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AN ALTERNATE PATHWAY FOR INDUSTRIALIZATION: A BIOMASS-BASED STRATEGY *

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Preface

The theme of this paper is that the renewable resource of biomass could be the basis for a significant component of an industrialization strategy in developing countries. To a considerable extent, technologies to process the biomass already exist, though their application varies considerably between developing countries, sometimes for lack of a coherent policy and sometimes even for the lack of information. Technological advances, particularly in the field of genetic engineering and biotechnology, open up further vistas.

The need for formulating and applying a biomass-based strategy for industrialization has always been there on account of the well-known benefits of decentralized production and rural industrialization. However, a sense of urgency has been imparted now when developing countries are trying hard to reduce their vulnerability to the external economic environment and to activate their internal growth dynamics as a means of industrialization.

The message of the paper, briefly, is the following. A variety of technologies already exist to use the biomass available in developing countries. What are needed are a policy framework, industrial promotion and the organizational modalities for the generation and collection of biomass. In addition to existing technologies, there are possibilities for developing new technologies through research and development. These possibilities have to be fully exploited. Action at the national level by developing countries is needed for policy actions and industrial promotion as well as research and development. International co-operation can play an important role in this respect, particularly in regard to research and development co-operation. Certain proposals for an institutionalized network for research and development are made in this context.

Introduction

The goal of any country is development. Development is the development of people: improving their standard of living and quality of life. This can be achieved only through optimal generation, mobilization and utilization of natural and human resources.

Industrialization is the engine of development: processing raw materials into usable goods and services; giving products added value; increasing economic returns, employment and purchasing power; and strengthening linkages with other sectors of the economy. This will lead to self-reliant development. The question is often asked: What kind of industrialization and for whom?

The exaggerated urbanization and concentration of investments in urban-oriented, capital-intensive activities have produced a severe imbalance in developing countries between the elite groups who monopolize power and wealth and the majority of rural people who remain poor. It is because of urbanization that both industry and agriculture have suffered. The cost of bringing a person to an urban area is several times more than the cost involved in providing the social infrastructure to keep him in the rural area. The aim is not to bring rural people to city slums, but to bring city comforts to rural areas, resulting in a rural-urban continuum and not in a conflict. There should be a net transfer of surpluses and income to rural areas correcting the historical inequities and imbalances.

This calls for rural industrialization. Such rural industrialization should really be based on generating, mobilizing, utilizing and maximizing natural and human resources that are available in rural areas. Biomass is a major natural rural resource and, hence, the strategy for industrialization can be based on the renewable sources of biomass.

An attempt is made in this paper to discuss some of the concepts, issues, technology options and policy implications of such a biomass-based alternate pathway of industrialization. A number of programmes and projects that could be undertaken commercially and some that require research, development and pilot and proving plants are also indicated. The need for setting up a Network of Institutes of Biomass Technologies and its likely structure, organization and management have been suggested.

Rural industrialization is not putting up large factories in rural areas. Rural industrialization is not setting up cottage and village industries, although age-long experience and traditional skills should be upgraded and fully utilized. Rural industrialization is also not based on appropriate and village technologies--in fact high-level intellectual inputs are needed to solve the ground-level problems. Rural industrialization is also not agriculture and food processing alone. Rural industrialization is much more than all of this.

Biomass is a major resource in rural areas and is often used with very low efficiency. In fact, the quantity of biomass consumed in the form of food, fodder and fuel is growing, resulting in deforestation, denudation, desertification and flooding, and causing great economic and social costs.

Biomass is an ideal raw material for rural industrialization. Rural areas are rich in biomass resources: agricultural, horticultural, sericultural, forest, animal and fish produce and residues; aquatic mass, algae and micro-organisms; manure and household, community, agricultural and industrial organic wastes and affluents. These locally grown, renewable resources generate employment. Tropical resources such as fast-growing energy forests; aromatic, medicinal, ornamental and economic plants; fragrant and colourful flowers, spices, oleo-resins and oil-bearing plants that fetch high economic returns when converted into usable products through industrialization.

