4. University Science and Technology Education and Economic Development

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Introduction

The centrality of the role of science in modern societies is unquestionable. Only the deep understanding of nature that the basic sciences provide explains the gap between the industrialised and non-industrialised worlds. This gap is increasingly widening as scientific knowledge in industrialised countries continues to grow. Though fundamental research is responsible for this ever-growing understanding, it is application of this understanding that brings the benefits that lead to an improved quality of life. That such benefits abound in industrialised countries, this chapter argues, is largely why people believe in science and technology rather than because they have an understanding of the subjects. Science and technology are a major belief system in such societies; a belief based on little evidence other than that it works. Similarly people in the countries of sub-Saharan Africa, we contend, believe in indigenous knowledge systems because they work for them, rather than because they have an understanding of the knowledge-generating processes and rules of evidence used by those systems. This chapter uses examples from Malawi and Namibia to show how the basic and applied sciences have and will lead to a demonstrably improved quality of life, and to demonstrate that such efforts are of major significance in popularising science and technology. Only when the evidence is overwhelming that science and technology are more effective in improving the quality of life will there be a popular belief in science and technology.

Examples from Malawi

ICRAF

As described below in Chapter 9, the International Centre for Research in Agroforestry (ICRAF), established in Nairobi in 1977 with sub-offices throughout the world including Malawi, is an autonomous, non-profit research body supported by the Consultative Group on International Agricultural Research. ICRAF aims to improve human welfare by alleviating poverty, improving food and nutritional security, and enhancing environmental resilience in the tropics. ICRAF conducts strategic and applied research, in partnership with national agricultural research systems, for more sustainable and productive land use.

ICRAF has five research and development themes, namely diversification and intensification of land use through domestication of agroforestry trees; soil fertility replenishment in nutrient-depleted lands with agroforestry and other nutrient inputs; socio-economic and policy research to allow policies that will benefit smallholder farmers; acceleration of impact on farms by ensuring that research results are used; and capacity and institutional strengthening through training and the dissemination of information. ICRAF's impact in Malawi is becoming highly visible, with many people in various parts of the country aware that it is this 'scientific' organisation that is leading to an improvement of crop yields, availability of wood-fuel, provision of animal feed and soil conservation.

The starch adhesives project

The project has a long history, going as far back as 1988 when the International Development Research Centre (IDRC), Nairobi, organised a meeting in Zimbabwe to discuss possible reasons why many good applied research projects that develop as far as pilot plant studies do not proceed to the stage of becoming commercialised. The meeting received reports from Botswana, Ethiopia, Kenya, Malawi, South Africa, Tanzania, Zambia and Zimbabwe which indicated that having completed their pilot plant studies, projects were unable to commercialise the processes or products developed. Project directors gave a variety of explanations, but a common thread was that scientists and engineers had implemented all the projects without close consultation with appropriate industrialists or potential investors with an interest in the processes or products concerned. In view of this, participants agreed that in future everybody seriously concerned with promoting their research projects beyond the laboratory and the pilot stage should involve potential users of the products or processes being developed.

As a follow up to this meeting, Fabiano applied for training in technology transfer and management and in 1991 was accepted by the Commonwealth

Secretariat to participate in a training workshop in New Zealand. The workshop required participants to identify the major constraints that prevented scientists and technologists in their countries from implementing their applied research beyond the laboratory or the pilot stage. Each participant took time to make their presentation to the other trainees and the resource persons, and discussion assisted in identifying the main constraint in each country that prevented commercialisation of research results in relation to specific projects cited in the presentations made. Presenters then developed and presented possible solutions to their country constraints. Presentations were discussed and major viable solutions were identified and prioritised. Each presenter then developed possible strategies to implement the solutions identified and presented these in turn to the group who assessed and prioritised available options. Thereafter, each participant was given an assignment to go back to his or her country and implement an applied research project that was capable of being implemented from the research laboratory, through pilot plant studies, to commercialisation of results.

