SCIENCE AND TECHNOLOGY, RESEARCH AND DEVELOPMENT, ENERGY AND THE LDCs : RAMBLING THOUGHTS FROM AN ACADEMIC

Prof. J Manrakhan
Vice-Chancellor, University of Mauritius, Reduit, Mauritius

TERMINOLOGY

There are innumerable ways of looking at "science", "technology", "research" and "development". In line with evolution of thinking and practice over the last few decades, it would be best to think in terms of a science-technology continuum. That continuum should be regarded as a strongly interacting "know-why/know-how" system, and for our purposes, the emphasis should be on the "know-how" part of the continuum. The "know-how" part of the continuum, in particular, has to operate within socio-politico-economic contexts, both national and international. Along similar lines, research and development (R&D), should best be regarded in "know-why/know-how" continuum terms, again operating within socio-politico-economic contexts; part of the science-technology continuum prior to, and excluding, mass industrial and commercial production operations. Moreover, "technology" would also include management concepts and techniques.

FROM TERMINOLOGY TO MODEL: MAURITIUS 2000

The view of science and technology outlined above has found expression, and practical application in the "Mauritius 2000" concept of the university.

(i) There is nothing particularly extraordinary about the year 2000 as such. The Mauritius 2000 concept is a flexible one which enables the university to use a fairly long time-horizon to build alternative internally consistent scenarios, working backwards to the present in attempting to find practical solutions to existing and foreseeable problems, within an integrated and dynamic context.

(ii) Various working groups at the University, operating on the 'swim or sink' principle, aim to cover among others biotechnology; energy; employment, productivity and industrial relations; macro-economic modelling; microelectronics and physical resources planning. And, among the new areas the Mauritius 2000 studies will shortly cover are food and nutrition; women studies; the small farmer concept; the welfare state; and industrialisation.

(iii) As anticipated there are interactions between the several exercises. Indeed, energy considerations have required review of initial aims of most of the Mauritius 2000 exercises in progress and planned. There is a need to develop a methodology concerning measurement systems to enable the integration of the various Mauritius 2000 exercises from the point of view of science and technology, and their repercussions in society. Energy considerations appear to constitute a useful starter here, for example, by adopting a "carrying capacity" approach.

CERTAIN ISSUES CONCERNING ENERGY RESTATED

It is convenient, at this stage, to restate certain general remarks on Energy.

(a) The distribution of non-renewable energy resources in the world is very uneven; "poor" countries are, in general, also "poorly off" in those energy resources (except for certain oil-exporting countries). Moreover these are becoming scarcer: at current rates of consumption, presently known oil resources are estimated to last 30 to 50 years, while coal resources may last 200 to 500 (possible 800) years. Any major increase in coal use may lead to environmental problems. In any case Africa, as far as is known at present, is deficient in coal reserves.

(b) The consumption of energy is also uneven throughout the world. Around 70% of the world's population, accounting for 20% of the world's annual energy consumption, have a per capita consumption of goods and services of between one-tenth and one-twentieth of the corresponding figure in highly industrialised countries. There is a relationship between gross national products (GNP) per head and energy consumption per head. Because of increasing population and rising average energy consumption per head, the world's energy consumption is increasing, although less rapidly than previously since the mid-1970s. Relationships, expressed in the language of mathematical statistics have been, and are being, found - for example, between GNP per head and commercial energy consumption per head, or in inter-sectoral input-output tables. These relationships, besides providing further insights into economic development processes are also very useful in more specific energy studies, particularly if non-commercial energy could be brought into the reckoning with implications for renewable energy resources.

(c) There is a need for considerable increases in costly and time-consuming efforts (including R&D) to explore and exploit new fossil fuel resources, geothermal resources, nuclear fission and fusion systems, and in connection with renewable energy resources (eg direct solar, wind, tide, hydroelectric and biomass conversion). Even so, most forecasts **(1)** seem to indicate that by 2000 AD the maximum contribution of renewable energy resources to overall world energy demand would be in the range of 5% to 10%. But Africa is more favourably placed than these world-wide estimates suggest. And in Mauritius biomass prospects are well beyond such estimates.

