to allow absorption and diffusion of innovation and technological change, leading to higher energy efficiency. In a paper published by this author and Professor J P Holdren[3] in 1991, scenarios of energy efficiency were developed for the nations of the Third World to project future energy consumption levels, and it was clear that even with improved efficiency these nations would require substantial increases in energy consumption. Table 1 illustrates this in quantitative terms.

| | | | Actual | Projections | | |
|---|---|---|---|---|---|---|
| | 1980 | 1990 | 2000 | 2010 | 2020 | 2030 |
| **Population (Millions)** | | | | | | |
| Industrialised | 1075 | 1158 | 1215 | 1260 | 1295 | 1315 |
| Developing | 3310 | 4085 | 5000 | 5900 | 6750 | 7575 |
| **Energy Use/Person (Watts)** ****"Business as usual"* | | | | | | |
| Industrialised | 7170 | 7255 | 7360 | 7465 | 7570 | 7675 |
| Developing | 615 | 770 | 965 | 1205 | 1500 | 1880 |
| "Energy Efficient" | | | | | | |
| Industrialised | 7170 | 7255 | 7435 | 7225 | 6325 | 6285 |
| Developing | 615 | 770 | 950 | 1340 | 1720 | 2300 |
| **Total Energy Use (****Terawatts)** *"Business as usual"* | | | | | | |
| Industrialised | 7,7 | 8,4 | 8,9 | 9,4 | 9,8 | 10,1 |
| Developing | 2,0 | 3,2 | 4,8 | 7,1 | 10,1 | 14,2 |
| World Total | 9,7 | 11,6 | 13,8 | 16,5 | 19,9 | 24,3 |
| *"Energy Efficient"* | | | | | | |
| Industrialised | 7,7 | 8,4 | 9,0 | 9,1 | 8,2 | 8,3 |
| Developing | 2,9 | 3,2 | 4,8 | 7,9 | 11,6 | 17,2 |
| World Total | 9,7 | 11,6 | 13,8 | 17,0 | 19,8 | 25,7 |

(These figures have been compiled from various reports, and the author's own calculations.)

*Table 1: Conventional projections for use of industrial energy forms*

It can be stated conclusively on this subject, and with adequate empirical support and evidence, that gains in energy efficiency will not in the foreseeable future, at least, prevent increases in energy consumption in the Third World if development is to take place. Why such development should be in the interests of the global community as a whole would form the subject of another address by itself.

There is another aspect of energy and development on which hardly any light has been shed through research, and which is often ignored in discussions and deliberations in the field of energy. This is the large population in the developing countries which is dependent on the use of traditional forms of energy, namely, fuelwood, animal and vegetable waste, agricultural residues, and biomass in different forms. The scale and size of this component of total energy consumption in the Third World continues to increase, even though its relative share is steadily on the decline. To understand the impli-

*** "Business as usual" results have been obtained by extrapolating 1980-90 rates of increase in per capita use of industrial energy forms for industrialised and developing countries.

**** 1 terawatt = $10^{12}$ W

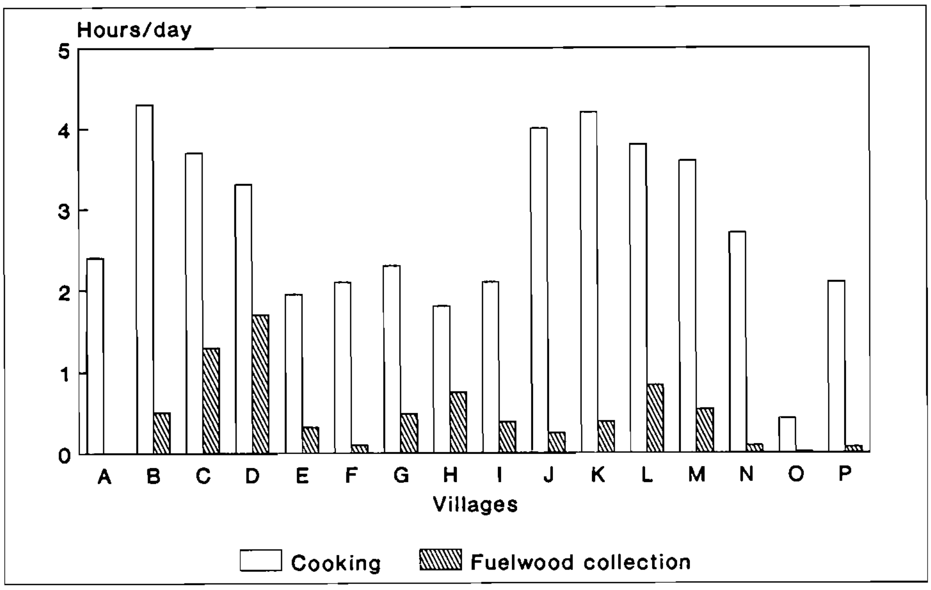


*Figure 3: Summary of household time allocation in rural areas of developing countries*

**Key of names:**

| | |
|---|---|
| A = Machiguenga, Peru | B = Huancarama, Peru |
| C = Pincos, Peru | D = Matapuquio, Peru |
| E = Mukono, Buganda, Uganda | F = Gombe, Buganda, Uganda |
| G = Nembure, Embu, Kenya | H = Pakistan |
| I = Neal (6 villages) | J = Bangladesh |
| K = Arjunahalli, Karnataka, South India | L = Hanchipura, Karnataka, South India |
| M = Keelava, Karnataka, South India | N = Kall Loro, Java |
| O = Long Segar, Kalimantan, Indonesia | P = Laguna, Philippines |

| Country | Trad. fuels | Total req. | % of trad. fuels total | Human devel. index |
|---|---|---|---|---|
| **Low Income** | | | | |
| Burkina Faso | 78 | 85 | 91,76 | 0,081 |
| Malawi | 132 | 147 | 89,79 | 0,179 |
| Mali | 50 | 58 | 86,20 | 0,072 |
| Mozambique | 148 | 162 | 91,35 | 0,155 |
| Sri Lanka | 79 | 159 | 49,68 | 0,665 |
| Kenya | 341 | 427 | 79,85 | 0,399 |
| India | 2603 | 9983 | 26,07 | 0,308 |
| **Middle Income** | | | | |
| Costa Rica | 33 | 100 | 33,00 | 0,876 |
| Philippines | 348 | 928 | 37,50 | 0,613 |
| Peru | 84 | 496 | 16,93 | 0,644 |
| Brazil | 2158 | 7133 | 30,25 | 0,759 |
| Colombia | 207 | 1216 | 17,02 | 0,757 |
| Chile | 58 | 547 | 10,60 | 0,878 |
| Portugal | 6 | 574 | 1,04 | 0,879 |

(These figures have been compiled by the author from the United Nations 1988 Energy Statistics Yearbook[5] and 1991 Human Development Report[6]).

*Table 2: Correlation between levels of human development and extent of dependence on biomass fuel (quantities in 1000 Terajoules)*

cations of the continuing and increasing use of biomass energy resources, it is necessary to look at various dimensions of this problem. Firstly, the use of biomass energy, in general, has serious environmental impacts. These environmental impacts include the felling of trees (even though the deforestation impacts are often exaggerated), the health effects of cooking with biomass energy on those who are exposed to the emissions, mainly women and children, and the general deterioration of air quality in an area where extensive use of biomass takes place. The other (perhaps the more serious) impact of continued biomass energy use, particularly in the situation of growing scarcity of biomass resources, lies in the fact that considerable time needs to be spent in the collection of the normal daily requirement of traditional fuels, and in cooking with the combustion of generally low calorific value, and often almost incombustible, fuels. Some data on the time spent on these activities are shown in Figure 3.

The social impacts of this expenditure of time are far more serious than the figures indicate. Firstly, the effects of these activities on the health of women, who are the main toilers in these activities, are serious. These impact unfavourably on the life of a family and, therefore, on society as a whole. Often, children are drafted into assisting with the task of fuel collection, and even in situations where elementary education is provided free of cost, the value that the family derives from fuelwood collection using children acts as a strong reason for school drop-outs. There is, therefore, a direct connection between the extent of time spent by a family on collecting and using biomass fuels, and the extent of education received by the community. At the aggregate national level, the human development index and extent of traditional biomass fuels usage show a strong correlation. These are brought out in Table 2.

It is not easy to establish cause and effect between one and the other set of variables, but it is quite clear that the association between these two is significantly strong. There may be some reason to believe, therefore, that the ability of a community to use substitute forms of conventional energy for basic needs like cooking and space-heating would reduce the burden on women and children, also providing thereby a more favourable set of conditions for the schooling of the next generation. At the national and global levels the alleviation of energy problems in rural areas, where the bulk of biomass energy consumption actually takes place, should be an important objective.

In order to assess the dimensions of this problem from the perspective of a transition to conventional energy sources it has been estimated that the total consumption of traditional fuels world-wide is currently 18,726 x $10^6$ TJ. The efficiency of use of this quantity is generally at a level of 8%, yielding, therefore, a useful energy output of barely 1,498 x $10^6$ TJ. If this quantity of traditional fuels was to be replaced by conventional fuels, which normally would permit a device efficiency of 50%, this could be achieved through a consumption of 35,78 million tonnes of oil equivalent (MTOE) of petroleum products annually. In other words, a total consumption of about 1,2% of the total world production of petroleum would be sufficient for reducing 50% of the traditional fuels used throughout the world. At a cost of US$20 per barrel of petroleum this would require a total expenditure of around US$5 billion annually. Such higher consumption of petroleum products in several countries would involve the import of refined products, particularly kerosene and LPG, but in some cases there may be a preference for enhancing indigenous refining, which would involve additional investments in new refinery capacity. The government or the petroleum industry in the country concerned would have to mobilise such investments as required. In addition, consumers would have to make investments in new stoves and connections to use the petroleum product in question in order to reduce traditional fuel use. Assuming costs that are applicable to India, it has been estimated that the total level of such private investments must be somewhat in excess of US$2 billion on a global basis. It must be emphasised that such an investment is generally beyond the capacity of the poorest people of the world, that is, those who would really be the target group for such a programme.

The computation above is presented only to outline the dimensions of what is possible and desirable, and to emphasise the fact that this is a target well within the reach of the global community. However, it would not be possible to achieve success with any such global programme unless appropriate investments are mobilised through channels which would ensure the success of such an initiative. Even more important than the investments themselves would be the creation or strengthening of the institutions and the infrastructure in these societies, both at the national and the grassroots level. In essence, local institutions would have to ensure the distribution of petroleum products as implied in the programme mentioned above. Then there is also a more difficult challenge, namely that of ensuring that those who receive this benefit are also able to pay for the fuel supplied. This, in the case of women who are currently spending time collecting fuelwood, could be attempted through an employment programme which has a commercial objective and which, in essence, supplies fuel for work to monetise the transaction at the level of the user. This, of course, is a difficult task to accomplish and would require a new dimension to be added to development programmes at the grassroots level. Its success would lie critically in a bottom upwards approach, rather than a centralised effort which is conceptualised and controlled at the top. What this implies, in the real sense, is the articulation and implementation of a new paradigm for economic development among the poorest communities of the world. In fact, nothing short of such an approach is likely to work. It is not suggested that a grand global plan of action be adopted. But in the initial stages of such an effort, the implementation of a few pilot schemes could be established to become the nucleus of a much larger global effort. The initiative for this must come perhaps more from national governments than from multilateral or bilateral donors, even though the involvement of these latter organisations may be important in accelerating the process.

**"Subsidies in rural electric supplies have . . . become a major barrier in the spread of renewable energy technologies."**

In discussing the problem of biomass energy used largely by rural populations in the Third World, only the very basic energy requirements for cooking and heating applications have been examined. Other major end-uses for which energy is largely deficient among the poorest masses of the world are in respect of lighting and motive power. The conventional approach for lighting throughout the world is through investments in the expansion of electric power grids, often with heavy subsidies which have become financially unsustainable in several countries. Given the high subsidies which permit the continuation of low tariffs for electric power in rural areas, the acceptance of alternative energy devices based on renewable forms of energy becomes financially unattractive to the consumer. Subsidies in rural electric supplies have, therefore, become a major barrier in the spread of renewable energy technologies in several parts of the world, where they have already become viable in economic terms. Here again the absence of local institutions for managing energy supply and distribution, and the predominance of large electric utilities whose traditional practices favour large grid expansion would, over time, become a major constraint. What applies to the distribution of fuels for cooking and the need for the development of local institutions applies with greater force to the dissemination of renewable energy technology. The development of local organisations and skills in rural areas for promoting the use of renewable energy sources is an important forerunner of development in these areas. Wherever renewable energy projects have been executed in the past they have generally followed the approach of technologies being developed in the countries of the north, and hardware being dumped in remote rural locations without the development of the necessary local infrastructure and expertise. It is no surprise, therefore, that most of these projects result in dismal failure.