Apart from the presentations made by each participant and the discussions that followed, there were lectures and visits to research institutions, universities, industries and government departments to learn how their projects developed to a point of being commercialised. One visit was to a government pilot plant used to assess the technical viability of research results from various research institutions and universities in the country. The plant has the human, material and financial resources to evaluate research results in engineering, biotechnology and chemistry. One lesson learned from the pilot plant was that on average out of every hundred research projects, about ten (10 per cent) produce results that justify the project being accepted for pilot plant studies. Similarly, out of every hundred projects accepted by the pilot plant for technical evaluation, only about ten (10 per cent) are found to be commercially viable. Thus, on average, only 1 per cent of basic or applied research projects succeed to the extent of being commercialised. The moral is that to increase the chances of a research project reaching the stage of commercialisation, there is need for careful planning in designing and implementing the project.

On returning to Malawi, Fabiano carried out a literature search at the Department of National Statistics to find out the different types of raw materials and products that could be manufactured locally using local raw materials. The intention was to develop a project that would lead to local production of one or more imported product. Among the many imported products that were bought in large quantities and could easily be produced locally were starch and some types of glues. The researcher compiled data on types of starch and glues imported, their quantities, countries of origin, unit prices and the users of these imports to Malawi. He then conducted a survey of industries to determine the quantities and types of starch and glues imported by the industries visited, as well as to identify for what the materials were used. The industries visited were also asked whether or not they would be willing to buy similar products if they were manufactured locally and sold at similar prices.

Having assessed the market for starch and glues in Malawi, a literature search was carried out to determine existing technologies, the raw materials used to produce starch and the different types of glues on the international market, with emphasis on the internal market as well as in neighbouring countries. Realising the importance of starch as a product and that of adhesives in the economy of the country, the University of Malawi initiated a project that was funded by IDRC and co-managed by the Forintek Canada Corporation (Canada) from 1993 onwards. The project was carefully designed so that it involved participation of industries and economists in its implementation to increase the chances of success beyond the laboratory. The main goal of the research project was to develop the technology needed to initiate production of adhesives in Malawi using cassava starch. It addressed the following specific objectives.

- Development of ten adhesive formulations (three hot-setting and seven cold-setting) using starch from bitter cassava varieties as a raw material;
- Demonstration of the technical and economic feasibility of production of adhesives through pilot operations;
- Dissemination of the research results for utilisation by local industry.

Major project activities included a market survey, starch analysis, adhesive formulation and evaluation, pilot plant operation, waste product handling, economic evaluation, transfer of technology and reports.

Anticipated project results and outputs included:

- ten formulations for making adhesives
- processes for manufacturing the developed adhesive formulations
- creation of a capability for producing adhesive raw materials in Malawi
- reduction of imports resulting in savings of foreign currency
- creation of rural income opportunities
- strengthening the research capabilities of the University of Malawi.

Achievements included:

- Four hot-setting adhesive formulations, two of which have been successfully tested in industrial plants;
- Four cold-setting adhesive formulations and product specifications which have been finalised, although none have been produced above pilot scale;
- Completed laboratory studies on waste product handling of the effluent, pulp and peel;
- Dissemination of research results at international and local conferences, at technology fairs and at a public lecture.
- Acceptance of project results for commercialisation. Negotiations are underway to establish an industry that will manufacture both the starch and some types of glues. For instance, four formulations for hot-setting adhesives have been developed for use by manufacturers of corrugated board, such as Packaging Industries Malawi (PI) Limited. Two of these formulations are based on a mixture of 50 per cent cassava starch and 50 per cent corn starch. Of the two, one formulation is based on a one-tank preparation (Formulation A) whereas the other is based on a two-tank preparation (Formulation B). Two other formulations are based on 100 per cent cassava starch using the principles of one-tank (Formulation C) and two-tank preparation (Formulation D).