(d) It is sobering to reflect that, only a few years ago, most forecasts were to the effect that the long-term trend in the world average energy price would be an increasing one in real terms. But by how much? Could renewable energy resources not come to the rescue?; if so, how and when? -these are some of the questions we need to reflect upon **(2)**.

ENERGY AND THE LEAST DEVELOPED COUNTRIES: THE BROOKHAVEN STUDY

The Brookhaven National Laboratory, commissioned by the US Agency for International Development, produced a report in 1978 covering the energy needs, uses and resources of developing countries up to the year 2000 AD **(3)**. Many non-OPEC developing countries were already in serious difficulties with increasing energy costs, growing populations and urbanisation, worsening unemployment and balance of payment problems, and with recurrent food shortages. In the absence of remedial measures, the Brookhaven study concluded, the position in those countries would be aggravated and become catastrophic, with the whole ecosystem supporting the rural poor increasingly at risk.

That study, by no means the most pessimistic at the time, recommended finding solutions to the energy problems of the LDCs, in terms of exploration and exploitation of renewable and non-renewable resources, production and consumption aspects and stressed both technological as well as social aspects. Energy, it stated, "drives the machinery of a nation in all its vast human, cultural and economic complexity"; energy assistance programmes would only succeed if conceived and implemented with "due respect" to that complexity. The Brookhaven study estimated the total investment required, up to the year 2000, to enable non-OPEC LDCs, as a whole, to reach energy self sufficiency at US $125,000 million in terms of 1976 prices.

APPEAL TO THE CONSCIENCE OF MANKIND

The Brandt Commission (1980) was to appeal to the conscience of mankind for the elaboration of a New International Economic Order **(4)**. It addressed itself to energy thus:

(i) Energy cannot be examined in isolation but within a generalised and integrated context of major world problems (including food, hunger, poverty, unemployment, health, education and so on).

(ii) Until the turn of the century, the main energy source of the world will continue to be oil; arrangements have to be made as a matter of urgency to protect the economies of 'poor' countries against sharp price increases in energy and to provide security of supplies to those countries.

(iii) Transitional measures are necessary in shifting from oil to other energy sources, including supply planning and management, very costly exploration and development of energy resources; the 'South' must not be forced to adopt expensive new technologies for alternative energy sources; a World Energy Research Centre should be set up under UN auspices.

(iv) Energy conservation is crucial and may necessitate international agreement and surveillance for all countries; however, the world's energy (and other) problems must be solved by peaceful means and not by force.

SHOCK WAVES

On the other hand, Toffler (1980), striving to shock us into becoming conscious of the advent of a new 'Third Wave' civilisation, has highlighted the following features:

1. Prior to the "Industrial Revolution", mankind lived within its energy "income" on many, dispersed and renewable energy sources, in the main. Thereafter, industrialisation, using concentrated and few energy sources, led to depletion of energy capital as a result of building "towering technological and economic structures" on the assumption that cheap fossil fuels would be "endlessly available".

   In the process, there was a "dramatic reworking of the landscape" requiring more complex coordination between city and countryside than hitherto, with considerable flows of people, food, energy, raw materials, on the one hand, and manufactured goods and services, including information, on the other. Moreover, while fossil fuels accelerated markedly technological and economic growth, "energy-thirsty, brute technology" exploited those very fossil fuels ever more rapidly. So much so, that the civilisation we know of today is in the throes of violent disintegration with many a crisis, including ecological, socio-politico-economic ones.

2. Many new ideas for centralised and decentralised large-scale and small-scale energy production have been thought of already. With other developments will come a new civilisation which will draw upon a very wide variety of energy sources - "hydrogen, solar, geothermal, tidal, biomass, lightning discharges, ultimately perhaps advanced fusion power, as well as other energy sources not yet imagined in the 1980s". The technological base of such a civilisation will be far more diversified, "springing from biology, genetics, electronics, materials science as well as outerspace and under-the-sea operations". Most technologies will use less, not more energy - thus the energy required to produce 90 miles of copper can even now be used to turn out 80,000 miles of optical fibre. They will be small in scale, simple and safe to operate, with "wastes of one industry predesigned for recycling into primary materials for another". Major societal changes, however, will only be felt when the new technologies such as biotechnology, sea nodule extraction and utilisation, microelectronics and computers, link together with a new multi-source, renewable energy base.