Industries are best started where the bulk produce biomass is located, namely in rural areas, which in turn provides additional gainful employment, income and infrastructure facilities such as water, electricity, transport and cinema for rural people.

The leaf-to-root concept. The traditional thinking that "agriculture is for food" and "forest is for wood" has to change for good. Apart from food and food processing, every part of an agricultural or forest plant can be utilized from "leaf to root". A cluster of industries can be set up around each plant, e.g. twenty-five industries revolve around cane sug r, using biomass. A cluster of industries could also revolve around animals--apart from food--by utilizing "hoof to horn". This also applies to fish and aquatic plants. There should be no such thing as waste. A rich country is one that converts waste into wealth.

Energy is now the fourth economic factor of production after land, labour and capital. In 1980, the oil import bill of developing countries was $US 50 billion. There is an urgent need for energy conservation and energy production from all sources. Biomass as an energy source deserves special attention.

While much of today's chemical production is based on gas and petroleum feedstocks, many chemicals can also be derived from various biomass resources. A great number of chemicals can be derived from carbohydrates (starch, sugars, cellulose and semicellulose), lignin, oils and triglycerides, and terpenes.

It is hoped that this discussion paper will be useful for further concrete and urgent action in the best interests of the developing countries.

I. TECHNOLOGY OPTIONS

Biomass is a bulk material with a large water content; it perishes easily and is seasonably variable. Therefore, technologies are needed to dry, handle, package, store, preserve and standardize the raw material product. Since this bulk produce is in rural areas, industrialization in rural areas centred around it would be ideal. At least bulk reduction processing should be done in rural areas.

Biomass technologies include chemical, thermochemical and biological conversion processes. Destructive distillation, combustion, gasification, pyrolysis and liquification are various techniques, each utilizing different routes. Much of the feedstock with a large water content may require high temperatures and capital-intensive equipment. Coupling solar energy for drying biomass may help. Bioconversion, on the other hand, is rather sensitive, dealing with micro-organisms that are easily affected by toxic elements and quality of water, and requires a steady supply of power. Some things are better done by non-microbiological methods. However, this conversion offers several advantages amenable to batch processing and decentralized small-scale production, which are energy saving and use less costly equipment. However, process control such as pH, temperature, quality of water etc. are more vigorous, particularly when dealing with a variable feedstock biomass.

Several process engineering details have yet to be worked out for biomass conversion. Similarly biocatalysts (micro-organisms and enzymes) have to be identified, singly or in mixture, and their performance rates determined. The conversion efficiency may vary from batch to batch because of the vagaries of feedstock, processing materials and catalysts. A critical examination must be made of all the parameters, including process equipment for water batch process or batch with recycling or continuous process. Biological Resource Development Teams (BIOREDS) with mobile pilot plants for bioconversion have been suggested, which would train the local people as well.

A. Existing technologies

Several technologies already exist, some commercially utilized, for the conversion of biomass into food, fodder, fertilizers, fuel, construction materials, chemicals, dyes, pesticides, fragrances, drugs, vitamins etc. What is presently needed is to extend their use for integrated processing of each plant, from leaf to root. Some illustrative examples of this type are provided under Programme I. in section V. Some examples are integrated processing of coconut, cassava, sugar, paddy, groundnut, banana, mango and cashew--building up a a cluster of industries around each plant.

The technologies that need pilot/proving plant production and testing for marketability and profitability are provided under Programme II. Similarly research and development projects at the laboratory level are given under Programme III and the trends in equipment and machinery manufacture in Programme IV. The policy support needed for these programmes is given under Programme V. It must be made clear that these are only indicative and do not constitute a comprehensive list.

B. Technological advances (TAs)

It is not rural technologies but rather emerging technologies or technological advances (TAs) that offer great promise for both increased generation and conversion of biomass. Biotechnology and genetic engineering have a great potential to solve the problem of increased food production by improving crop/biomass yields, adapted to fragile environments, and treating problem soils, making them resistant to pests and diseases by the efficient use of energy and biological fixation of nitrogen. The newer techniques such as tissue culture, cell fusion and cloning have been already applied with success to improve the yields from oil-bearing palm and coconut trees; several fruits, vegetables, roots and tubers; forest plantations such as teak, eucalyptus, bamboo, and plantation and cash crops such as sugar cane, banana, tobacco, cassava, potato, turmeric, ginger and cardamom.