What science has the starch project promoted?

In development of the starch adhesive project, aspects of indigenous science and modern technical practices were overridden by applied science. Being a continuum of sciences in practice, it is not always easy to draw a line from one type of science to another. Therefore, a selection of examples will help make this distinction.

The project has some practices that have become common among people, such as production of different grades of starch from cassava for domestic use. Technology for the extraction of starch from cassava and technology for making household-type cold setting cassava adhesives already exists. Therefore the large-scale production of high-quality cassava starch runs parallel to indigenous practices. However, the development of new formulations of adhesives to meet specific requirements makes use of applied research with high-technology equipment

Depending upon raw materials and the intended application, starch-based adhesives contain between 17 per cent and 40 per cent of solids by weight, the rest being water or another solvent. The solid portion is mostly made up of starch (at least 16 per cent by weight of the total adhesive) that is chemically modified during processing, as well as small amounts of sodium hydroxide (<1.0 per cent of the total) and borax (1.0 per cent of the total). Other substances, such as formaldehyde, tamanori, sodium silicate and clay, can be added in small amounts to increase the adhesive's stability or to improve binding properties. All the components are mixed and heated in different sequences, depending upon the desired adhesive properties (binding wood, paper, labels on glass, foil lining and so on). The type of starch, such as corn, potato or wheat, also affects the final properties of the adhesive because of the different initial chemical structure. The critical variables in adhesive chemistry are pH, viscosity, wet-strength, stability and setting time; all need adjustment for each application.

How can school science benefit from these examples?

Schools can benefit from these examples in that a number of activities are within the capabilities and capacities of schools as long as they select what to do based on human, material and financial resources available to them. For instance, some of the practices of artisans in their trade make use of many of the principles taught in standard technical schools and conventional schools that have technical subjects in their curriculum. The project leader enabled all schools in Malawi to obtain 1 kg of starch and 0.5 kg of dextrin free of charge. Schools were also sent a brief write-up on how they can produce their own high-quality starch from cassava and an address to write to should they need help. A problem in many African countries is that applied research results and principles do not trickle down to lower levels of education in a way that is useful to both teachers and pupils. As a result, such work does not contribute to popularising science and technology among those who are responsible for the future of science and technology in our countries.

The Cassava Starch Adhesives Project was implemented by first identifying a need and moving forward to satisfy that need. This is the principle of technology push. However, once development of the process or products exceeds the need, it is important to identify ways of implementing a component of technology push so that the initiative can go beyond what clients already know and accept. The beneficiaries will include existing industries that will provide services to the Starch Manufacturing Industry (SMC) and buy starch from SMC, as well as the people who will obtain productive employment at the industry. Since the SMC will depend on a sustainable supply of cassava, the employees at the farms will also be beneficiaries. Thus, many Malawians, industries as well as the government, will benefit from the establishment of the SMC. Similar arguments apply for future R&D in the expansion of the uses of starch This is because more cassava will be bought from small-scale farmers, industries will benefit from the new products and employment will come about as a result of increased or new agricultural and production industries. The country will save foreign exchange as a result of import substitution by cassava starch products. The project is expected to improve incomes of the rural cassava producing community, providing resources needed for local development. At the same time, introduction of advanced technologies, and especially mechanisation of cassava root production, may adversely affect gender balance in the community because technology-related jobs are often dominated by men, while cassava production is traditionally dominated by women.

Some Examples from Namibia

Africa is richly endowed with an enormous variety of natural resources in the form of industrial and other minerals, enviably rich biodiversity and a wide range of environmental regimes with a capacity for sustainable biomass production as well as unique scenic beauty, giving the continent an enormous potential for highly profitable ecotourism. Yet millions of Africans are classified as living in absolute poverty and many others die every day from diseases that could be prevented through society's enlightened use of Africa's rich indigenous knowledge of her natural resources.