Significantly, both the Brandt Commission (1983) and Alvin Toffler (1983) have maintained their previous views; if anything, the latter have indeed become reinforced.

THE DONS IN CONGRESS AT VANCOUVER, 1978

Less than six months after the publication of the Brookhaven study, the Executive Heads and other representatives of Commonwealth Universities met in congress at Vancouver in August 1978. Topic 1 on the agenda dealt with 'The World Food Problem and the Universities'; there were to be four subtopics; namely 'production potential', 'population', 'energy' and health'. **(7)**

Significantly, the interrelationships among food, energy, poverty and general socio-economic factors as well as more obvious scientific and technological considerations loomed large in the papers presented (illustrated with statistical tables) and the ensuing discussions. Among topics raised and debated were energy budgets, sources and potentials on a world scale and for certain individual countries, the uneven distribution of energy production and consumption, effects of prices, international issues including a New Economic order, renewable energy technologies including conservation ones, new social arrangements to utilise energy (eg communal cooking, biogas generation), energy farming, energy analysis of agricultural systems (including subsistence ones), how to increase energy efficiencies on farms, the transition from traditional energy resources to more commercial ones, energy dependencies of LDCs, scientific technological assistance to LDCs and so on.

Obviously, the role of universities was highlighted. Apart from teaching and the ability to provide a forum of discussion for clarifying and sharpening arguments objectively, the multidisciplinary nature of most universities provide the latter with undoubted advantages in energy studies and research:

> "Universities, through the skills and dedication of their staff and students, have unlimited possibilities to contribute to the solution of national and international energy problems. Specialised research contributions on the scientific and technological aspects of energy production, storage and consumption represent obvious areas for detailed work and much is already going on in these domains. As research moves away from the fundamental end of the spectrum towards the development and demonstration stages, university personnel may need to contribute more in governmental and industrial settings than within their own laboratories, but this is a familiar concept not restricted to energy research. The techniques of energy analysis and modelling (with a view to assessing the complex interactions of economic, social and environmental factors with medium and long-term projections of energy supply and demand) are still at an early stage of their development and can present an intellectual challenge to the problem of providing energy for developing countries is a challenge to the idealism (hopefully) in us all."

George (1979)

MEANWHILE IN MAURITIUS

Energy considerations were also to loom large on the University's agenda in Mauritius, as well as on those of organisations and persons outside the Reduit campus.

Put briefly, the number of Mauritian qualified scientists, engineers and economists (in terms of full-time equivalents) working on one aspect or another of the energy situation in Mauritius over the past 5 years would be of the order of 10 to 15, of which the University would have contributed between half to one-third. Taking recurrent expenditures and cost of supporting staff into account, the value in 1980 prices would be of the order of Rs 1.5 million to Rs 2.5 million per annum. The above-mentioned estimates exclude:

(a) Capital Costs of R&D energy projects - where these largely utilise resources already available for other purposes.

(b) Foreign R&D costs associated with bagasse pelletisation, Champagne Hydro-Electric Project, Medine & FUEL power generation bagasse/coal generation plants, and the Riambel Sea Wave Project.

Three national seminars and conferences were held (in February 1977, December 1980 and February 1981) by the University, singly or in conjunction with other institutions and agencies, both governmental and private. The last national seminar led to the elaboration of a National Plan of Action on Energy, which was presented at the UN Conference on New and Renewable sources of Energy held at Nairobi in August 1981. I understand that Plan of Action was received with fair interest there.

The following are relevant:

1. Analysis of Papers presented in February 1977 and December 1980

		1-Day Energy Seminar (8) Feb 1977		1-Week National Conference (9) Dec 1980		
1.	Energy Resource Assessment	2	(0)	6	(0)	
2.	Energy Conversion Technologies	4	(4)	23	(23)	
3.	Energy Utilisation Technologies	3	(2)	11	(5)	
4.	Energy Policy Formulation and Planning	0	(0)	8	(2)	See (ii) below
		9	**(6)**	**48**	**(30)**	

Notes: (i) The numbers in brackets denote those specifically devoted to renewable energy.