TAs also are bringing about a quiet industrial revolution and offer great scope for the conversion of biomass into food, fodder, fertilizer, fuel, pharmaceuticals, insecticides, pesticides, chemicals and construction materials.

Biotechnology will influence the use of biomass as a fuel by (1) increasing the amount of biomass available, (2) improving its conversion into versatile fuels such as methane and alcohols, and (3) reducing the pressure on existing energy sources through the introduction of energy-saving processes and improved recoveries. The conversion processes include biological, chemical, and thermo-chemical technologies. These technological advances do not conflict with but actually upgrade traditional technologies with the potential for decentralized production, lower scale of operation, and leap-frogging. They are versatile, efficient and economic, and appear to be specially designed for rural industrialization, using biomass and micro-organisms as raw materials.

This then--the coupling of biomass with technological advances utilizing every part of a plant from "leaf to root"--is the alternate pathway for industrialization, with a strong equation between agriculture, food processing, energy and industry, which will improve the standard of living and quality of life of the majority of rural people.

The major problems are to separate lignin, semi-cellulose and cellulose in lignocellulosic materials and to convert lignin to synthesis gas or a chemical feedstock. Hydrocracking of lignin into phenol steam explosion and solvent extracts of low molecular weight lignins provide new opportunites for using lignin. Cellulose can be converted into protein and/or glucose which in turn becomes the raw material for a number of chemical products. Cellulose, semi-cellulose and starch require acid and/or enzymatic hydrolysis before most microbiological processes can convert them into chemicals.

In regard to chemicals from biomass, it is reported that chemicals such as glycerin, acetic acid and methanol offer attractive opportunities, with large established markets. Similarly opportunities exist for producing synthesis gas, methanol, ammonia and modified natural polymers, such as cellulose, rayon, cellophane, cellulose acetate, and starch. Biomass-based chemicals may recapture the ground it lost earlier with respect to fatty alcohols and fatty amines. But this depends upon the economies and prices of petroleum hydrocarbons. Biomass has always had advantages as the starting material for producing complex chemicals with sterochemical features. In view of the toxicity and effluent problems, some of the synthetic products are now being replaced by natural biodegradable materials such as pesticides and polymers.

Technologies to produce a wide varity of products from the same biomass feedstock may be favoured. Similarly technologies that permit decentralized, efficient, small-scale production would be more useful. Upgrading the existing technologes by introducing technological advances would result in lower capital costs.

It is not as though one has to wait for new technologies or processes to use biomass. Several technologies and markets already exist that would permit a more optimal and rational use of biomass in order to realize maximum returns from the same resource. Coupling the existing technologies with emerging technologies would offer even higher yields for both generation and conversion of biomass. The technology opportunities and options are, however, determined by social and political decisions.

II. POLICY FRAMEWORK

In moving forward in this alternate pathway for industrialization based on biomass, what are the constraints and issues and the problems and prospects? Some of these are presented below.

A. Competing claims

There are competing claims on the use of biomass for food, energy, construction and industry. It is important to ensure that food security for the poor is not sacrificed for liquid-fuel security for the rich, or that public good is not sacrificed for larger private profits in perfumery components. The strong nexus between agriculture, food, energy and industry has to be clearly understood and several competing complex equations have to be solved, including the environmental aberrations. The question really is: How much excess biomass is available for industry after food and energy requirements are met?

B. National bio-resource policy

If biomass is the starting industrial raw material, a national bio-resource policy is imperative for each country and may cover the aquatic and land-based biomass, taking advantage of the sunbelt speciality, tropical plants. Such a policy should cover not only what to grow and how to grow more, but also how to mobilize and optimally utilize every bit of the biomass by setting up a cluster of industries around each plant. Rational and responsible use of biomass with proper environmental protection will reduce or abolish rural poverty. Such a policy should include (1) a biomass resource survey, (2) biomass generation, (3) the mobilization of biomass through a resource management system and (4) industrial conversion. Such a policy should be integrated with other industrial, economic and national policies. The focus should be on resource management, industrialization and the quality of life. A step-by-step examination may reveal some of the problems and prospects.