The development of local capabilities and institutional strengths lies at the core of promoting development in a sustainable manner in the poorest regions of the world. Capabilities and capacities have to be strengthened not only in the scientific and technical field, in energy planning at the national level and, of course, also at the most decentralised grassroots level. In this regard, the records of several multilateral and bilateral organisations have been nothing short of a disaster. The favoured approach has been to engage a group of consultants from countries in the North, often with mediocre skills and inadequate familiarity with local conditions, to carry out studies and consulting assignments by "parachuting" them into a country for a few weeks, at the end of which they are supposed to have identified all the energy problems of the country and also to have evolved solutions to eliminate them. What is left generally at the end of these consulting assignments is a voluminous report on energy strategy which is of value neither as a professional exercise nor of direct use to the organisations in the country for devising local plans and investments. In the technological field, again there has hardly been an attempt to involve local institutions, for instance, in the development of renewable energy devices. In the absence of such an approach technological change does not get endogenised.

Today there is a powerful need for setting up a network of institutions in the developing world and providing them with adequate resources for research and development on renewable energy technologies, devices and their dissemination. If this approach is not adopted, the developing countries would be constrained to follow the fossil fuel path of the developed countries, even when there is a compelling economic reason for other choices based on renewable energy sources which are becoming more and more relevant in view of technological change and environmental costs, both globally and locally. But resources would again have to be found for such a programme of networking, which is not only beyond the capacity of the developing countries to harness, but which developed countries have a moral responsibility to provide, at least for global environmental reasons.

Agenda-21 not only represents an imaginative and forward-looking attempt to embody a sustainable energy development programme for the world in its broad entirety, but also a moral basis for a mutually beneficial scheme of resources flows which must finance such a programme in the years ahead. The questions before the global community are really whether it is willing to make major changes in lifestyles at the level of society as a whole and whether governments are willing to seize the advantages of an elusive peace dividend. There are still nations that spend in excess of 20% of their GDP on military hardware and equipment. Despite the disappearance of tensions between East and West, wars and trade in arms and the instruments of war have not disappeared. Robert McNamara[4] has recently made a strong plea for a co-ordinated reduction in military budgets, which unfortunately cannot happen unless the most powerful nations in the world make this a matter of priority and set an example for others to follow. According to McNamara, over the period 1978-88 the Third World imported the equivalent of US$450 billion in 1988 prices in the form of arms and military equipment. This represents more than three-quarters of the arms traded internationally. This may be an attractive arrangement for several leaders and politicians in supplier and recipient nations and, of course, for those who are in the business of producing the equipment of war and its trade, but in effect it represents the continuation of a gigantic human tragedy, even as over a billion poor people in the world are struggling to keep the fires of their primitive cookstoves from dying, and emaciated women and children use their human energy beyond their limits to collect a few twigs and pieces of combustible material to continue subsistence. It is, therefore, time for the global energy community to see development in the perspective of a larger global problem which cannot be solved unless major changes are implemented in the priorities that have been followed much too long, if the basic problems afflicting the human race and this planet are to be solved.

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# Agricultural wastes as an energy resource

*** N MAGASINER**

Wastes derived from the processing of agricultural crops are used extensively as fuels. In recent years considerable progress has been made in identifying their combustion and handling characteristics. Fuel moisture content plays the most important role in determining combustion equipment design. Ash chemistry dictates the selection of furnace, convection bank, heat recovery equipment and gas clean-up equipment type and geometry. Agricultural wastes have low bulk densities. This makes them difficult to handle. Some, such as, sunflower seed hulls, flow readily. Others, such as bagasse and bark, have matting properties. This makes them very difficult to store and convey. Most agricultural wastes can be burned in an environmentally acceptable manner. They generate very little, if any, $SO_3$ and $NO^x$. This, taken together with the escalating cost of fossil fuels, provides an incentive to use them to fuel cogeneration plant designed not only to meet in-house process steam and power requirements, but also to produce electricity for export to the grid. The higher steam temperature and pressure conditions required by these stations introduce a number of interesting steam cycle options to the designer. These manifest themselves in unorthodox boiler heat recovery plant configurations.

**KEYWORDS:** biomass fuels; cogeneration

## Introduction

Agricultural waste materials can be used profitably as a renewable energy resource. They are in fact used extensively in certain industries, such as, the cane-sugar industry and the forest product industry, to generate steam and power. They are also used to a more limited extent in a wide range of food processing industries. This paper describes the combustion characteristics of these materials (biomass fuels) and the effect which these characteristics have on the design of the combustion equipment used to burn them and on the design of the associated boiler plant and ancillary equipment. Biomass fuels have the additional advantage of being environmentally friendly.

While most processing plants use biomass fuels to generate only their in-house steam and power requirements, there is a growing realisation, particularly in the cane-sugar and paper industries, that by upgrading steam cycles these fuels can also be used profitably to export power to the grid. This paper also deals with the effect which the higher pressures and temperatures required by these stations have on boiler design.

Adapted from a paper delivered to the Mauritian Sugar Research Institute's 1991 symposium on boiler design and operation.

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## Commercially important wastes

Agricultural wastes generally burned in boilers include:

- bagasse
- forest wastes
- palm-oil wastes
- cotton seed and sunflower seed hulls
- rice hulls
- fruit tree prunings
- nut shells
- straw
- etc.

Of all of these, bagasse is the most abundant.

## Fuel characteristics

In common with fossil fuels, biomass fuels have four important properties:

- heating value
- chemical properties
- physical properties
- combustion properties.

Two heating values are defined: the Gross Calorific Value (GCV) and the Net Calorific Value (NCV). The GCV is determined in the laboratory in a "bomb" calorimeter and represents the total heat released by the fuel when it is burned. The NCV is derived from the GCV by deducting the heat absorbed by the moisture in the fuel and the moisture formed from the combustion of the fuel's hydrogen.

The GCV of most fibrous fuels can be written approximately as:

$$GCV = K(1 - m - a) \text{ kJ/kg}$$

Where K varies from about 17 500-21 000. For bagasse, K is about 19 475. Fuel moisture content varies from 5-60% and ash content from 1-13%.

Boiler efficiency varies largely with exhaust gas temperature and fuel moisture. For example, if the exhaust gas temperature is 200 degrees C a boiler burning a 45% moist fuel will operate at an efficiency on the GCV of about 70% (84,4% on NCV). At 55% moisture, with the same exhaust gas temperature, the efficiency will be about 62,5% (82,0% on NCV) - see Figure 1.

Chemically, when taken together, the proximate analysis, ultimate analysis, ash chemistry, and ash fusion temperature characteristics, paint a picture of a fuel's potential commercial possibilities. Most biomass fuels have almost the same proximate and ultimate analyses on a dry ash-free basis. In fact, it is practically impossible to distinguish chemically one from another.

Table 1 schedules the chemical characteristics of a range of biomass fuels. From their proximate analyses it is clear that they will behave essentially as gaseous fuels. Bagasse, for instance, contains less than 6% solid carbon.

The composition of the ashes (Table 2) differs considerably. While each has a characteristic composition, these can vary over a wide range. Of the elements which play an important role, the proportion of alkali metal oxides and silica are crucial in determining the design of the boiler. The ratio of these compounds dictates the furnace size and the geometry of the superheater and convective heating surfaces.

If this ratio is less than 0,1 the ash will probably exhibit erosive properties. Rice hulls are a typical example. If the ratio is greater than 0,3 the ash will usually exhibit fuming properties. These fumes condense out in the boiler causing severe fouling. To minimise this problem, the furnace must be sized to bring the furnace exit gas temperature down to below the condensation temperature of the alkali metals.

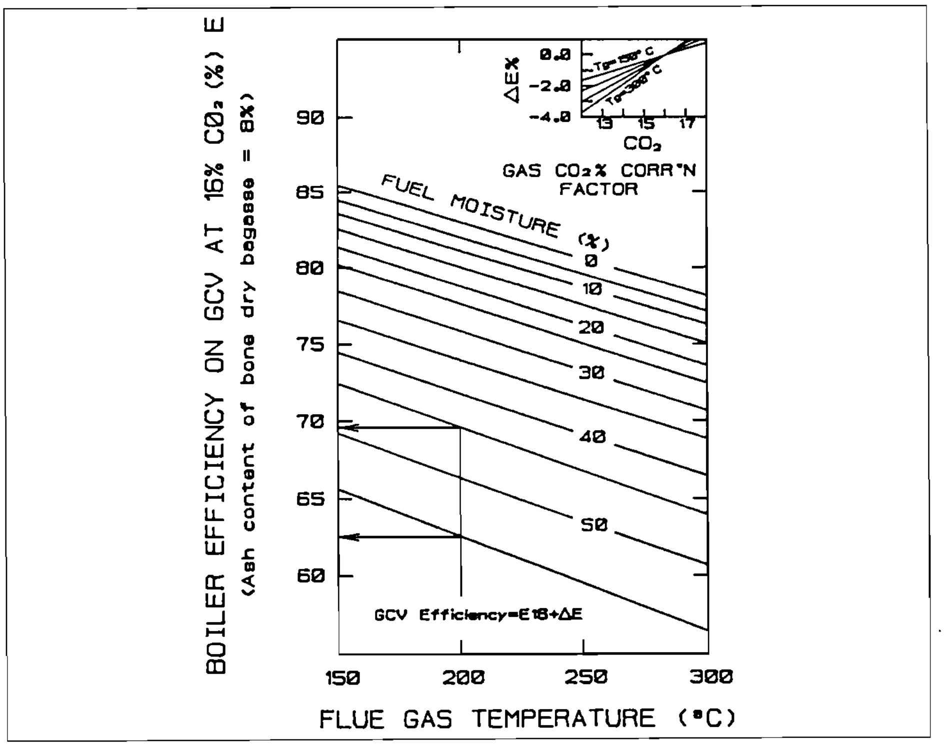


*Figure 1: Effect of flue gas temperature and fuel moisture on boiler efficiency*

**FUEL ANALYSIS of some TYPICAL FIBROUS FUELS**

**PROXIMATE - As Fired**

| | Sunflower seed hulls (USA) | Cotton stalks (Israel) | Cotton gin waste (USA) | Sugar cane bsgasse (S Africa) | Sweet sorghum bagasse (Austria) | Refused derived fuel (USA) | Pine bark (USA) | Rice hulls (Australia) | Jack pine waste (USA) | Cotton seed hulls (Israel) |
|---|---|---|---|---|---|---|---|---|---|---|
| Ash % | 3.8 | 3.8 | 8.4 | 1.7 | 2.7 | 8.9 | 1.5 | 21.5 | 1.3 | 2.3 |
| Volatile % | 66.1 | 57.3 | 73.7 | 37.9 | 34.8 | 51.6 | 36.4 | 35.7 | 44.5 | 68.7 |
| Carbon % | 19.6 | 22.1 | 7.6 | 5.4 | 8.5 | 13.8 | 12.1 | 34.8 | 14.2 | 19.3 |
| Moisture % | 10.5 | 16.8 | 10.3 | 55.0 | 54.0 | 25.7 | 50.0 | 8.0 | 40.0 | 9.7 |
| TOTAL % | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |

**ULTIMATE (daf)**

| | Sunflower seed hulls (USA) | Cotton stalks (Israel) | Cotton gin waste (USA) | Sugar cane bagasse (S Africa) | Sweet sorghum bagasse (Austria) | Refused derived fuel (USA) | Pine bark (USA) | Rice hulls (Australia) | Jack pine waste (USA) | Cotton seed hulls (Israel) |
|---|---|---|---|---|---|---|---|---|---|---|
| Carbon % | 51.1 | 53.6 | 54.1 | 47.7 | 51.0 | 51.2 | 55.0 | 49.4 | 53.4 | 49.9 |
| Hydrogen % | 6.3 | 5.2 | 8.2 | 5.9 | 5.6 | 6.7 | 5.8 | 6.2 | 5.9 | 6.3 |
| Oxygen % | 41.5 | 38.9 | 35.7 | 44.6 | 41.5. | 40.5 | 39.0 | 43.7 | 40.6 | 42.7 |
| Nitrogen % | 0.9 | 1.3 | 1.6 | 1.8 | 1.8 | 1.0 | 0.1 | 0.3 | 0.1 | 1.0 |
| Sulphur % | 0.2 | 1.0 | 0.4 | 0.0 | 0.1 | 0.6 | 0.1 | 0.4 | 0.0 | 0.1 |
| TOTAL % | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |

*Table 1: Proximate and ultimate analyses of fibrous fuels*

Ash fusion temperature characteristics do not always indicate whether a fuel will exhibit slagging properties. They do, however, provide a pointer. One must remember that a lot will depend on whether combustion takes place in an oxidising or reducing atmosphere.

Fossil fuels are sometimes burned as a supplementary fuel in conjunction with biomass fuels. Gas and oil can be accommodated fairly readily. Coal, however, presents special problems. While it has been burned in large quantities as a supplementary fuel in the Southern African cane-sugar industry since 1954, it is only recently that it has become of interest to sugar-mills in other parts of the world. Experience in Southern Africa does not always parallel overseas experience. In this region, coal ash and bagasse ash tend to form an eutectic which melts at fairly low temperatures to form large "plates" (500 mm diameter) of slag on the grate surface. These "plates" choke off the air supply causing the grate to overheat and burn out. In other parts of the world, such as Australia, this phenomenon has not been reported to the same extent.