Africa must significantly intensify her efforts in science and technology education and training if the poverty prevailing amongst its people is to be eradicated and if rapid socio-economic progress is to be brought about. Thus the innovations pioneered by the University of Namibia aim to:

- Promote awareness of the significance of science and technology as an engine for alleviating and eradicating poverty in the Southern African Development Community (SADC) region and on the continent, and of how universities can play a major role in promoting development by taking science and technology to the people;
- Remind ourselves that Africa is blessed with a rich endowment of natural resources, whose potential as economic assets has hardly been tapped;
- Promote sharing of information and expertise on unrealised wealth based on Africa's rich biodiversity and on Africa's mineral resources heritage;
- Demonstrate, by way of local examples, what African nations are likely to achieve in terms of human development through increased government investment in science and technology education at all levels.

We view increased expenditure in science and technology as a critical necessity for liberating Africa from the poverty trap.

As the Vice-Chancellor of the University of Namibia has often said, our vision of the future of Africa, and especially of our SADC region, should not be that of a warring or a war-torn continent. Our vision should be that of an enlightened, free, well-informed and healthy people, living as a harmonious, integrated and caring community, guided by a democratic culture of peace based on shared values, open to positive interaction with other cultures, with access to lifelong learning at all levels, in an economy that is productive, diversified and sustainable, and which provides meaningful employment. All this is only possible if we invest in science and technology education and training of our people, and demonstrate to them how the power of science and technology can bring about development and improvement of the quality of human life on our continent.

Knowledge of science and technology is the key

Good science and technology education will serve to enlighten our people that we need to treasure all categories of resources we have on our planet, since each is a potential source of wealth (Mshigeni, 2000). We must have profound knowledge of their chemistry and their biology, and this can only be unravelled through both basic and applied research.

That science and technology education is the engine that drives economic development and growth can be best realised by making reference to Japan. In the late nineteenth century, Japan developed a sharp, long-term vision directed towards the promotion of scientific and technological knowledge, which is both the key and the engine to industrial development. What should we do, as Africans, to achieve the same? What roles can universities and other institutions of higher learning and research play? What should be the role of African governments? These are questions and issues that need to be addressed so that solutions and recommendations can be made to deal with the problems facing Africa today.

Implementation of the ZERI Principles

The Zero Emission Research Initiative (ZERI) looks at a wide spectrum of materials that are normally discarded as wastes, often polluting the environment, with a view to transforming them into raw materials for new marketable, value-added products. The ZERI concept is driven by a global concern that society must respond to the world's growing needs for water, food, health care, shelter, energy, new jobs, sustainable productivity and wise environmental management.

Under the chairmanship of Gunter Pauli, the founder of ZERI, the ZERI Foundation based in Geneva co-ordinates all ZERI activities worldwide. The University of Namibia became involved with ZERI in 1994 and currently houses the UNESCO/UNU ZERI Chair, as well as the ZERI Africa Regional Project Co-ordinating office, with Professor Keto E. Mshigeni as Regional Co-ordinator, with financial support from the United Nations Development Programme (UNDP). As a concept, philosophy and new vision, ZERI made sense to us, and today we are proud to report a few success stories on the implementation of the ZERI concept in Namibia.