(ii) The National Energy Conference of December 1980 was followed by a 1-day National Energy Seminar held in February 1981; both were organised in integrated fashion to help elaborate a National Plan of Action on Energy until 2000 AD **(10)**.

2. Among the main features of the National Energy Plan of Action were:

(i) With GNP per head increasing at 2% per annum in real terms, the total amount of energy demand projected up to 2000 AD was 440,000 tonnes of oil equivalent (toe) from 210,000 toe including 190,000 toe of net imports in 1979. This was projected to be met thus:

			'000 toe
A.	Renewable Energy except from Sugar Industry		89
	Hydro	21	
	Woody Biomass	33	
	Solar	15	
	Wave	20	
B.	Renewable Energy via Sugar Industry (Bagasse, Cane Tope, Ethanol)		114
C.	Conservation		94
D.	Oil Imports (electricity, transportation)		143
	Total (exclusive of autoconsumption in sugar industry)		440

(ii) The investment required over the period 1980-2000 in real terms would be of the order of Rs 2500 million. Of this amount, investment in the sugar industry for energy purposes was estimated at Rs 1300 million (Rs 1000 m for electricity generation and Rs 300 m for ethanol production).

(iii) It was stressed that no document on energy could be expected to remain up-to-date for very long, and would necessitate frequent revisions; in any case a 2% GNP increase per head per annum might not be sufficient. On the other hand, the projections in the National Energy Plan of Action suffice to illustrate the considerable prospects which exist in terms of renewable energy resources in Mauritius - well beyond the 5 to 10% of total energy consumption by the year 2000 and into the range of between one-half and two-thirds of the total (exclusive of autoconsumption in agricultural industries almost wholly renewable).

(iv) Various proposals relating to R&D in the energy field were made.

MORE ON R&D CONSIDERATIONS

An account of the thinking and work of the University of Mauritius in R&D of energy technologies will be presented at this Conference. Here and now, I restrict myself to the following:

1. Since 1980-81, further steps in the elaboration of energy models have been made; some exercises have begun producing results towards the 2020

time horizon. Another interesting ex is that of attempting to discover the possibilities of 'tunnelling' through the 'hump' which empirically seems to exist in commercial energy consumption/GNP per head curves with increasing industrialisation: various energy input-output models are being worked out.

2. A further scrutiny of the R&D proposals in the National Energy Plan of Action has been made, first, to assess current R&D capabilities and, second, the extent to which such capabilities can be harnessed at the University in the light of other, and competing, tasks. The results of such a scrutiny are illustrated in Appendix IV.

3. Among some of the questions, with R&D implications which we are asking ourselves at the University are:

(i) Is pelletisation the 'best' techno-economic solution for storing bagasse without significant deterioration for periods up to 6 months?,

(ii) Can biotechnology provide a satisfactory answer to the problem of the disposal of "vinasse", the residue left over in the fermentation of molasses to alcohol?,

(iii) Is there any really effective R%D work left to be done on the Riambel Sea Wave Project unless the proposed 1 MW 'prototype' be constructed even if the cost of the latter at Rs 10 million appears high?,

and (iv) What are the prospects of increasing the usefulness of the River Champagne Scheme to the national electricity grid?; what about other sources of renewable energy which were not incorporated in the National Energy Plan of 1981, for example, agricultural wastes, marine algal ocean thermal conversion, and geothermal energy, among others?

4. Thoughts such as those which inspired the various texts I have mentioned in my address, have also guided us in Mauritius: the necessity to look at energy in a more generalised and integrated context; problems and prospects associated with renewable energy resources, particularly biomass; the ever-growing impact of science and technology in society, changing at ever-faster pace, among other considerations.

But, undoubtedly, most of the energy studies in Mauritius, inside and outside the campus, have tended until recently to be unduly dispersed and insufficiently interconnected and coordinated. Certain fields of enquiry have, in consequence, been unnecessarily over-subscribed in terms of efforts but not necessarily in terms of results, while others have been left untouched or only timidly covered. A natural process of rationalisation has come about over the past few years, particularly within the University, with the help of the Higher Education Division of the British Council and the Commonwealth Science Council, within the context of Mauritius 2000. Is it fast enough? And what about the rationalisation of R&D efforts on energy in Mauritius as a whole?