It is very difficult to predict how serious the problem might be when mixing fossil and biomass fuels. As very little is known about the problem, it is best, at this stage, to play safe by burning them separately.

A fuel's ash sintering temperature is probably more important than its ash fusion temperature. The sintering temperature is the temperature at which the ash particles begin to stick together when they come into contact with each other. The process causes ash particles to build up on the boiler tubes. The screen tubes and superheater are particularly susceptible to this type of fouling. The problem, as with high alkali-metal oxide to silica ratio fuels, can be minimised by ensuring that the furnace has sufficient heating surface to reduce the gas leaving temperature to below the sintering temperature.

The important physical properties are:

- bulk density
- particle size, and
- matting properties.

All biomass fuels have a low bulk density. This varies from about 100-400 kg/m$^3$. At a density of about 140 kg/m$^3$ something like 20 times as much biomass fuel by volume than coal must be burned to generate the same quantity of steam. Bagasse and bark have strong matting properties which makes storing and handling them into a boiler and distributing them evenly into a furnace a major problem for the boiler designer.

Other biomass fuels, such as sunflower seed hulls, flow readily. These materials must be handled with completely different equipment.

Fuel moisture plays the dominant role in characterising the required combustion parameters. Table 3 summarises selection considerations for fuels of different moisture content.

In designing a furnace for high moisture fuels, it is important to bear in mind that because biomass fuels are very porous they are usually very good insulators. Experiments have shown that they are difficult to ignite by radiating energy down onto a fuel bed. Far better results are obtained by blowing hot combustion air through the pile. This dries the fuel and makes it more readily ignitable.

# Furnace designs

From what has been shown so far, it is clear that fuel moisture and ash chemistry determine furnace size. Larger furnaces with greater heating surfaces are required for fuels having a high alkali-metal to silica ratio and for fuels having low sintering temperatures.

**ASH ANALYSIS of some TYPICAL FIBROUS FUELS**

| | Sunflower seed hulls (USA) | Cotton stalks (Israel) | Cotton gin waste (USA) | Sugar cane bagasse (S Africa) | Sweet sorghum bagasse (Austria) | Refused derived fuel (USA) | Pine bark (USA) | Rice hulls (Australia) | Jack pine waste (USA) | Cotton seed hulls (Israel) |
|---|---|---|---|---|---|---|---|---|---|---|
| $Na_2O$ % | 0.4 | 2.0 | 0.0 | 2.8 | 1.4 | 3.2 | 1.3 | 0.1 | 0.0 | 1.4 |
| $K_2O$ % | 39.3 | 30.0 | 11.3 | 2.9 | 5.0 | 2.1 | 6.0 | 1.2 | 4.1 | 42.0 |
| CaO % | 9.2 | 16.4 | 16.1 | 4.5 | 8.9 | 7.0 | 25.5 | 0.2 | 51.6 | 7.8 |
| MgO % | 7.2 | 5.2 | 8.0 | 0.0 | 0.0 | 1.9 | 6.5 | 0.2 | 5.5 | 12.1 |
| $Al_2O_3$ % | 0.1 | 0.8 | 4.3 | 3.3 | 3.6 | 6.8 | 14.0 | 2.0 | 6.3 | 0.6 |
| $Fe_2O_3$ % | 0.6 | 0.5 | 3.3 | 2.4 | 2.2 | 4.9 | 3.0 | 0.1 | 5.0 | 0.9 |
| $SiO_2$ % | 1.7 | 8.4 | 40.7 | 62.6 | 56.6 | 41.9 | 39.0 | 95.6 | 16.0 | 0.4 |
| Total | 58.5 | 63.3 | 83.7 | 78.5 | 77.7 | 67.8 | 95.3 | 99.4 | 88.5 | 65.2 |
| | | | | | | | | | | 4.5 |
| $\frac{Na_2+K_2O}{SiO_2}$ | 23.35 | 3.81 | 0.28 | 0.09 | 0.11 | 0.13 | 0.19 | 0.01 | 0.26 | 108.50 |
| ASH FUSION TEMP °C | | | | | | | | | | |
| IDT °C | 940 | | | | 1236 | +1400 | 1193 | +1400 | 1343 | 1390 |
| HT °C | 980 | | 1195 | 1350 | 1244 | +1400 | 1277 | +1400 | +1400 | +1400 |
| FT °C | 1020 | 1200 | | | 1252 | +1400 | 1266 | +1400 | +1400 | +1400 |

*Table 2: Ash analyses of typical fibrous fuels*

| Effect of MOISTURE CONTENT of FIBROUS FUEL on COMBUSTION CHAMBER DESIGN | | |
|---|---|---|
| **MOISTURE RANGE** | **PREFERRED COMBUSTION CHAMBER and HEAT RECOVERY COMBINATION** | **COMMENTS** |
| > 56% | • Refractory lined | •Combustion unstable<br>•Pre-drying required.<br>This can be done either internally as in a hearth furnace or by means of an externally located drying system. |
| 50 - 56% | •Partly watercooled with air preheater<br>• Undergrate air temp of at least 200 °C required at 56% moisture. | •Combustion relatively stable.<br>•Some refractory required in furnace to improve combustion stability. |
| 40 - 50% | •Partly watercooled with air preheater or economiser<br>OR<br>•Fully water cooled with air preheater. | •Combustion stable.<br>•Unlikely for slag to form in partly water cooled furnace.<br>•In fully water cooled furnace an air preheater advisable to improve combustion stability. |
| 30 - 40% | •Fully water cooled with economiser. | •Combustion stable with tendency to slag. |
| <30% | •Fully water cooled with economiser. | •Combustion stable. Strong tendency to slag. |

*Table 3: Effect of fuel moisture on combustion chamber design*

Experience dictates what leaving temperature the designer should aim for.

Three typical furnace concepts have been used with varying success with biomass fuels. Hearth-type furnaces, such as, the "self-feeding" furnace and the "horse-shoe" furnace are used extensively in the forest products and cane-sugar industries. Most of these are de-ashed manually. In recent years a number of mechanical de-ashing systems have been developed for them. The hearth furnace has one major advantage over all other furnace types: it contains a large mass of "ready to burn" fuel. This makes it easy to control and less susceptible to fuel supply failures. Unfortunately it is very difficult to distribute the air supply evenly to the fuel bed. The penalty is a lower efficiency. It is also difficult to build large furnaces of this type. This restricts boiler output to around 50 t/h. Larger water-cooled furnaces have been used in the forest product industries. This technology has recently been transferred to the cane-sugar industry in Brazil.

Most modern biomass-fired boilers employ some form of suspension-fired furnace. These have been mounted above dump grates, continuous ash discharge stokers and water-cooled grates.

A complicated relationship has evolved over the years between the grate surface heat release rate, fuel moisture content, ash content and ash chemistry. This is illustrated in Figure 2. In essence, experience shows that higher grate heat release rates can be obtained with drier fuels (curve G). This relationship is tempered by ash chemistry. For a given furnace heating surface, it is clear that as the fuel gets drier, the furnace-leaving temperature must increase. This means that if a limit is placed upon this parameter, the grate heat release rate must come down accordingly. Finally, one can superimpose upon this relationship the effect of using hot combustion air. This increases the permissible grate heat release rate at high moisture content and reduces it at low moisture content.

The corollary of this is that hot air should only be used with high moisture fuels and only cold air with low moisture fuels. The dividing line is about 45% moisture.

Boilers burning high moisture fuels operate best when they have combustion chambers designed to cater for a broad range of fuel moistures and when they have a stable fuel supply.

Despite the fact that upset process conditions can often lead to erratic fuel supplies the conveying and storage system must be designed to maintain a constant flow of fuel to the boilers.

Tall choke-fed chutes located above the feeders to prevent cold tramp air being drawn into the furnace are essential for the successful operation of a biomass-fired boiler.

Three roll feeders specifically designed for matting fuels (Figure 3) which provide both a metering and "scarifying" action have been developed. Scarifying breaks up the lumps of fibre to ensure good spreading. These feeders are able to operate without jamming with tall choke-fed chutes. They do not work well with free-flowing fuels such as sunflower seed hulls. In these instances screw feeders are preferred.

Because fibrous fuels are light and "feathery" they are best distributed into the furnace pneumatically. The idea is to blow the fuel to the back of the furnace. While in suspension the fuel dries and the volatiles are driven off.

Secondary air is injected at the back of the chamber to create gas and particle circulating patterns. The primary air supply, which is introduced through the grate, cools and dries the heavier fuel particles which are not burned in suspension.

The designer's key problem is a fuel's diminishing ability to sustain combustion with increasing moisture content.

It has already been shown that hot

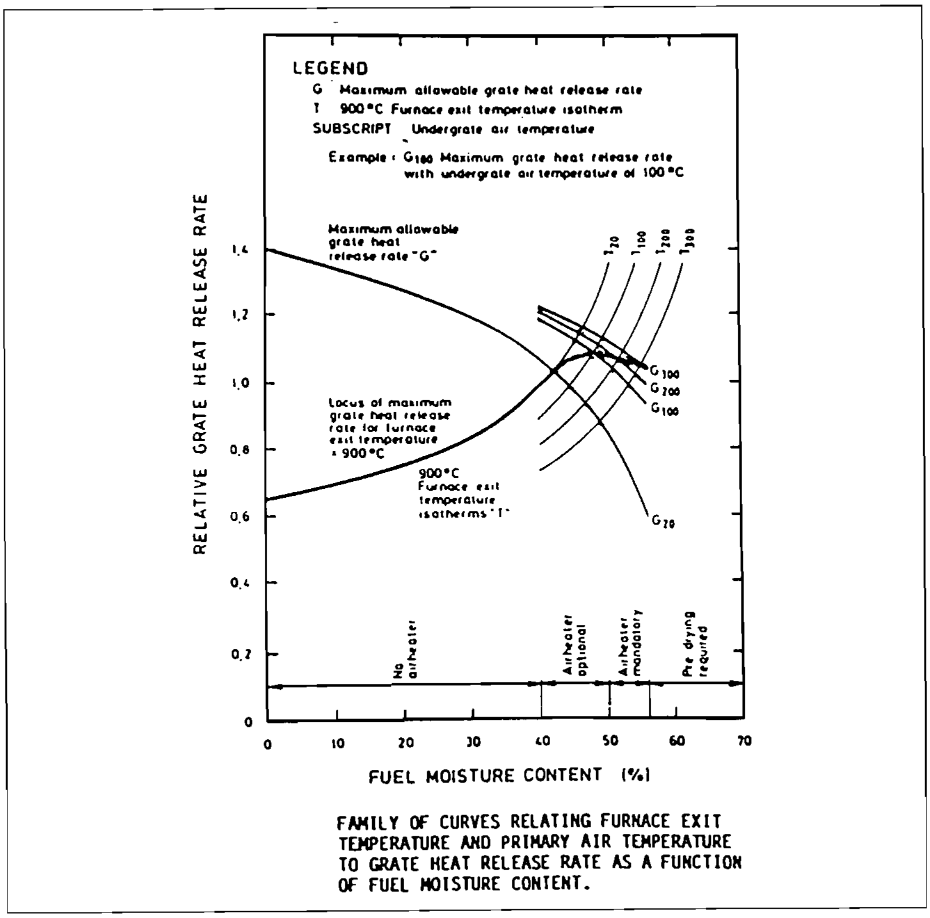


*Figure 2: Grate heat release rate*

combustion air (Figure 2) helps overcome the problems associated with high moisture and poor spreading, both of which are manifested by piles of unburned fuel accumulating on the grate. Hot air passing through these piles is able to dry wet fuels much more rapidly than cold air. This accelerates the combustion process and allows the boiler to tolerate a much wider range of adverse conditions. In addition, air-heaters extract additional heat from the exhaust gases, thus improving boiler efficiency. Economisers also extract additional heat from the exhaust gases but they do not help to stabilise and enhance combustion. The two-fold benefit which an air-heater provides is particularly advantageous when retrofitting heat recovery equipment in order to increase the output of an existing unit.

Combustion stability can also be improved by including an optimum amount of refractory in the furnace at a strategic level.

Fluidised bed combustors have been used recently to burn biomass fuels. So far they do not appear to offer any advantage over conventional systems. They have a limited turndown ratio, they absorb more auxiliary power, and can only operate efficiently within a narrow fuel bed temperature range.

## Stack emissions

Figure 4 illustrates typical size gradings of the dust emitted by biomass fuels. Bagasse and bark char particles are large, making them relatively easy to collect. The normal inlet dust burden from a well-designed boiler burning a wet biomass fuel runs at about 5 000 mg/Nm$^3$. While mechanical collectors can bring this down to about 450 mg/Nm$^3$ on test, they normally operate consistently at about 600 to 750 mg/Nm$^3$.

Dust emissions of less than 150 mg/Nm$^3$ can be achieved consistently from medium pressure drop (1 500 Pa) wet scrubbers. Having collected the dust, the problem then is to separate it from the water so that the water can be recycled. A scrubber fitted to a 100 t/h boiler will generally require about 80-150 m$^3$/h of scrubber water!