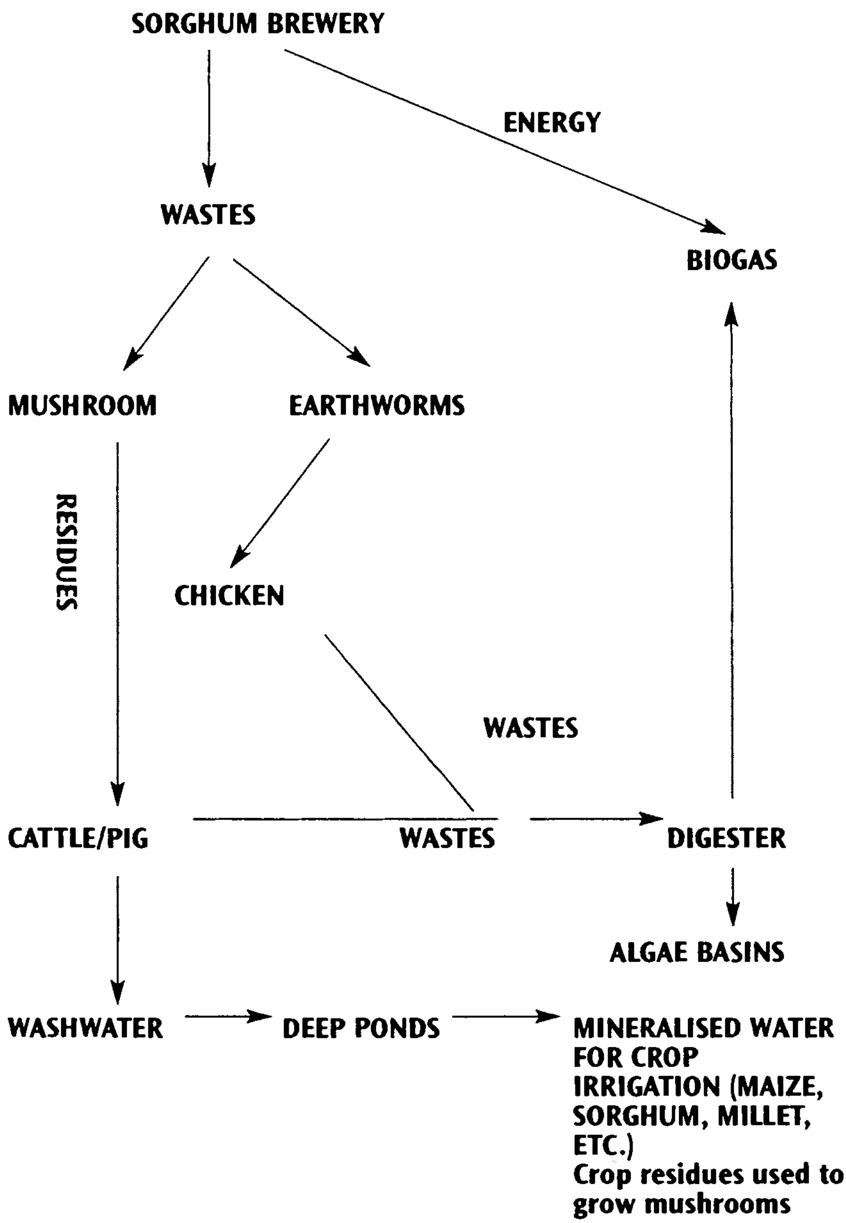
The ZERI Brewery in Tsumeb

ZERI activity in Tsumeb, Namibia:

- Was the first project selected for implementation in Namibia, and indeed Africa, to demonstrate that the ZERI concept to a large extent works and has great potential in creating job opportunities, thus contributing to poverty reduction;
- Was a pioneer example in Namibia demonstrating a functional university-industry partnership, between the University of Namibia and Namibia Breweries;
- Was directed towards addressing Africa's increasing energy needs with a view to demonstrating that if appropriate technologies are applied, renewable energies (in this case biogas energy) can be generated from the enormous quantities of organic biomass around us;
- Involved multidisciplinary teams of scientists, management experts, engineers, and technicians such as Professor George Chang, an expert on biogas digesters, Professor S.J. Chang, an expert on mushroom production, and the University of Namibia's experts in animal science, crop science, and biology who, working together, were able to generate a tangible impact;
- Serves as a demonstration to the Namibia public and Africa at large that with the application of the ZERI vision we can alleviate poverty, recreate new high-quality food and other products from what others conceive as waste, reduce overdependence on firewood as a source of fuel, create new jobs for the people and alleviate the problem of environmental degradation;
- Provides a framework for environmental education to our school communities.