In parenthesis, may I point out that, as a University, we must also think in terms of teaching and training. Apart from workshops and seminars, we are giving thought to the incorporation of energy components in various subdegree and degree courses as well as in proposed Masters' courses in Administration, Management and Technology.

INTERNATIONAL SUPPORT

Finally, it gives me great pleasure in acknowledging, with gratitude, the support from overseas which the University of Mauritius is deriving for its work in the energy field. In particular, thanks must be expressed to the Commonwealth Science Council and the Higher Education Division of the British Council, whose efforts (supplemented occasionally from the United States) underpin much of our efforts in the energy field. Although I would like to think that we have earned such support through hard sweat, I must also regard that support in the context of efforts in the international community to help the LDCs in science and technology and in other fields of endeavour.

This Conference itself would never have been possible without the support, financial and otherwise, of the international community, competently motivated, marshalled and managed by the Commonwealth Science Council. If perchance, I have said anything that might be of some use to the participants to this Conference, I shall be delighted.

NOTES AND REFERENCES

1. See, for example, George, D.W.
in Association of Commonwealth Universities (ACU): Pressures and Priorities; The Report of the Proceedings of the 12th Congress of the Commonwealth; Vancouver; August 1978; Lond.; 1979; p. 134.

2. See, for example, Chaudheri, N. in A.C.U. (1979), p. 143.

3. Palmedo, F. and others (1978) Energy Needs, uses and Resources in Developing Countries. (Brookhaven National Laboratory for US Agency for International Development). Shortened to Brookhaven Study in main text.

4. North-South: A Programme for Survival; The Report of the Independent Commission on International Development Issues under the chairmanship of Willy Brandt (shorted to Brandt Commission in main text); Pan Books Lond.; 1980.

5. Toffler, A. (1980) The Third Wave; Bantam Books, N.Y. See p. 25; p. 106; p. 134; p. 331; p. 141; p. 351; p. 339

6. See The Brandt Commission (1983): Common Crisis; North-South: Co-operation for World Recovery; Pan Books; Lond. p. 15, pp. 133-138, in particular.

and

Toffler, A. (1983): Previews and Premises; Pan Books; Lond.; (1984): see pp. 25-26 and p. 88, in particular.

7. See ACU (1979); pp. 26-183.

8. Proceedings of Seminar on Energy, University of Mauritius, 1977. (Maudarbocus, Y. and Deerpalsingh, N. - Eds.)

9. Proceedings of the National Energy Conference, University of Mauritius 1980. (Carver, G.; Baguant, J.; Fagoonee, I; and Yeung Lam Ko, L.K.C. - Eds.)

10. National Energy Seminar: Plan of Action - Feb 1981. Journal of the University of Mauritius; No. 10-11; July-Dec 1981, pp. 159-216.

Appendix I

CHARACTERISTICS OF SCIENCE COMPARED WITH THOSE OF TECHNOLOGY AND INDUSTRY

Science	Technology	Industry
understanding	utilisation	mass production
from unknown to known	from known to useful	from useful to popular use
system of thought	system of method	system of production and sale
passive (natural)	active (artificial)	passive to active (demand-supply to produce-consume)
objective	subjective	objective to subjective
meaning	means	efficiency (organisation & management)
discovery	invention	development
truth convenience	convenience	profit = output/input (organic system)
satisfaction of mind	satisfaction of body	satisfaction of economy
academic	professional	entrepreneurial
scholar	specialist	entrepreneur
100 year scale	10 year scale	1 year scale

Source:

Chan, Y.W., Evolution of Scientific Thought in Physics, Chinese University of Hong Kong; Professional Inaugural Lecture Series 3; Supplement 10, 1982

Appendix II

In general R&D is defined as any creative systematic activity undertaken to increase the stock of scientific and technical knowledge and to devise new applications.

It should exclude scientific education, scientific and technical information, general-purpose data collection, routine testing, standardisation and other technological activites related to production or use of established products or processes, as well as large-scale mineral and petroleum prospecting for exploitable deposits and not essential for basic geological knowledge. In the social sciences include activities of a research nature related to the solution of economic or social problems, but exclude routine activities such as censuses, market studies, etc. In the medical sciences exclude intensive medical care. In general, defence R&D should be included.