Biomass fuels with high alkali-metal contents produce a fume which is very difficult to collect. Only bag filters and electrostatic precipitators are able to achieve anything like an acceptable efficiency. Both these machines are expensive to purchase and operate.

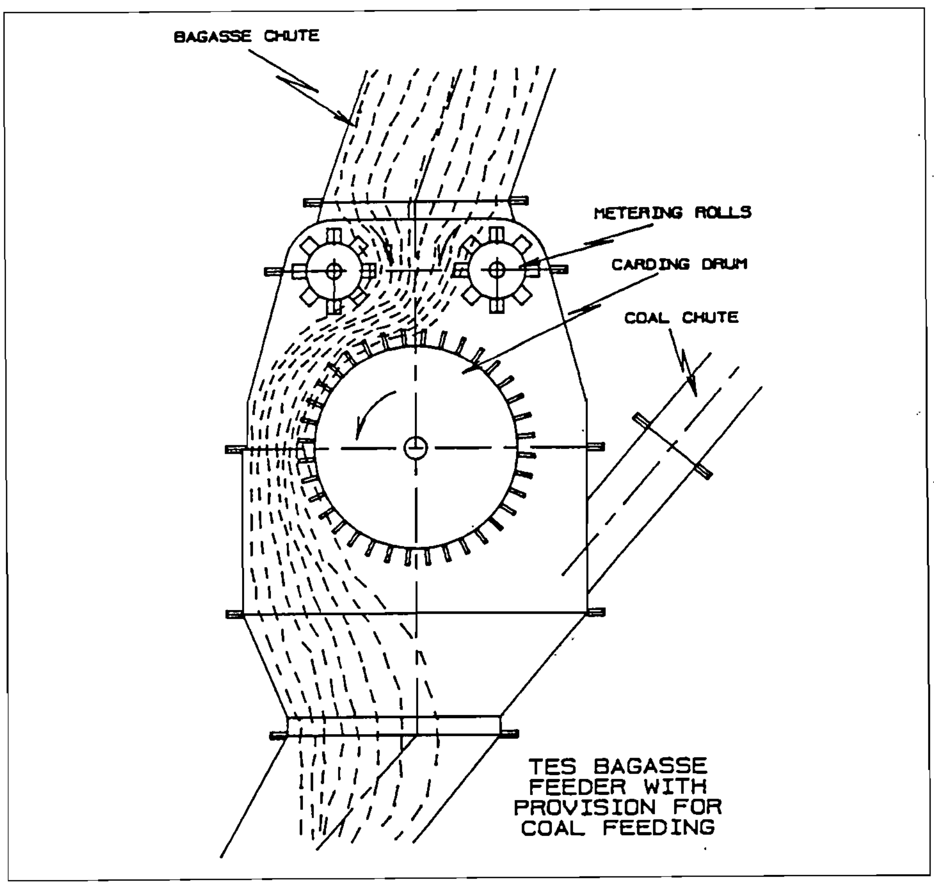


*Figure 3: Three-drum fibrous fuel feeder*

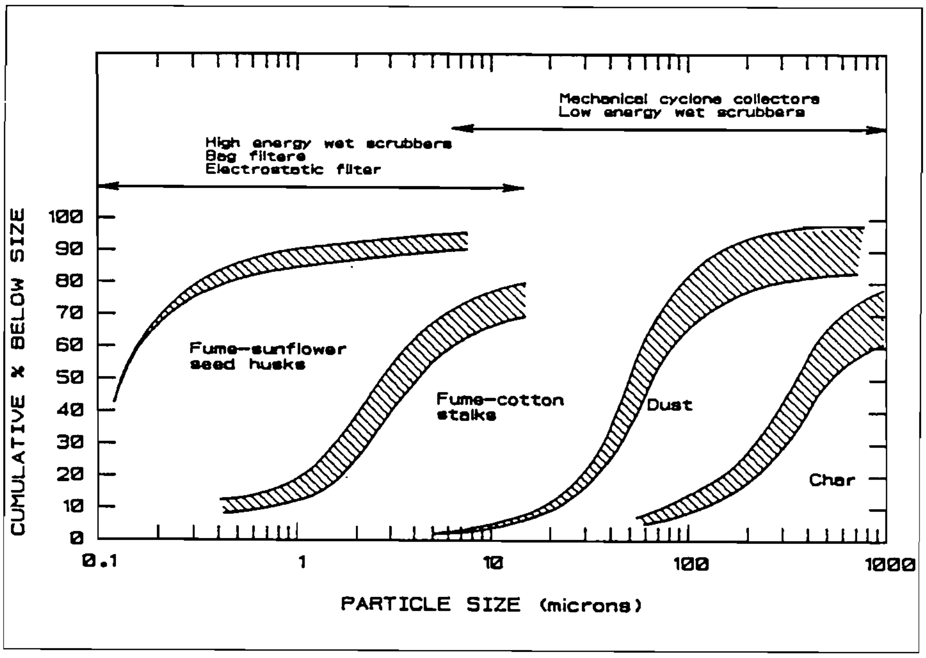


*Figure 4: Dust particle sizes*

## Fuel handling

It has already been shown that a continuous recovery system must be installed to maintain a constant flow of fuel to the boiler. With spreader stokers this is more important than with hearth-type furnaces. A storage system that achieves this with a matting fuel, such as, bagasse or bark, is shown in Figure 5. The store should, ideally, be sized for at least 12 hours firing. With "slippery" fuels, such as, sunflower seed hulls, under pile reclaiming can be used. This has the advantage of being a "first in, first out" system.

Which ever system is used, it is important for the conveyors to be designed to carry between 150-200% of the boiler's fuel requirements to the feeders. This ensures that the feed chutes are always full. The excess is returned to store.

## Ash handling

The dust produced by wet biomass fuels, such as bagasse and bark, contain a high proportion of char. This is an "activated carbon" which, if exposed to air, burns very readily. The best way of handling this dust is to douse it in water and then convey it with this medium. This system, as with scrubbers, introduces the problem of separating the dust from the sluice water. A number of devices have been developed to do this job. A simple submerged scraper conveyor often suffices.

The dust produced by low moisture fuels is usually inert. Screw conveyors can be used at low risk to handle the discards. If there is any likelihood of upset combustion conditions occurring which could cause unburned fuel to be carried over into the dust and ash handling plant, it is best to use a wet system.

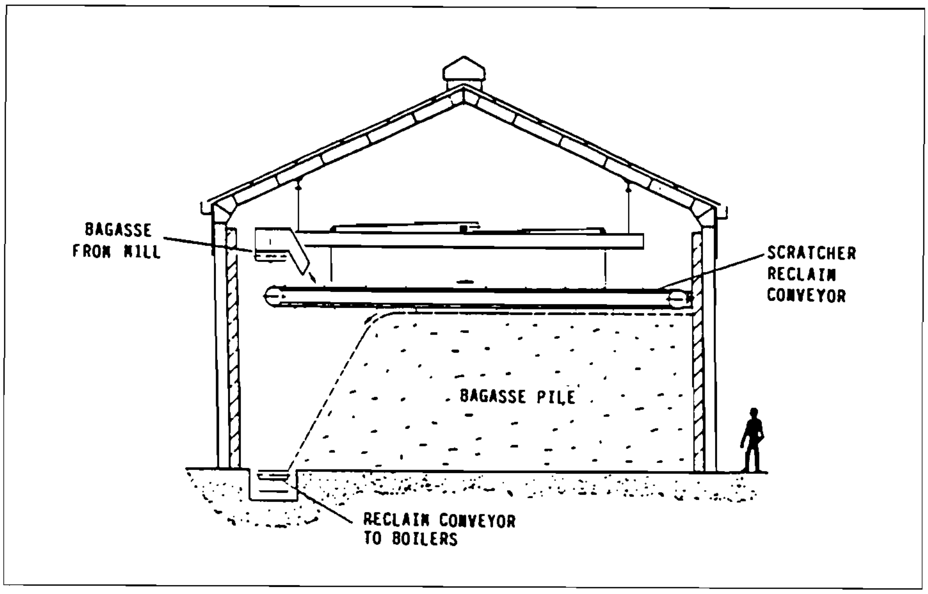


*Figure 5: Typical bagasse store. Fuel added to and reclaimed from top.*

## Boiler design

The concept of designing a boiler for operating stability must be carried through to the heating surfaces and to the steam drum in particular.

At the pressures and temperatures generally used in industry, multi-pass boilers offer a good balance between furnace, superheater, convection pass, and heat recovery surface. Where harvesting techniques result in a large amount of sand ending up with the fuel these units have become susceptible to tube erosion.

While this problem can be "designed out", the single-pass boiler, which does not have the same degree of thermal balance, appears to be free of erosion.

While three-element water level control - controlling feed flow against steam flow and drum water level - has gone a long way to stabilise boiler operation, an over-large steam drum should be incorporated to provide the latitude needed to cater for abnormal operating situations.

Drum level control can be adversely affected by uneven gas flow which in turn is usually caused by the uneven introduction of fuel across the boiler width. The fuel feed philosophy described above and an over-large steam drum largely eliminates this problem.

Some points of design philosophy which are worth noting are:

* The boiler setting must be designed as a gas-tight enclosure. Refractory work must be minimised.
* Superheater steam flow should be arranged in parallel flow wherever possible in order to reduce the chance of overheating and burning out tubes. Creep resistant steels should be selected for superheaters even though these are not strictly required by the construction codes.
* To minimise tube erosion, gas velocities should be kept below 15 m/s (preferably below 12 m/s). In addition, in the case of three-pass banks, gas baffle tips should be positioned to exclude turbulence in the vicinity of tubing.
* To minimise corrosion, air-heaters should be designed as co-current units.

* Finally, an adequate arrangement of galleries and ladders should be provided to enable operators to gain access to all areas requiring maintenance.

## Power generation

Food processing factories often operate their boilers at steam conditions of around 17-30 bar, 350-400 degrees C. For power generation, much higher steam conditions, 64-80 bar, 500-520 degrees C are required. As these conditions increase, new opportunities are opened to the designer. Perhaps most significant is the fact that, at very little extra cost, high pressure steam - say, 17 bar - can be extracted from the turbine. This steam can be used to heat the combustion air in a steam/air-heater. This not only improves cycle efficiency but also allows the designer to use an economiser to recover heat from the exhaust gases. High metal temperatures are easier to maintain with this type of heat recovery equipment than they are with gas/air-heaters. While this is not so important if the boiler only has to burn bagasse, most power generating stations are required to burn high sulphur coal or oil. These fuels have highly corrosive exhaust gases with dew points usually in excess of 125 degrees C. Simple high-pressure feed water-heaters which use pass out steam can be used to elevate the feed water temperature to this level.

A typical modern "sugar" boiler is illustrated in Figure 6.

A "power station" type unit designed to burn coal and bagasse is shown in Figure 7. The power station boiler has a higher furnace, a much larger superheater, and a large economiser rather than an air-heater.