The key inputs for any brewery industry are an organic source, in this case sorghum grain (microbial biota that catalyze the fermentation process) and water. (Figure 4.1 summarises the ZERI activity in Tsumeb.) Spent sorghum

Figure 4.1. A Simplified Schematic Representation of an Integrated Production System



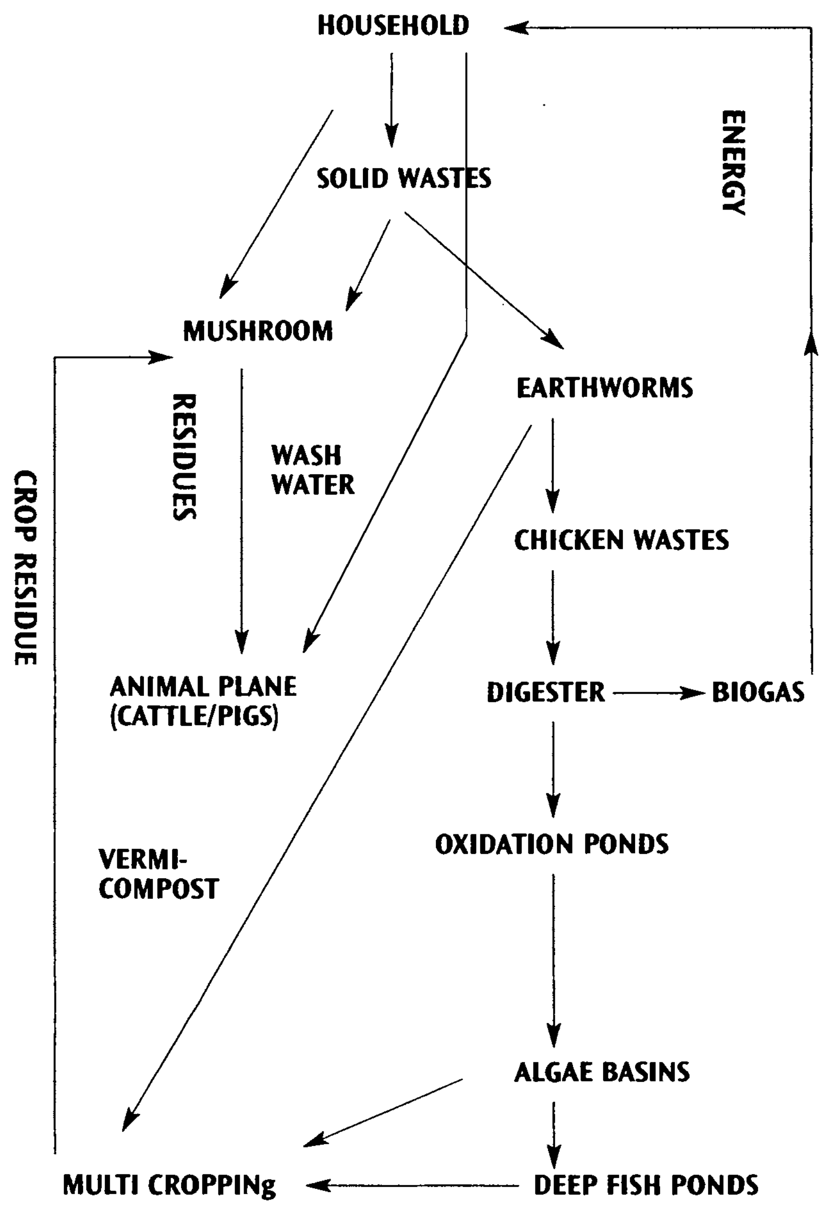
waste from the brewery is used to feed earthworms which are good feed for chicken, while the vermi-compost is good organic fertiliser for crops. The sorghum waste is also used to grow mushrooms, which is a very high value crop. Residues from mushroom farming that have improved nutritional quality are fed to pigs and cattle. Waste-water from the factory and all the wastes such as manure from the animal pans are flushed into a biogas digester where anaerobic digestion takes place eliminating most potential harmful pathogens. Biogas generated from the digester is used to provide heating energy, while solids are a good source of organic fertiliser. The effluents from the digester pass through a series of algae ponds, which further cleans and purifies the water that becomes rich in nutrients and stimulates growth of phytoplankton that is good food for fish before it flows to the deep ponds. If there is enough water, it can also be used to irrigate crops that provide food, while crop residues are a good source of the substrate for growing mushrooms. Thus value-added products are produced from wastes providing food and income as well as energy, and at the same time the problem of environmental pollution emanating from wastes generated by the brewery can be solved.