1. A biomass resource survey

A biomass resource survey should be carried out in order to assess and evaluate biomass resources, to identify and develop plant species, woody and non-woody, and micro-organisms with special attention to their use as an industrial raw material, apart from food. Biomass includes agricultural, forest, animal and fish produce and related residues; aquatic mass, algae, micro-organisms and enzymes (a treasure chest of biocatalysts for industrial processes), manure, and household, community, agricultural and industrial organic wastes and effluents. A resource survey is painstaking and consumes time and money. Apart from national botanical, zoological and agricultural survey organizations, students and teachers from village primary schools and beyond should be involved in taking an inventory of existing biomass resources: it is less expensive and is one sure way of making the student and teacher learn about their environment and study several disciplines of life sciences in an integrated manner. Such an integrated system of teaching and learning is sadly missing today. Similar to plant and animal species, there is a need for metabolic mapping of micro-organisms and for goal-oriented selection and characterization of strains isolated from the natural environment.

2. Biomass generation

A careful sieving of the information obtained through the biomass resource survey is the first step toward choosing plants with selective advantage. Since there are competing claims on biomass for food, energy and industry, both generation and utilization of biomass should be dovetailed to this question.

A few examples will clarify the importance of choosing plants with selective advantage. Energy farms, based on fast-growing trees, can produce only 15 tons/acre/year (or 9 mm litres of alcohol), whereas algae production can reach 60 tons/acre/year (70 mm litres of alcohol). Solar energy converters such as water hyacinth have the highest production and reproduction rate--850 kg/ha/day dry weight. However, it is difficult for the fish to grow underneath hyacinth. Other fast-growing species are giant kelp, elephant grass and algae grown on sewage. Through bioconversion, all this biomass could be used as fuel. Similarly, one could consider growing plants that directly yield hydrocarbons. The question is, which plants?

Careful selection and manipulation of medicinal plants can now lead to the creation of tissue cultures that can produce drugs such as alkaloids, steroids, hormones, cardiac glycosides and antibacterial/viral agents. Similarly, aromatic plants can be used to produce insecticides, plant hormones, oils, aromatic flavours, pigments and perfumes. Much depends on costs of efficiency and regulatory testing, which in the drug field often amounts to 80 per cent of developmental costs.

The food industry is showing keen interest in plant-tissue culture, not only to grow a better quality and quantity of vegetables, fruits, food grains and tubers, but also because of the potential biomass resources for edible colour, flavour and microbiologically-produced essential amino acids and vitamins.

The question is: Can we simultaneously produce more food as well as more biomass from one plant, such as wheat and rice? Can we both meet the demand for food and use the excess biomass, leaf to root, together with the excess starch for industrial raw materials? Through improved techniques and emerging technologies, one can also increase the biomass of plants and grow crops in problem soils and in fragile environment where little is grown now. Increased availability of biomass depends upon increasing the productivity of a given hectare of land by upgrading the present techniques and using new techniques for growing biomass in presently unusable soils. This entails considerations such as water and soil management; ecological and environmental factors and balances; and the level and cost of technologies.

3. Mobilization of biomass through a resource management system

The next question is: Why is biomass not grown? Is this due to lack of knowledge, or markets, or profitability?

An integrated management system is needed in order to mobilize biomass and make it available as industrial raw material. The generation of newer tools, techniques and technologies; a laboratory for land demonstration and dissemination of the know-how; training of personnel; afforestation/deforestation; policies, rules and regulations for generation and marketing; and maintaining the ecological balances are one set of equations. Yet another set of equations relate to collection, handling, storage, drying, packing, transport, etc.

It has to be remembered that biomass is subject to seasonal and soil variations and is likely to decay, influencing the quality. This requires good management for treating the bulk produce. Similarly, several technologies have to be screened and tested with concurrent initiatives in order to intensify basic and applied research on local resource and to generate, import, adapt, transfer and utilize relevant technologies. The technological advances may also call for developing new pilot and commercial production equipment, machinery and process-control systems.