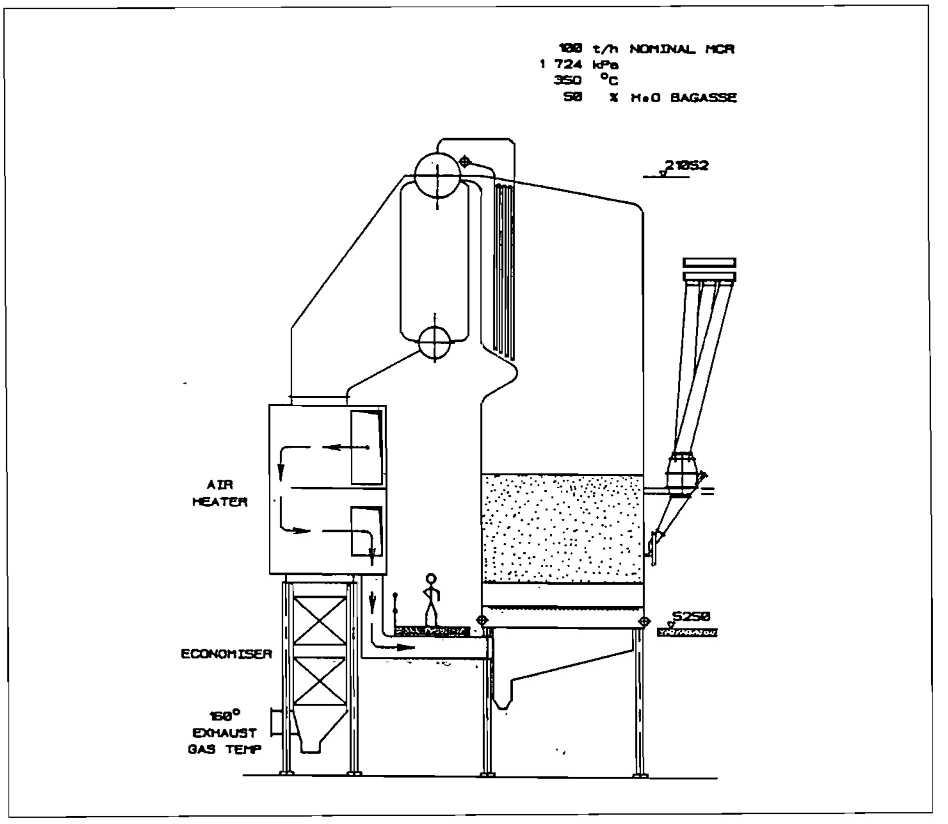


*Figure 6:* *Typical modern "sugar factory" boiler*

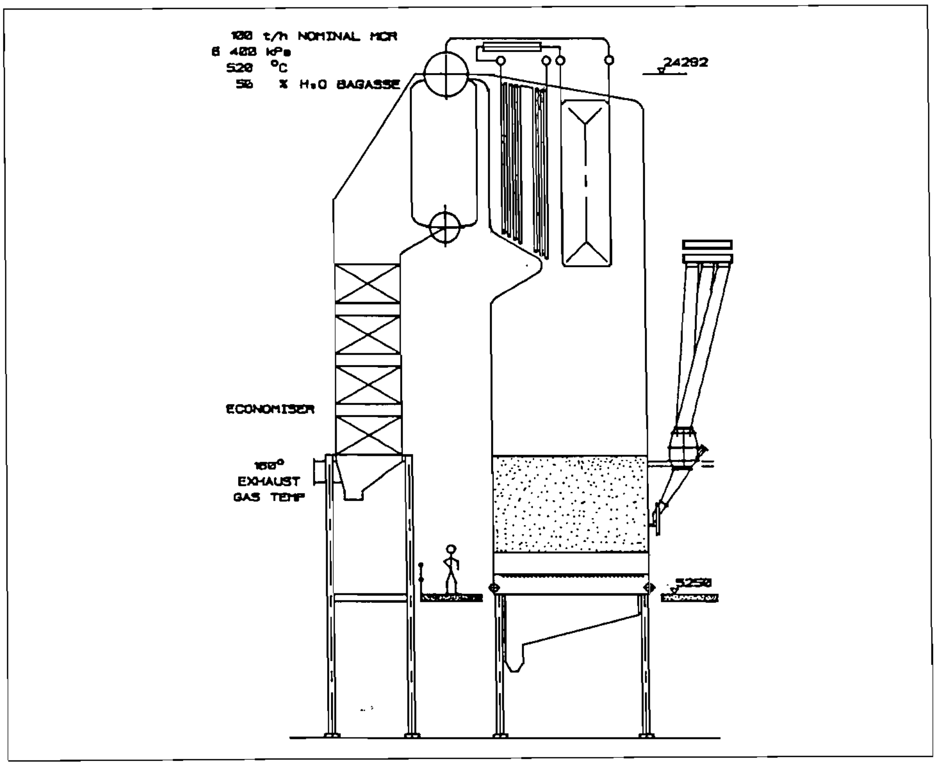


*Figure 7:* *Typical "power station" boiler*

## Concluding remarks

Biomass fuel boiler technology is now a mature science. The parameters and design details required to produce a sound engineering solution for most applications have been identified. While not all the problems have been solved, there is a sound body of knowledge available to ensure that those which do remain, can be minimised.

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# The enhanced greenhouse effect and the South African power industry

* S J LENNON

Global climate change due to a potentially enhanced greenhouse effect, where "enhanced" refers to the contribution of non-water vapour components, most of which are man-made, is currently receiving attention internationally. One of the major focus areas has always been the energy sector and in particular, the power generating industry, due to the fact that the burning of fossil fuels contributes to increasing the concentrations of radiative gases in the atmosphere. In South Africa, coal provides approximately 80% of the country's primary energy needs[1]. About 50% of this coal is used for power generation. It is therefore essential to determine the potential impact of international initiatives on the South African power generating industry and to put the local situation into perspective. This paper addresses these issues, and details current and future initiatives being taken by the local industry to support local and regional management of global climate change.

**KEYWORDS:** enhanced greenhouse effect; carbon dioxide; power generation

## Introduction

In preparing this paper, due cognisance has been taken of the current levels of scientific uncertainty and debate surrounding the enhanced greenhouse effect. In this regard the "certainty statements" of the IPCC (Intergovernmental Panel for Climate Change)[2] are assumed to be valid and cognisance is taken of the broad range of predictions currently available[2,3]. It is not the intention of this paper to discuss the science of global warming or cooling, but rather to put the South African situation into perspective.

## The natural greenhouse effect: Relative background contributions

It is important to note that, of the various radiation absorbing and emitting trace gases in the atmosphere, the largest contributor to the natural greenhouse effect, which is that phenomenon which keeps the earth's surface 33°C warmer than its "free space" temperature, is water vapour. This accounts for 21°C of the total 33°C, with $CO_2$ next, accounting for 7°C[4]. Other radiative gases account for the balance. It is, however, the changing concentrations of the "non-water vapour" portions of the natural effect that are currently responsible for the concerns relating to the enhanced greenhouse effect.

## The enhanced greenhouse effect: Relative contributions

In any assessment of the appropriate action required in addressing a specific issue, it is essential to have a full appreciation of the nature, source and extent of the contributing factors. In the case of the enhanced greenhouse effect, it is necessary to adopt a holistic approach to the situation. In this regard, the relative contributions of all trace gas emissions must be considered.

Figure 1 illustrates the proportional annual contributions, world-wide, of various gases to the enhanced greenhouse effect[5]:

World-wide, power generation accounts for approximately half the coal used[6]. In this regard, Figure 1 indicates that the enhanced greenhouse effect contribution from coal-fired power generation is 8% of the total, due to human activities. Even the most conservative estimates do not succeed in increasing this figure beyond 15%. It is considered essential to factor the above details into any national or international strategy relating to the greenhouse effect.

It should, however, be noted that $CO_2$ does play the major role in the enhanced greenhouse effect and it is for this reason that it is focused on in most international deliberations. The increase in $CO_2$ concentration with time is, however, unlike methane ($CH_4$), not directly proportional to population growth or GNP growth[3]. $CH_4$ concentrations in the atmosphere are increasing at 0,9% per annum, as opposed to $CO_2$ concentrations which are increasing at 0,5% per annum. In the light of the fact that $CH_4$ is 21 times more heat-absorbing than $CO_2$, the long-term importance of $CH_4$ must not be underestimated or ignored.

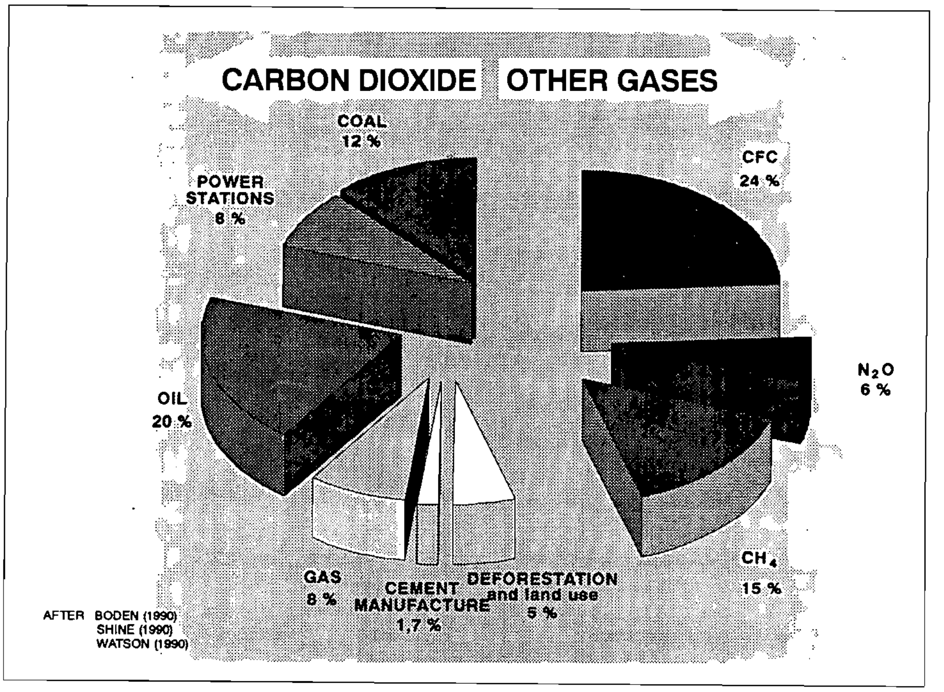


*Figure 1: Enhanced greenhouse effect: Gases*

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# South Africa's contribution to the enhanced greenhouse effect

International figures for total greenhouse gas emissions are not generally available. In order to compare emissions on an international scale, $CO_2$ emissions, as calculated from national fossil fuel budgets, are generally used.

In this regard, the total $CO_2$ emissions and $CO_2$ emissions per capita, are illustrated for several nations in Figures 2 and 3[7]. It should be noted that South Africa's $CO_2$ emissions currently total approximately 300 million tons[8] out of a global total of some 20 100 million tons[7].

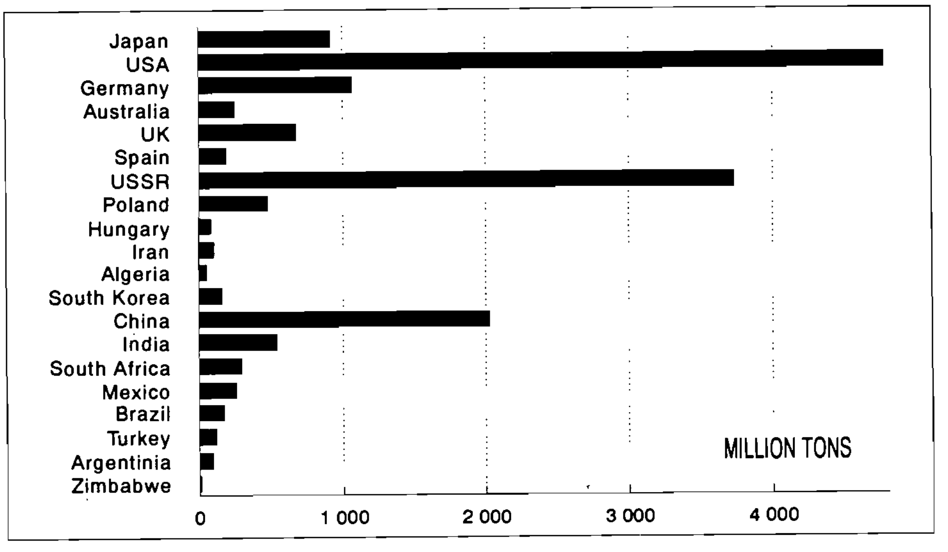


*Figure 2: Total $CO_2$ emissions*

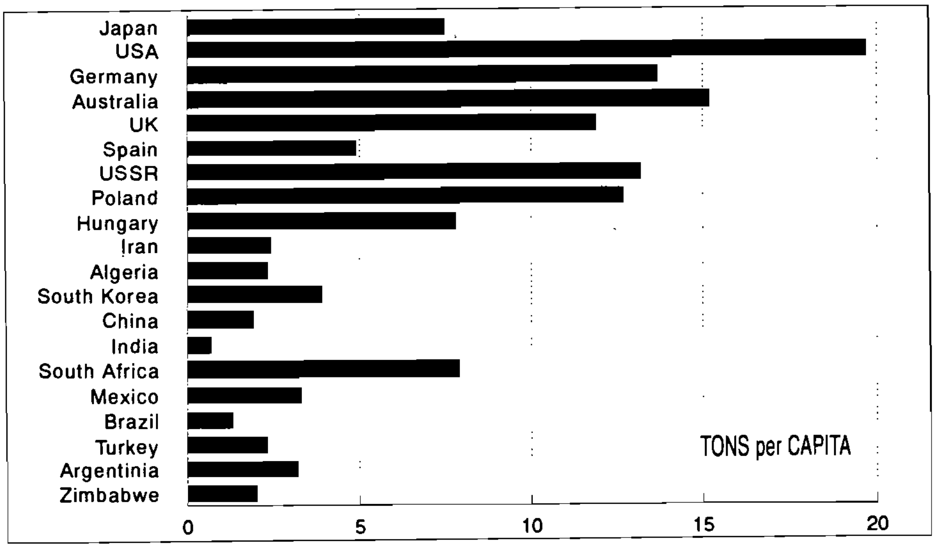


*Figure 3: $CO_2$ emissions per capita*

From the abovementioned data of Bach and Jain[7] several points are apparent:

(1) Developing nations are currently responsible for 19,3% of global $CO_2$ emissions. If 50% of this amount is sourced from coal-fired power stations, then the contribution to global $CO_2$ emissions from coal-fired power stations in developing nations is approximately 9,7%.

(2) South Africa contributes approximately 1,5% of world $CO_2$ emissions. It is estimated that the power industry is responsible for approximately 50% of this figure or 0,75% of the world's total.

(3) The figures for South Africa clearly reflect the mixed nature of the nation's economy, that is, First and Third World, as well as the strong reliance on primary industry, namely, mining, primary minerals processing and metallurgy.