Today, the operation and maintenance of the system is fully managed by Namibia Breweries that generates 100 kg of tasty, nutritious and marketable oyster mushrooms per week from materials that would otherwise be discarded as waste. The University of Namibia is proud to be associated with this success, which has the potential to be replicated by many breweries on the continent.

ZERI peri-urban agriculture in Windhoek

From the experience acquired in Tsumeb, the University of Namibia, through its Faculty of Agriculture and Natural Resources, subsequently undertook to promote the application of ZERI principles towards generating value-added products such a vegetables, mushrooms, and biogas for cooking and general domestic use for the benefit of poverty stricken peri-urban communities at Goreangab in the vicinity of the city of Windhoek. The integrated bio-system at Goreangab makes use of household generated organic wastes for value addition (Figure 4.2). Through this innovation the communities involved in the project are no longer tempted to destroy the vegetation in their ecosystems to produce firewood, or to use their meagre financial resources to purchase charcoal. Thus the innovation, which is supported by the European Union, albeit modest, is successfully demonstrating that we can address both the problem of environmental degradation, and of peri-urban poverty, through the application of ZERI principles. Discussions are in progress with Government to promote this vision in other communities in Namibia.

Figure 4.2. A Typical Rural-Urban Household Integrated Biosystem Setting



ZERI UJAMS project

Again building from the Tsumeb experience, with some inputs provided by UNDP, the University of Namibia, in partnership with various industrial establishments based in Windhoek, such as Namibia Breweries, MEATCO and Hartlief together with Windhoek Municipality, is planning to undertake a joint venture known as the ZERI UJAMS Project, which will involve the construction of large biogas digesters and replicate the Tsumeb vision on a larger scale to help transform Windhoek's urban wastes into renewable energies and other value-added products. MEATCO and Hartlief, for example, generate large quantities of livestock stomach contents in their slaughter houses every day, which could be used as vital components of substrates for mushroom cultivation. We believe that when successfully executed, this innovation will serve as a model for Africa's cities of the future. We are currently looking for additional funding to facilitate the implementation of the project vision.

Encouraged by these and other related achievements, UNDP Africa is supporting a Regional Africa-wide ZERI project, directed towards promoting sustainable human development from the continent's rich biodiversity, which, to a large extent, will also encompass many elements of the Tsumeb experience. This initiative is also based at the University of Namibia. We have already begun to implement the regional project and we have reason for a high level of optimism, since Africa has such rich biodiversity and such enormous quantities of biomass which are currently discarded as waste but which could be put to many sustainable uses. The rich biomass includes a wide range of agricultural crop residues, a huge tonnage of water hyacinth biomass and enormous quantities of marine resources that have to a large extent remained untapped. Our ZERI Tsumeb initiative has revealed the suitability of seaweeds such as *Laminaria* and *Ecklonia* as a component of mushroom cultivation ventures (Molloy *et al.*, 1999). It is in realisation of that fact that H.E. President Sam Nujoma has committed government resources to promote the development of a marine resources research centre of excellence in Henties Bay on the Namibian coast (Mshigeni *et al.*, 2000). We need additional donor funding support to promote the success of the envisaged ZERI research activities at the centre. Some of the identified projects focusing on Africa's biomass resources are:

- Production of value-added products from Africa's seaweed resources including their utilisation for goitre control, for the production of industrial hydrocolloids, livestock feed supplements, fertiliser and so on.
- Sustainable utilisation of the water hyacinth that is a challenge involving turning a regional environmental problem into a development-oriented opportunity.
- Production from organic wastes of edible and of marketable mushrooms, including those of medicinal value, and also production of earthworms for

use as a high-quality protein-rich poultry feed. The production of iodized mushrooms will be attempted by using algae species that contain high levels of iodine as a substrate for growing mushrooms. This innovation is intended to produce iodized mushrooms that will not only provide valuable nutrients but also make available the iodine to consumers, thus helping to solve the problem of iodine deficiency which is said to affect at least 30 per cent of the African population south of the Sahara.

- Production of *Salicornia* in selected coastal village communities on the continent for industry and commerce, using technologies involving crop irrigation with seawater.
- Promotion of integrated biomass systems in Africa's grossly neglected marshlands.
- Research on harvesting fog along the Namibia coast, and on harnessing water condensation from the cold Benguela ecosytem. In doing this, we are attempting to mimic nature. Indeed, *Welwitschia mirabilis*, the wonder plant which is endemic to the Namib desert, and which deserves to be considered as a unique world heritage, has survived for millennia by harvesting the desert fog that condenses on its leaves.
- Sustainable development of Africa's bamboo resources for housing, construction, and various value-added products.
- Sustainable development of selected high value micro-algae abounding in Africa's aquatic ecosystems with special reference to *Spirulina* for its protein, and *Dunaliela* for its beta carotene. Here we are attempting to mimic the lesser flamingoes, which discovered that *Spirulina* was edible long before humans did so.

Back to Malawi

Everywhere one drives in Malawi, one sees guinea-fowl; they are not restricted to the 'bush' as they are in most of Africa, but wander around villages pecking away at the dirt in the way chickens do. Both the flesh and the eggs of these birds are delicious; people in some countries regard them as gourmet foods! Yet in Malawi, one of the poorest countries of the world, everybody seems to eat them. So they are a suitable bird for villagers in Africa to domesticate. Since Africa is their natural habitat they are much more resistant to diseases than chickens, and the species flourishes by foraging in the bush.

The wide-spread presence of guinea-fowl in Malawi is the result of a modest but persistent project of the Wildlife Society of Malawi and university staff that conducted the painstaking research needed to domesticate the bird, as well as their promotion through donations of breeding pairs and advice.

We close with this example to demonstrate that the sophisticated approaches and facilities of science are not always needed. It is the problem-solving ingenuity of science and technology that often leads to breakthroughs; this ingenuity can be practised anywhere and by almost anyone. Why then do our schools, universities and other educational institutions continue to teach as if they were located in some 'culture-free' zone similar to the 'tax-free' zones that some claim will transform the continent?

Conclusion

Science and technology can be popularised directly or indirectly. This chapter suggests the power of doing so indirectly; AFCLIST's contention is that throughout the world, including the industrialised world, people believe in and support disciplines because they so demonstrably work. But most of Africa has yet to experience the improved quality of life that science and the applied sciences can bring.

The examples in both Malawi and Namibia also highlight the power of well-focused and planned university co-operation with the private sector, indeed its necessity. Frequently in Africa, the research capacity of the private sector is based in the already industrialised world where priorities are different, and neither government nor the university has the financial and human resources necessary for large-scale implementation.

AFCLIST has supported a number of projects that attempt to link school science with community and industrial science and technology, yet the science curriculum in African universities rarely does so. These two examples of how universities have contributed to popularising science and technology show how, if the science curriculum in all educational institutions better addressed developmental needs, the continent might succeed more rapidly in the socio-economic transformation and achievement of improved quality of life that is a prerequisite to a belief in science as a world view.