4. Industrial conversion

a. Existing use of biomass

Biomass is presently used for food, fodder, fertilizer, fuel and construction materials. What is the excess amount of biomass available for industrial use? If biomass is not in excess, is the proposal to divert biomass for a better, rational use and to add manufacturing value? What are the alternatives for the present use of biomass and what is the cost? If biomass is in excess, by how much? Is the quality and quantity of supply assured? If biomass is used for industry, who will receive the profits? Will it mean robbing the villages of the little resource they have? These and many other questions arise.

b. Alternate uses of biomass

Assuming biomass is available for industrial conversion, it would be an interesting exercise to list the industrial technologies, processes and products centred around each plant. For example, 54 products of commercial value constitute the product spectrum around rice plants. For each product, there is a technology which has subsystems and alternatives. It has been shown that integrated use of plants, leaf to root, may fetch $500 for paddy crops, apart from additional employment, as compared to a net yield of $130-$150 per acre. The advantage of integrated utilization of cassava, coconut and sugar-cane has been fully established and the products have been marketed already. This approach should be extended to other plants, utilizing leaf to root.

However, the following questions arise: What is the demand pattern for these products? Are they marketable? Are they competitive and profitable? Are they entirely new products or are they competing with existing products? Are they socially acceptable? To what extent will a biomass-based strategy replace current industry in the next 20 years? What is the special niche for a biomass-based strategy?

A biomass-based industrial strategy could substitute or supplement food, energy and chemical industries. Biomass-based industries may not affect heavy chemical industry to any extent, except in cases where seaweed and backwaters of the sea could be used for plants to entrap elements, such as potassium, magnesium and manganese, and micro-organisms for leaching minerals such as copper.

A biomass-based industrial strategy is likely to have more effect in the areas of pharmaceuticals, alkaloids, steriods, hormones, insecticides, pesticides, fertilizers, substitutes for mineral-oil-based fuels, chemicals, polymers, biopolymers, ethylene, propylene, acrylics, proteins, amino acids (e.g. acetic, citric, lactic, acrylic, and adipic acids), alcohols, glycols, ethylene dioxide, glucose, fructose, essential oils, aromatics, pigments, flavours and perfumery components.

Several chemicals are currently made from terpenes on large commercial scale. Similarly, ethanol made from starch or sugar, acetene, butanol, lactic acid and sorbital have been commercially produced from cellulose converted into glucose. Soyabean, castor, cotton-seed based fatty acids and several polymers and other products such as glycerin are well-established commercial products.

C. Modalities for selecting biomass for industrial conversion

The selection of biomass for industrial conversion depends upon several factors. The first consideration is the specific set of products that could be produced from a single feedstock; the time, costs and market conditions have then to be evaluated. Another approach would be to consider the same set of products that could be produced from different types of biomass feedstock and estimate the techno-economic viability and marketability.

The other element is the conversion processes. Using the same feedstock, but with different technological routes, the same products or a variety of products could be produced. The equation thus becomes: biomass-technology-products.

One would have to weigh the potential use of each material for either food, energy or an industrial product and decide which of these is economically attractive. If a product can be obtained from the same biomass by using five different technological routes and if the same product can be obtained by the same technology from five different biomass feedstocks, a set of calculations can determine the most profitable route in order to compete in the existing market. The calculations bec me even more complicated if the same products can be obtained from five different biomass feedstocks by five different routes.

What then is the policy framework for such a national bioresources policy for an alternate pathway for industrialization? How does one integrate this bioresource policy with the country's present industrial policy and other economic, trade and international policies?

Biomass in its many different forms has many competing uses. Wood is used to make paper and pulp, for construction purposes and for fuel. Biomass is the major source of energy in developing countries. Agricultural crops provide food, fodder, fuel, fertilizer and raw material for several industries. It is therefore essential that biomass potential for energy, food and industry is assessed and balanced in an integrated manner, matching the alternative tech ologies and biomass with the needs, resources and socio-economic conditions of developing countries. Producing industrial products need not be in competition with food or fuel but it may be in addition to it.