(4) The industrialised nations are not only still responsible for the major share of $CO_2$ emissions (73% in 1990), but historically they have contributed in excess of 80% of the current man-made $CO_2$ loading in the atmosphere.

In determining any actions related to the enhanced greenhouse effect, the above contribution must be considered in conjunction with the developmental priorities of developing nations. It is further clear that insufficient attention is being paid to other important radiative gases, such as, $CH_4$.

# The policy approach of developing nations

The policy debate surrounding the enhanced greenhouse issue over the past few years has been shaped by two potentially conflicting viewpoints:[9]

### *The "No Regrets" Principle*

This policy suggests that organisations should act now on the basis of current knowledge and take the action that is justified for other reasons as well. Where two options have equal merit at equal cost the most "greenhouse friendly" option prevails. Under this principle, it is considered that current scientific uncertainties are still too large to warrant costly preventative action which could damage the national economy. Instead, more research should be pursued to reduce the scientific uncertainties. Activities which would be beneficial, whether climate change occurred or not, will be implemented.

### *The Precautionary Principle*

Under this principle, it is considered that the current scientific uncertainty is balanced, that is, if major warming occurs, inaction could have catastrophic consequences. Society should, therefore, pursue investments and policies now to minimise risks.

It is not, however, considered that these two principles are mutually exclusive. An evaluation of current policy-type literature tends to indicate that developing nations are opting for the "no regrets" principle, whilst the industrialised countries are considering implementing the precautionary principle[9.] It is considered that this approach is essentially prescribed in the United Nations' Framework Convention for Global Climate Change[12].

In adopting this two-pronged approach it is clear that the $CO_2$ emissions in developing nations will increase with development, whilst industrialised nations must substantially reduce emissions. In this regard, two possible scenarios to international $CO_2$ emission targets are likely. They are represented graphically in Figures 4 and 5.

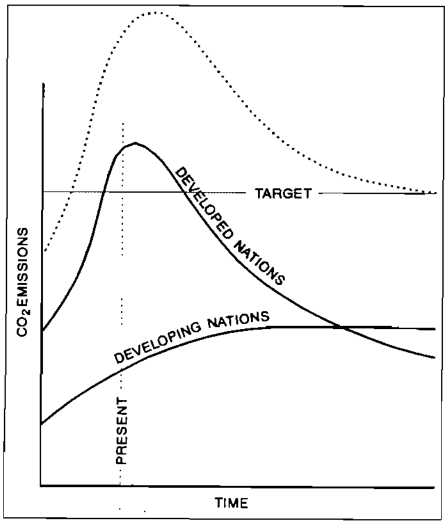


*Figure 4:* *$CO_2$ emissions: Scenario 1*

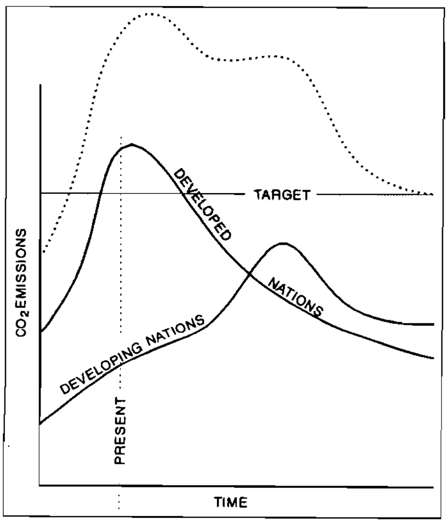


*Figure 5:* *$CO_2$ emissions: Scenario 2*

The scenario illustrated in Figure 4 is only feasible with substantial, funded, technology transfer, as well as financial and technical assistance flowing from the developed nations to the developing nations. This would ensure that, ideally, optimal use is made of energy and technology to ensure that global reductions are maximised. This is considered to be an ideal scenario. A more likely scenario is presented in Figure 5.

In terms of this scenario, it is considered likely that developing nations' emissions will increase substantially before they decrease gradually as technology utilisation is optimised. This reduction is likely to be driven by technological advances, efficiency improvements and economic factors.

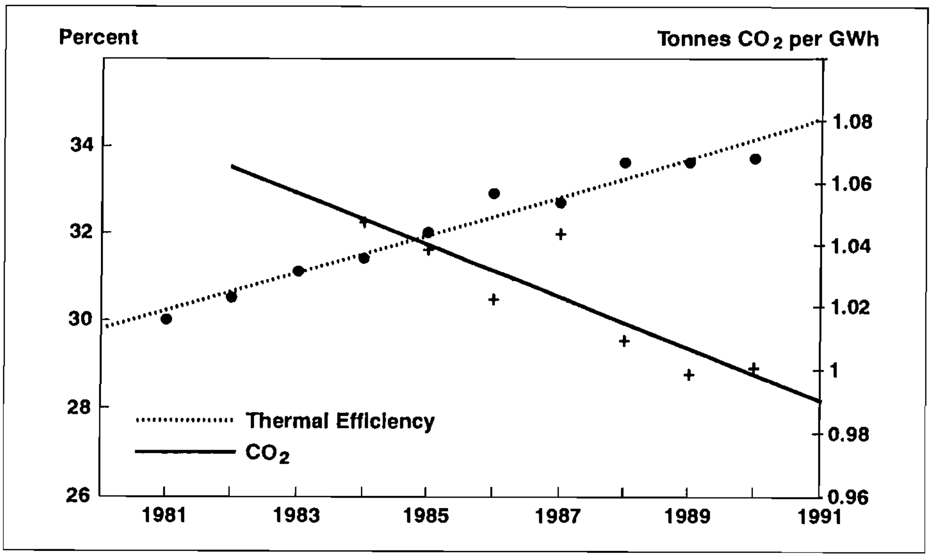


*Figure 6:* *Thermal efficiency and $CO_2$ emissions: Eskom power stations*

Given the developmental priorities of South Africa and the need to supply electricity to that 70% of the population who are currently without this resource, it is clear that pragmatism is vital and that the "no regrets" approach should be adopted.

# Historical application of the "No Regrets" approach in the South African power industry

In applying the "no regrets" approach, it is essential that a broad-based awareness exists as to the validity of the concept in addressing perceived threats.

It is furthermore important to note those major historical actions which may, in a "no regrets" approach, be regarded as having reduced the rate of increase of $CO_2$ emissions. This implies the adoption of a "business as usual but with conscious sensitivity" approach.

## *The South African national grid*

The well-developed South African national electricity grid[13] has been instrumental in ensuring the widespread and efficient transmission of power across the country. The $CO_2$ emission reduction fringe benefits are as a result of centralised power generation and reduced secondary impacts due to fuel transport, etc. A further benefit of centralised generation lies in the optimisation of spinning reserves and hence, a more efficient use of national resources and lower emissions per kilowatt hour consumed.

## *Enhanced thermal efficiencies*

The thermal efficiency of the major local power generating units has increased on average from 30% in 1981 to nearly 34% in 1990[14]. This has resulted in a substantial reduction of $CO_2$ emissions per gigawatt hour of 6%. This is graphically illustrated in Figure 6.

This improvement has been achieved via the application of innovative new technologies and the optimisation of plant performance.

## *Electrification*

The major electrification drive currently being applied has already resulted in a substantial reduction of net $CO_2$ emissions. This is mainly due to the controllability of electric heating and the inefficient combustion processes associated with wood- and coal-stoves. Net $CO_2$ reductions of up to 50% are achievable. Relative emission comparisons for cooking a basic meal and space-heating are provided in Figures 7 and 8[14]. It should be noted that electrification seldom replaces open fires for cooking and heating. In order to realise the full benefits of $CO_2$ reduction via electrification, means of displacing traditional cooking and heating sources need to be found. This requires that any electrification programme be accompanied by a public awareness and training programme.

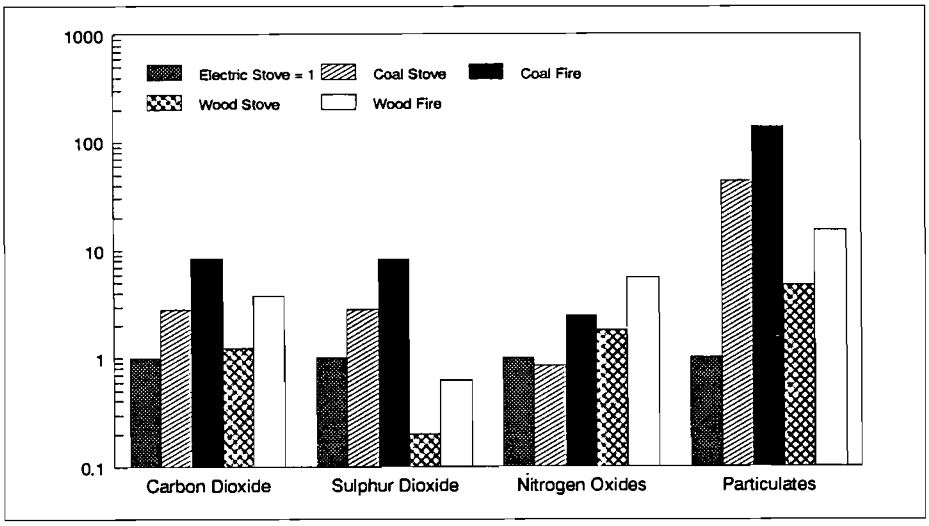


*Figure 7:* *Cooking a basic meal*

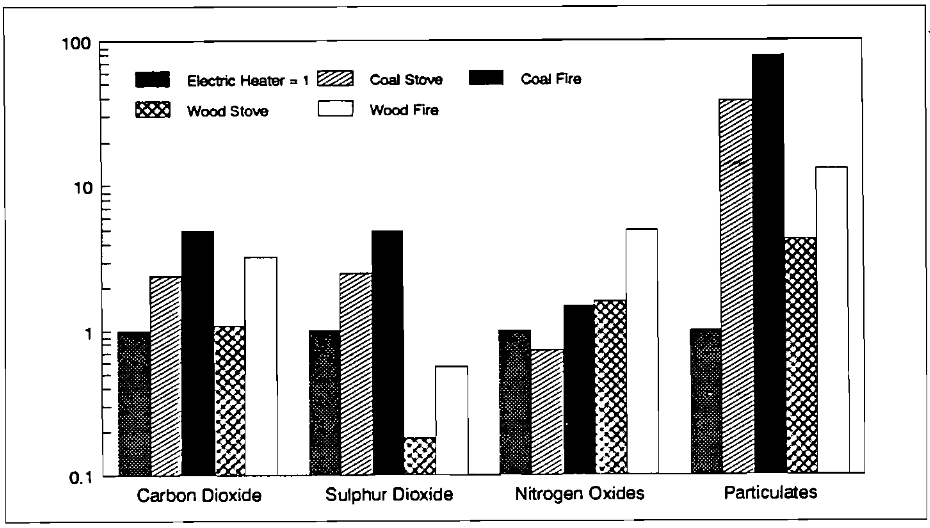


*Figure 8:* *Space-heating*

# The future application of the "No Regrets Approach" in the South African power industry

## *Short-Term*

In the short term it is clear that the emission savings achieved to date may be maintained and enhanced in the normal course of business by further emphasising the environmental aspects of the benefits. Activities currently in hand or planned for expansion include:

— improved plant efficiency

— replacement of inefficient energy processes in industry with more efficient electricity-driven processes

— demand-side management

— electrification (conventional and stand-alone)

— energy conservation

— national grid

— development of a Southern African grid

— research and development into alternative energies.

## *Medium-Term*

In the medium term, as ageing existing plant requires replacement, several options are open to the local power industry, all of which have benefits in terms of the "no regrets" principle. These are clearly complementary to the on-going short-term actions. Future options include:

— advanced pulverised fuel technology, for example, supercritical boilers

— advanced coal technology and use of natural gas, for example, integrated gasification combined cycle and fluidised bed plants

— alternative energy sources for stand-alone systems

— nuclear power

— hydro power

— Southern African grid and increasing the use of regional hydro power resources

— promotion and development of electric transport

— fuel cells.

It should be noted that current air quality research, indicating no need for flue gas desulphurisation plant to existing power stations[16], will result in substantial $CO_2$ emission avoidance due to the avoidance of a 6% plant efficiency penalty.

## *Long-Term*

In the long term the current projected technological developments are likely to be realised. Options open to the local power industry could include:

— Southern African powerhouse concept

— nuclear fusion

— solar power (bulk generation)

— advanced alternates (fuel cells, magnetohydrodynamics, etc).

## CONCLUSIONS

The following conclusions have been drawn from this work:

(1) South Africa's contribution to global greenhouse gas emissions is low and is comparable with other developing nations.

(2) The responsibility for the reduction of global greenhouse gas emissions rests primarily with the industrialised countries for the time being.

(3) The "no regrets" principle should be adopted by South Africa in approaching the enhanced greenhouse issue.

(4) Existing initiatives in the local power industry should be developed and enhanced to ensure optimal development.

## ACKNOWLEDGEMENTS

The author gratefully acknowledges Eskom's permission to publish this paper.