The criterion for distinguishing R&D from non R&D activities in the presence or absence of an appreciable element of novelty or innovation.

source: UNESCO 1978

APPENDIX III

RESEARCH AND DEVELOPMENT

The following broad lines of research and development need to be given priority in the light of the discussions which had taken place during the National Energy Conference held on 15th to 19th December 1980.

1. A systematic collection/compilation of data/statistics on energy and their analysis.

2. Use of the energy statistics for the construction of a proper energy balance for the country, and within the framework of an input-output table.

3. Using (1) and (2) above, to work out an appropriate aggregate energy demand model which will eventually be used for planning and policy-making purposes.

4. Detailed studies (both technical and economic) of the following projects are to be carried out:

   (i) Hydro-power - A proper re-assessment of the total potential of hydro-power will be required.

   (ii) Electricity from bagasse (including close cropping, use of cane-tops and leaves), improvement of thermal efficiencies, etc, need to be looked carefully into.

   (iii) The use of coal as a substitute for oil in electricity production and for out-of-season electricity production from sugar estates should be objectively examined.

   (iv) Woody biomass. Rational studies and surveys on woody biomass and energy forms as a source of energy and otherwise have to be undertaken as a matter of urgency, being given that maximum use of solar energy can thus be obtained.

   (v) Ethanol from molasses as an energy source. A complete study of the technical feasibility, production costs, effects on the government and the balance-of-payments of the ethanol project is required to settle once and for all the differences of opinion on this issue. (The new Lonrho report will be helpful in this respect).

   (vi) Solar water heaters. Further investigations for locally constructed, low cost and cyclone resistant water-heaters, and their financial implications for the government and the public should be looked into.

   (vii) Wave power. Careful consideration of this new venture is required with special emphasis on technological, environmental, economic and other aspects.

(viii) Conservation. Various conservation measures have been proposed at the Conference. New conservation methods have to be looked into.

(ix) Nuclear energy option. Relevant information to be collected and analysed so as to keep options under continuous review.

(x) Wind. Statistical data on wind potential at relevant sites to be collected and analysed. Information on wind generators to be compiled and updated periodically.

(xi) Geothermal. Present investigations to continue.

(xii) Miscellaneous. Investigations to be initiated and/or continued: OTEC, photovoltaics, efficient wood stoves, biogas, diesel poor gas, oil refinery, methanol from bagasse, vacuum distillation of ethanol, use of straight alcohol, contingency planning for fuel (warfare and isolation), examination of possibilities of local manufacture of equipment.

5. The research and development aspects relating to energy should be continuously examined by the proposed National Research Council, the latter should make relevant recommendations to the High Level Committee proposed for sorting out energy policy matters.

Appendix IV

ASSESSMENT OF UNIVERSITY OF MAURITIUS R&D IN ENERGY

	Current Capability	Present Use of Capability	Two Main Reasons for Underuse of Capability
1. Collection, compilation and analysis of energy data	.....	XXX	B, C
2. Utilisation of (1) for input-output tables and Energy Balance	.....	XXX	B, F
3. Energy Modelling Planning & Policy, incl integrated energy strategy	.....	XXX	B, D
4. Techno-Economic Studies			
(i) Hydro (incl mini-hydro)	...	X	F, G
(ii) Electricity from bagasse and other fibrous residues	.....	XX	F, G
(iii) Coal as alternative energy source	...	XX	A, E
(iv) Woody biomass	...	XX	C
(v) Ethanol/methanol from molasses/fibre	...	XX	A, G
(vi) Direct solar	...	XX	B, G
(vii) Wave, Ocean	..	X	C, F
(viii) Conservation	...	X	A, D
(ix) Nuclear	.	X	E, F
(x) Wind	..	X	B, F
(xi) Geothermal	.	X	E, F
(xii) Biogas	....	XX	A, D

Explanatory Notes

.....	Very high
....	High
...	Fairly high
..	Medium
.	Low
XXXXX	Excellent
XXXX	Very good
XXX	Good
XX	Average
X	Poor
A	National policy
B	Computing facilities
C	Funding
D	Coordination
E	Information
F	Staff resources
G	Infrastructure/ equipment