The tech ologies for converting of biomass into a vast variety of usable products and energy span a wide range from simple, small low-cost technologies to complex, large-scale technologies (e.g. from direct combustion in stoves to pyrolysis, thermal decomposition into gases and liquid fuel and from simple ancrobic digestion to produce biogas to complex separation of cellulose from lignin and conversion of cellulose into biogas, sugars and alcohols. The end-product range also varies from simple to complex products, such as food, fodder, fertilizer, fuel, pharmaceuticals, chemicals, insecticides, pesticides and construction materials.

Even the existing traditional technologies could be upgraded. For example improved wood-burning stoves reportedly save 30 per cent energy, and smokeless fuel is the housewife-friendly technology. Similarly, traditional processes may be improved to produce standardized, more nutritive fermented foods.

The threat that carbohydrate sweeteners and protein sweeteners will rapidly replace cane sugar in the soft drink industry is real. Similarly microbial sweeteners could be used instead of plant-based sugar. Sugar is one of the best biomass yielders and yet the sugar-cane industry is threatened. In policy formulation such facts have to be kept in mind. Similar threats have already been noticed for many plant-based industries such as jute, coir, leather, textile, rubber and construction materials. These industries could become more competitive, even regain lost markets, through the application of newer techniques or by blending them with synthetics.

Overselling the application of technological advances to biomass conversion has to be guarded against. Industrial hazards in the field of microbiology must be avoided. On the other hand, the technological advances offer great promise and developing countries should fully participate and take advantage of them.

Biomass technologies may not receive the attention due to them because the rural poor cannot generate the necessary market forces. In addition, the industrialized countries us an industrial structure that is highly capital intensive; they may not be interested in biomass technologies. Developing countries both biomass and micro-organism resources. Developing countries, as a part of a national biomass policy, can set up suitable award and reward systems for inventions, innovations and developing industrial technologies for biomass conversion. It should be remembered that although the problems may be global in nature, the solutions must be site-specific.

Competition between an industrial pattern based on biomass and fermentation versus the present chemical industry pattern will largely depend upon agro-industrial policies, marketing possibilities, industrial technology, the processing limitations and the capacity to integrate food-energy-industry equation. The utilization of some agricultural crop residues may also mean food at cheaper prices.

If growing certain plants fetching higher economic returns is encouraged, will there be an environmental and ecological imbalance? These issues need careful consideration.

Yet another key aspect of substitution is the greater need for co-operation between the biomass producer and buyer. Why should a farmer take a chance on growing something new, knowing little about the reliability of the seed, the cultivation practices and whether it will sustain higher prices. However, a rural agriculturalist will certainly grow a crop that is profitable, as past experience in several developing countries has shown A farmer might also consider growing the biomass required by an industry as a double crop, while he grows regular crops for food, fodder, fuel, fibre and fertilizer.

The prospects for biomass-based industrialization depend upon the availability of biomass and its pricing as compared to the availiabilty and pricing of the present feedstocks, such as fossil resources. It also depends upon the availability and status of technology in competing processes and finally the costs and the marketability. Breakthroughs are needed for generating, harvesting, collecting, drying, and transporting biomass to the processing site or preferably developing technologies for small-scale, decentralized production at site. The whole thesis is to have decentralized production with centralized manangement. Breakthroughs are needed to separate lignin, cellulose and semi-cellulose in lignocelluloses and to process them spearately for end use.

Yet another factor is the inertia on the part of the farmer, industry and government. Change is always resisted. Industry is wedded to the classical pattern of large-scale, capital- and energy-intensive technology, and could feel threatened by a biomass-based strategy.

No attempt is made here to analyze in depth the techno-economic and social aspects of biomass conversion and biomass-based strategy for industrialization. Only some of the several issues, problems and constraints are discussed to indicate the methodology for policy, planning and programmes for biomass generation, mobilization and industrial conversion. There is also a need for a interdisciplinary, integrated approach for biomass conversion. The technologies need to be specific: resource-specific and site-specific. A team of specialists should examine these issues closely for a promising and elegant alternate pathway for industrialization.