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# United Nations Conference on the Environment and Development (UNCED - Rio'92): A power utility perspective

* S J LENNON

The United Nations Conference on the Environment and Development (UNCED) was held in Rio de Janeiro in June 1992. This conference was a further step along the long road to achieving international consensus on co-operation on environmental matters. UNCED was an event characterised by major media exposure and political grandstanding. This paper summarises the author's impressions of the major outcomes of the Earth Summit portion of UNCED and related events, and highlights aspects of the Global Forum. In this regard, matters pertinent to the power industry and implications for South Africa have been focused upon. It should be noted that this paper is solely based upon the perceptions and experiences of the author and should not be interpreted as a policy document.

**KEYWORDS:** Earth Summit; power generation; environment

## The Rio "Process"

During the month of June 1992, there were several major events in Rio, two of which are considered in this paper:

— The International Chamber of Commerce (ICC) Conference on Environment and Development. This was a high profile business conference, which focused on the changing role of business in the environment. This conference was held immediately prior to UNCED and was well-supported by the South African Industrial Environmental Forum (IEF).

— United Nations Conference on the Environment and Development. This conference was divided into two main events:

(a) The Global Forum, which was a non-governmental organisation (NGO) event. The Global Forum consisted of an ongoing exhibition and hundreds of seminars, workshops, conferences, meetings, etc. An extremely broad-based representation was evident at the Global Forum, and opportunities were afforded to debate pertinent issues being negotiated at the Earth Summit. NGO representation at the Summit then ensured integration of selected points with the negotiation process.

(b) The Earth Summit, which was the main negotiating forum attended by heads of state, political organisations and selected representatives of NGOs. The purpose of the Earth Summit was to finalise five main international treaties or conventions, namely:

* The Forestry Convention for the protection of the earth's forests.
* The Rio Declaration - a declaration outlining the rights and responsibilities of countries towards the environment.
* The Biodiversity Treaty for the protection of biodiversity in nature.
* Agenda 21 - a recipe for international environmental management which would result in sustainable development.
* The Framework Convention on Global Climate Change for the management of climate change.

## The ICC Conference on Environment and Development[1]

This conference highlighted the successes achieved by business in integrating environmental issues with business goals. The following points of relevance to the energy industry were made:

— Technology transfer should be achieved via joint ventures and trade. It was stressed that technology transfer must be appropriate to a nation's needs and that "technology dumping" will only ensure that mistakes made in the developed nations will be repeated in developing nations.

— Energy efficiency, conservation and demand-side management are essential in order to conserve resources, increase productivity, and manage environmental impacts.

— Energy starvation in the Third World is of concern. Affordable energy for all is an issue that requires substantial attention.

— Local and regional environmental issues in developing nations outweigh global issues.

— Coal as an energy source will be used for many decades. Clean coal technology is receiving substantial R&D funding. In parallel with this, the use of alternative energy sources, electric transportation, and emission reductions are being developed as priority areas.

The ICC conference was encouraging in that industry was seen to be taking ownership of environmental matters and no longer seeing the "Greening of Business" as a threat. The potential for tokenism or "greenwashing" was raised as a concern and clearly needs to be carefully managed. This conference did, however, display a disconcerting lack of appreciation for those environmental priorities applicable to Southern Africa and, in fact, to Africa as a whole. As a counter to this fact, it was encouraging to note that many South African businesses, especially in the energy sector, are extremely progressive in matters related to environmental management.

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# The United Nations Conference on the Environment and Development

## *The Global Forum*

Numerous NGOs organised events relating to the energy industry during the Global Forum [2-8] Technical Issues. Those which received detailed attention, were:

- Holistic energy efficiency coupled with integrated resource planning, energy conservation and demand-side management
- Industrial symbiosis (or energy farms)
- Technologies for sustainable energy development:
  - biomass
  - biogas
  - energy storage
  - energy conservation
  - cogeneration
  - hydro power
  - solar power
  - wind power
  - geothermal power.
- Global issues in energy and climate change
- Environmental economics and accounting
- Electrification.

It is clear that any power utility needs to incorporate all of the above issues into its current research and development portfolio. It is encouraging to note that these have been researched for some years in South Africa.

The Global Forum events once again highlighted the importance of regional co-operation in addressing issues of regional concern. The facilitation of research into the regional contribution to and impact of climate change on Southern Africa is considered by the author to be crucial to future development.

## *The Earth Summit*

The Earth Summit was primarily a political event related to the negotiation of the conventions and treaties already mentioned. South Africa's primary contributions to the negotiations took the form of:

- Informal input to the "prepcons" (preparation conferences)
- Input to NGOs
- The Department of Environmental Affairs report to UNCED[9]
- Government observers at the Summit
- An ANC statement to the Summit[10].

As the convention of main interest to the energy industry is the Framework Convention on Global Climate Change, other conventions and treaties will not be covered in this paper. The Framework Convention details actions for the amelioration of global climate change[11]. It is clear in the convention that developed nations are primarily responsible for contributing to the changes measured in atmospheric composition to date. The prime responsibility for emission reduction therefore rests with the developed nations, whilst developing nations must be permitted to grow unimpeded in terms of their developmental priorities. (Disagreements as to the degree of unimpeded growth and funding priorities resulted in major North vs South debates characteristic of the Earth Summit.) This development should however be facilitated to ensure that the mistakes made by developed nations are not repeated. In this regard, technology transfer is essential to ensure that development progress with appropriately managed environmental impacts. This is best illustrated schematically in Figures 1 and 2[12].

It is clear that, given South Africa's developmental priorities and socio-economic imbalances, developing nation status is appropriate to this country, and that actions for international participation in the Framework Convention should be formulated accordingly.

In this regard, priority attention should be given in South Africa to issues such as:

- integrated energy planning
- electrification
- holistic energy efficiency
- demand-side management
- national policy
- appropriate technology
- education and training.

In all cases, it is essential that development is not sacrificed to address the postulated impacts of climate change. Actions should be based upon existing knowledge and only those which will be beneficial, whether climate change occurs or not, should be applied. This approach is often referred to as the "no regrets" approach.

It is considered that South Africa is well-positioned to meet the challenges and commitments facing the nation. The current drafting of policy by the Department of Environmental Affair's Interdepartmental Co-ordinating Committee for global environmental change, will ensure focused national direction. The opportunities afforded by the creation of the International Global Environmental Facility (GEF) to fund "greenhouse friendly" activities and R&D will be readily realisable by structures such as the South African Global Change Committee and the recently constituted Environmental Scientific Forum.

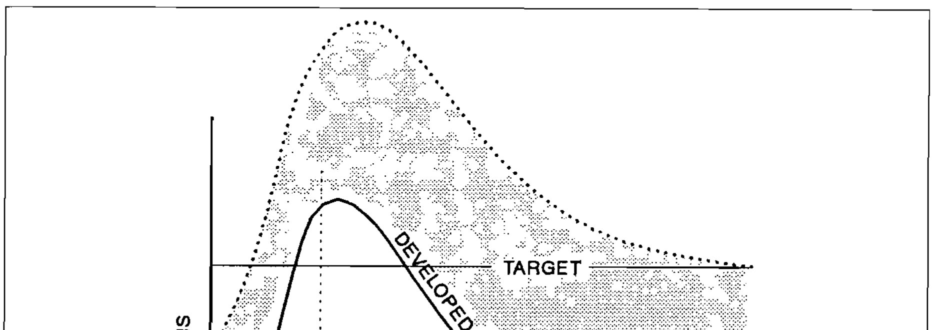


*Figure 1: Targets met with optimal application of technology and development*

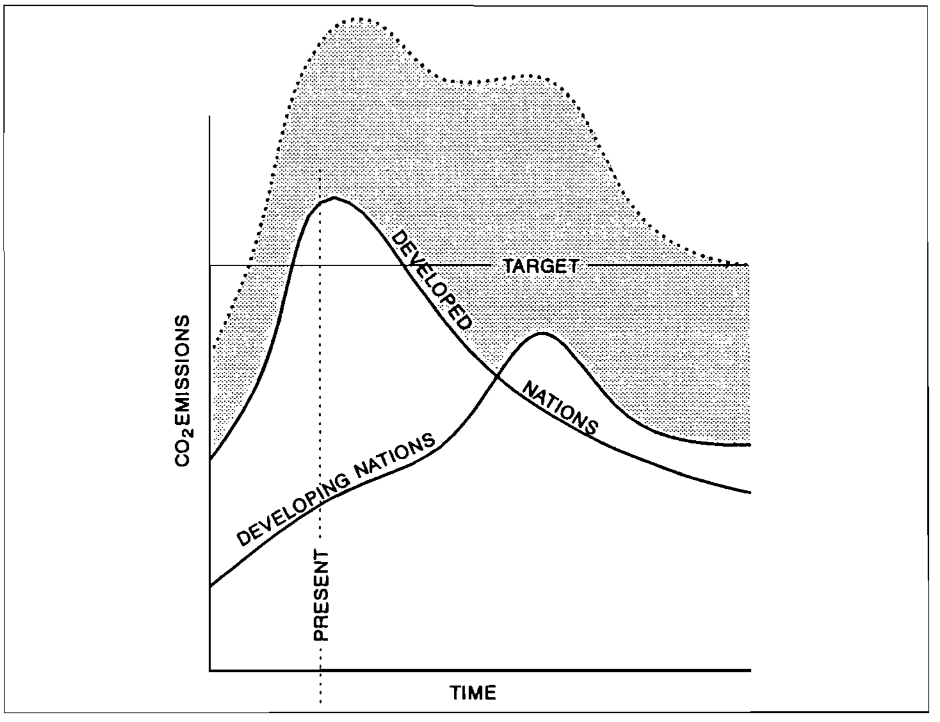


*Figure 2: Non-optimal development resulting in an emission peak in developing nations ("most likely scenario")*

South Africa cannot, however, afford to "go it alone" in this regard. It is considered essential that every attempt should be made to establish a regional strategy with neighbouring states. Regional initiatives in R&D should be established. In particular, projects such as the determination of regional radiative gas inventories, renewable energy pilot projects, and air quality monitoring networks should be created. Regional environmental networking and co-operation will enhance existing networking and generate a greater awareness as to the successes achieved to date and future strategies. It should be noted that the South African power industry already has a well-integrated portfolio of actions and priorities, which not only facilitates development but also ensures that this development is achieved in the spirit of the Framework Convention on Climate Change[12].

## Conclusions

The events in Rio in June 1992 should be viewed as part of a process. The fact that all treaties and conventions were not finalised should not be cause for concern. The fact that UNCED happened is in itself significant. The progress made in facilitating international co-operation in environmental matters should not be underestimated. Specific conclusions drawn by the author are:

- The "greening" of business is occurring at an encouraging rate.
- A strong R&D and technology transfer thrust will be of benefit to developing nations.
- The meeting of technology challenges facing the energy industry is feasible and will ensure long-term sustainable development.
- The South African energy industry is well-positioned to meet the challenges imposed by balancing environmental impacts with developmental needs.
- Southern African regional co-operation is essential to ensure success.
- A Southern African policy based on pragmatism and the "no regrets" philosophy should be developed.

## ACKNOWLEDGEMENTS

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# COMMENT ON PAPER:

# *Recent hydrological trends in the Zambezi basin and their effect on the present electrical energy situation in Zimbabwe and Zambia

The paper describes a very dramatic reduction in average Zambezi and Kafue run-off over the last 10 years to about 50% of that of the previous 20 years. Given that the storage reservoirs on the two rivers are not very large compared to the respective run-offs, as shown in Table 1 below, it is not clear whether an analysis based on total or average run-off is valid because floodwater may not be fully usable for generation. Figure 7 in the paper gives the impression that at Itezhi-Tezhi the change may be due to the absence of years with above-normal flow from 1981/82 onwards.

However, alternative analysis of the data in the paper, given in the following two tables, shows that the changes are not confined to an absence of wet years but that relatively dry years were also more frequent during the last 10 years compared to the previous 20 years. The result is that the power stations can only be operated at about 55% load factor as long as the present situation continues.

| | KARIBA | ITEZHI-TEZHI |
|---|---|---|
| Gross MAR (milliards) | 51,40 | 10,70 |
| Live storage (milliards) | 64,80 | 5,00 |
| Ratio | 1,26 | 0,47 |

*Table 1: Reservoir live storage compared to MAR*

| Gross inflow (1) Milliards/a | Net inflow (2) Milliards/a | Energy (3) $10^3$GWh/a | Percent LF (4) of 1266 MW | Occurences during Period (1) 1961/2-80/1 | 1981/2-90/1 |
|---|---|---|---|---|---|
| 18,7 - 28,7 | 10 - 20 | 2,31 - 4,63 | 21 - 42 | 1 | 3 |
| 28,7 - 38,7 | 20 - 30 | 4,63 - 6,94 | 42 - 63 | 0 | 3 |
| 38,7 - 48,7 | 30 - 40 | 6,94 - 9,25 | 63 - 83 | 6 | 3 |
| 48,7 - 58,7 | 40 - 50 | 9,25 - 11,56 | 83 - 104 | 2 | 1 |
| 58,7 - 68,7 | 50 - 60 | 11,56 - 13,88 | 104 - 125 | 5 | 0 |
| 68,7 - 78,7 | 60 - 70 | 13,88 - 16,19 | 125 - 146 | 3 | |
| 78,7 - 88,7 | 70 - 80 | 16,19 - 18,50 | 146 - 167 | 1 | |
| 88,7 - 98,7 | 80 - 90 | 18,50 - 20,81 | 167 - 188 | 2 | |
| EXPECTED LOAD FACTOR | | | | 107% | 56% |

*Table 2: Energy potential of Kariba in-flows from 1961/62 to 1990/91*

(1) Data from Figure 5
(2) Assuming 8,7 Milliards/a evaporation loss
(3) 4,324 Milliards/$10^3$
(4) Load factor of installed capacity at Kariba North and South Power Station

* This paper by A P Dale was originally published in the Journal of Energy R&D in Southern Africa, Vol. 3 No. 4, November 1992, pp. 3-11.

| Gross inflow (1) m³/s | Gross inflow Milliards/a | Net inflow (2) Milliards/a | Energy (3) $10^3$GWh/a | Percent LF (4) of 900 MW | Occurences during Period (1) 1961/2-80/1 | 1981/2-90/1 |
|---|---|---|---|---|---|---|
| 50 - 150 | 1,58 - 4,73 | -0,63 - >2,52 | -,61 - >2,44 | -8 - 31 | 1 | 1 |
| 150 - 250 | 4,73 - 7,88 | 2,52 - 5,67 | 2,44 - 5,49 | 31 - 70 | 5 | 7 |
| 250 - 350 | 7,88 - 11,04 | 5,67 - 8,83 | 5,49 - 8,54 | 70 - 108 | 3 | 2 |
| 350 - 450 | 11,04 - 14,19 | 8,83 - 11,98 | 8,54 - 11,59 | 108 - 147 | 4 | 0 |
| 450 - 550 | 14,19 - 17,34 | 11,98 - 15,13 | 11,59 - 14,64 | 147 - 186 | 2 | |
| 550 - 650 | 17,34 - 20,50 | 15,13 - 18,29 | 14,64 - 17,69 | 186 - 224 | 3 | |
| 650 - 750 | 20,50 - 23,65 | 18,29 - 21,44 | 17,69 - 20,74 | 224 - 263 | 0 | |
| 750 - 850 | 23,65 - 26,81 | 21,44 - 24,60 | 20,74 - 23,79 | 263 - 302 | 2 | |
| EXPECTED LOAD FACTOR | | | | | 128% | 54% |

*Table 3: Energy potential of Kafue flows from 1961/62 to 1990/91*

(1) Data estimated from Figure 7

(2) Assuming 2,21 Milliards/a evaporation and other uses

(3) 1,034 Milliards/1000 GWh

(4) Load factor of 900 MW Kafue Gorge Power Station

The paper also discusses possible factors influencing the recent hydrological trends. Tyson and Dyer's 18-20-year rainfall cycle over South Africa is mentioned, but that variation is much weaker than the severe changes in run-off observed at Kariba and Itezhi-Tezhi. Equally severe changes in the level of Lake Malawi was, however, described by Dyer (S A Journal of Science, Vol.72, 1976, p.381).

The maximum level decreased from about 1 546 masl in 1895 to about 1 537 in 1915, thereafter it increased to about 1 556 masl in 1935 and fluctuated between about 1550 and 1 557 masl until 1975. It would be significant if the Malawi Lake level also started to decrease in 1981/82. If that is the case, the global warming, $CO_2$-driven hothouse idea will be undermined.

In order to discriminate between various factors suspected to be responsible for the current flow reduction, it may be helpful to determine the time series structure and to construct a stochastic run-off model for the Zambezi and Kafue Rivers. Eskom uses this method to study the water supply to its coal-fired power stations. It is expected that the Zambezi and Kafue River models will show much more persistence than the South African rivers in the summer rainfall area.

Strong annual serial correlation might help to explain the long-lasting fluctuations as a natural property of the rivers. To gain confidence in such an explanation one would assess the time series structure of the run-off of the major rivers in the Southern African geographical region, from Zaire to South Africa and from Angola to Mozambique. This region could eventually be linked by one electricity grid, and knowledge of the spatial and improved variation of water availability over this region would be valuable.

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# Energy news in Africa

There has been mixed reaction to the signing of a treaty in 1992 which transformed the Southern African Development Coordination Conference (SADCC) into the Southern African Development Community (SADC). It is generally agreed that regional co-operation and closer union are essential if the countries of the Southern African region are to realise their economic potential. However, SADC has committed itself to more than this - economic and political integration, apparently by 2034 in step with OAU plans for an African Economic Community. SADC intends first to harmonise macro-economic policies, then to work towards a free-trade zone, a customs union and, ultimately, full economic union with integrated monetary and fiscal systems, and a regional parliament.

SADCC's record has shown that it has made little significant progress with its main objectives, namely, to reduce dependence on mainly South Africa, and the forging of links to create a genuine and equitable regional integration. However, SADCC has created a sense of regional identity and focused international attention on South and Southern Africa. SADC has realised that integrated policies on trade, investment, labour mobility, and so on are considered essential in order to promote economic development and its more equitable distribution among member countries.

(Source: Africa Insight, Vol.22, No.3, 1992)

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Engen has been granted a license to explore for oil in an area in the Orange River basin, off the southern coast of Namibia. The exploration work will be undertaken by Engen's international exploration arm, Eagle Energy, together with the Chevron Oil Company of California.

(Source: Engineering News, 6 November 1992)

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Zimbabwe Electricity Supply Authority (ZESA) has appointed Simbarashe Mangwengwende as new General Manager. Meanwhile, ZESA Chairman, Mr Solomon Tawengwa, said that the authority was implementing a restructuring exercise to fill the functions of finance, corporate services, consumer services, generation and technical services.

(Source: The Herald (Harare), 3 December 1992)

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The Government of Malawi is prioritising the development of that country's hydroelectric resources to meet the growing demand for cheap power. The Commonwealth Development Corporation, the World Bank, the European Investment Bank and the African Development Bank, is to finance the first phase of a new hydroelectric project at Kapchira Falls on the Shire River.

This will include the construction of a dam and the installation of a 2 x 25 MW powerplant by 1997, with scope to install a further three units by the year 2000.

(Source: International Water Power & Dam Construction, November 1992)

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Mozambique and Zimbabwe have signed an agreement under which electricity generated at the Cabora Bassa hydroelectric plant on the Zambezi River in the northwestern Mozambican province of Tete will be sold to Zimbabwe.

The agreement involves the construction of two parallel transmission lines running from the plant to Harare, a distance of 350 km. The cost of the lines is about US$200 M, of which 50% will be raised jointly by Mozambique and Zimbabwe.

(Source: International Water Power & Dam Construction, January 1993

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Electricite de France (EdF) and Lahmeyer of Germany have begun work on a US$4 M contract to prepare a feasibility study for a power transmission line from Zaire to Egypt. The study is being financed from a US$10 M grant from the African Development Bank.

Zaire's present installed capacity is only 1 600 MW but there is potential for this to be increased to 30 000 MW.

(Source: International Water Power & Dam Construction, January 1993

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The Coal Export Joint Venture (Coalex), consisting of a group of South Africa's large coal producers, is examining the possibility of establishing a new multi-million Rand coal export terminal at Richards Bay. Coalex Chairman says that increased demand for coal from South Africa, through natural growth, was expected to be 2 million tons (Mt) a year over the next five or six years. By the year 2000, coal demand from South Africa is expected to be about 63 Mt. The consortium says it has about 12 Mt/year of coal for export which its members would export on an individual basis.

Richards Bay Coal Terminal recently completed an expansion of its facilities to handle 53 Mt of coal, making it the biggest single coal export terminal in the world. It is expected that the size of the terminal should be sufficient until 1996.

(Source: Sunday Times, 10/1/93 Business Day, 13/1/93)

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# Details of authors

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Steve Lennon spent one year with the CSIR's Division of Materials Science and Technology before joining Eskom's Engineering Investigations' Metallic Corrosion Group in 1986. He was appointed Head of the Corrosion and Non-Metallic Group one year later. In 1989, he was appointed Scientific Investigations Manager, which meant that he was responsible for chemical, materials and environmental tests, investigation and research at Eskom. He became Scientific Services Manager in 1991.

His interest in environmental matters is reflected further in some of the other offices he holds. These include President of the S A Corrosion Institute, Chairman of the S A Electrolytic Corrosion Committee, and Chairman of the Energy Use Task Group of the Interdepartmental Co-ordinating Committee for Global Climate Change.

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After serving a tool- and die-maker apprenticeship, Norman Magasiner graduated from Wits in 1955. He then spent a year in London doing research on the dynamics of overhead travelling cranes, after which he joined John Thompson Ltd in Wolverhampton as a boiler designer.

In 1957 he established a boiler design office for John Thompson's local subsidiary. In the roles, firstly, as Project Engineer, then as Technical Director and, finally, as Managing Director of John Thompson Africa (Pty) Ltd, he was responsible for the development of a range of coal-fired packaged shell boilers and a range of fibrous fuel-fired water-tube boilers which have won acclaim on the international market.

After 31 years with John Thompson he set up his own company, Thermal Energy Systems cc, which provides technical advice, project management services and boiler hardware to organisations interested in using biomass and fossil fuels to generate process steam and power.

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Since 1981, Dr Pachauri has been the Director of the Tata Energy Research Institute. He has held posts at various universities in the United States of America, such as, West University, Raleigh, North Carolina. In 1988 he was President and between 1989/1990 Chairman of the International Association for Energy Economics. He is presently the President of the Asian Energy Institute and the Solar Energy Society of India (SESI).

Dr Pachauri served as a member of the Advisory Board on Energy to the Indian Government from 1983 to 1989 and is currently a member of the World Energy Council.

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Miguel Schloss joined the World Bank in 1969, and has since held various positions in the Technical Department of the Africa region and in the Country Departments of the Latin America region. He was recently assigned to head the Corporate and Budget Planning Division.

Prior to joining the World Bank, Mr. Schloss was the Deputy Manager of Marplan (Interpublic) in Chile, and Credit Manager of Dow Chemical in Mexico.

# Forthcoming energy and energy-related conferences:

## 1993

### MAY 1993

31-1/6

ITEC - 93 : FIRST INTERNATIONAL THERMAL ENERGY CONGRESS Marrakesh, Morocco

Enquiries: Prof. A Mir, Cadi Ayyad University, Faculty of Science I, Bd Prince Moulay Abdellah, BP S-15 Marrakesh, Morocco

### OCTOBER 1993

11-12

CLEAN AIR CHALLENGES IN A CHANGING SOUTH AFRICA Pretoria, South Africa

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Tel.: (012) 63 1681, Fax.: (012) 63 1680

21-28

IST INTERNATIONAL SYMPOSIUM ON ENERGY AND DEVELOPMENT Maputo, Mozambique

Enquiries: Henrique Lopes, FENEDSA, Engineering Faculty, Eduardo Mondlane University, P O Box 257, Maputo, Mozambiques

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# Recent energy publications

**ERENS P J and DREYER A A**

Optimal design of combined wet/dry cooling systems for mining, industrial or power generation systems: Spray-cooled heat exchangers. Energy Branch, Dept of Mineral and Energy Affairs, September 1992.

Project Ref. No. ED9003

**ERENS P J** *et al.*

Indirect evaporative cooling for air conditioning. Energy Branch, Dept of Mineral and Energy Affairs, September 1992, 44p. + appendices
Project Ref. No. ED9001

**LETCHER T M**

The cost effectiveness of exploiting methane from landfill. Energy Branch, Dept of Mineral and Energy Affairs, December 1992, 299p.

Project Ref. No. EO8907

**SCABERG P W and PRIEDE T**

Effect of octane enhancers on fuel octane values. Energy Branch, Dept of Mineral and Energy Affairs, November 1992 (Revised), 127p.
Project Ref. No. VE 7/3/11

**STRONG R A G**

S A light vehicle transport profile. Energy Branch, Dept of Mineral and Energy Affairs, September 1992 (Revised), 35p. + appendices

**UKEN E A and BEUTE N**

Source document on the effective use of energy in westernised dwellings. Energy Branch, Dept of Mineral and Energy Affairs, November 1992, 119p.
Project Ref. No. ED8909

**VAN EEDEN A**

Opname oor kennis, houdings en gedrag van spesifieke teikengroepe vir aanwending in 'n brandstofbesparingsveldtog: Fase 1. Energy Branch, Dept of Mineral and Energy Affairs, December 1992 (Revised), 47p.
VE 13/26 Phase 1

**VAN NIEKERK H R**

Status report on electric vehicle technologies. Energy Branch, Dept of Mineral and Energy Affairs, September 1992 (Revised), 32p.
Project Ref. No. VE 9/9

All these reports are Final Reports. The publications can be ordered from: The Librarian, Energy Branch: Department of Mineral and Energy Affairs, Private Bag X03, Lynnwood Ridge 0040, South Africa, unless otherwise indicated. Prices are available on request from the Energy Branch: Department of Mineral and Energy Affairs.

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