In the last analysis, the policy decisions are social and political. The will and commitment of the Governments to serve the people, particularly the large majority of the rural poor, will favour biomass-based industrialization.

III. RESEARCH AND DEVELOPMENT

A number of possibilities for research and development exist. Some work is being carried out in this area. It is clear that the type of biomass, the technologies, processes, products for end use, and the needs and priorities of each country may vary widely. It is also clear that each country should develop local technological and managerial competence to generate, mobilize and utilize biomass profitably, particularly in view of the fact that both bioresources and end products are site-specific.

Irrespective of networking and bilateral, regional and international co-operation, each country should have a bioresources survey and a biomass policy and plan that are reflected in national programmes and projects in order to acquire, adapt, develop, transfer and utilize relevant technologies. An indicative list of such programmes and projects is presented here. A programme is a broad area and several projects could be listed under a programme. Such projects could be implemented by the country itself or through bilateral, regional and international co-operation. UNIDO could help each country to prepare such programmes and projects and to implement them.

The programmes cover broadly:

1. Those that are known to be produced already commercially or are in a proving plant stage (technologies, markets well established)
2. Those that require further testing in pilot/proving/commercial scale.
3. Those that need research, development and testing
4. The variety of new equipment, machinery and process control systems and
5. The policy support and management back-up needed.

An attempt is made to indicate a few of such programmes and projects. This list is by no means comprehensive.

PROGRAMME I--PILOT PLANT PRODUCTION/COMMERCIALIZATION:

The processes that have already been tested on a pilot plant, proving plant and commercial scale are indicated here. Also a representative sample of agricultural and cash crops are presented to give an indication that such possibilities do exist for other similar crops as well. The countries that grow such crops and the research institutes concerned could well join in the Network. Newer techniques of tissue-culture and cloning have also been applied with success to several of these plants, resulting in yields with increased quality and quantity. The countries and the institutes that may be interested in the project are given in brackets. Reference to Information contained in the Directory of Industrial and Technological Research Institutes: Industrial Conversion of Biomass (UNIDO/IS.372) is indicated by the letter X. Reference to information contained in UNIDO's computer print-out is indicated by the letter Y.

Integrated processing of the following crops, from leaf to root, as already established:

Project I:

1. Coconut All the processes and the products have been tested and marketed (see UNIDO/IOD.377, 1980, Part 1-7, and UNIDO/IO.528).

- Leaf: for roof thatch, lignocellulose conversion.
- Stem: coconut long fibre
- Trunk: building material
- Root: fuel
- Sap: Toddy, alcoholic beverages, sugar, edible
- Nut-Kernel:
  Copra, edible oil, fatty acids, coconut cream, jam, foods, soaps, detergents etc.
- Water: Soft drink, methane, plasma extender

- Nut-shells:

  activated carbon, fuel, charcoal, shellflour, filler, extender, coating

- Nut-husk:

  coir and coir products such as mats, brushes, rubberized foam beds etc.

- Coir dust:

  Particle board, lignocellulose conversion, fillers etc.

  (X: 8, 20, 48, 50, 90, 91 among others Y: 013449/1984 (Kenya), 013450/1984 (Colombia), 012199/1982, 013444/1984, 012493/1983, 012512/1982)

Project 2: Date Palm and Oil Palm

The leaf-to-root concept applies to these plants as in the case of coconut and, hence, not detailed (X: 21, 75, 80).

Project 3: Banana Plant (X: 59, 60, 76, 92)

- Leaf: Packing material, lignocellulose conversion, animal feed.
- Stalk: Paper, cardboard, food, fodder.
- Banana fruit:

  Food products, flour, beverages, chips, jam, liquor, soft and alcoholic beverages etc.

  - Banana peels:

    Fodder, biogas

  - Roots:

    Fertilizer

  - Tissue culture and cloning: improved varieties of bananas

Project 4: Mango fruit (countries in Africa, Asia and South America):

- Fruit as such:
  for eating, export
- Fruit:
  juices, slices, jam, jelly, beverages, liquor
- Fruit peel:
  pectin, beverages
- Mango seed:
  outer: cellulose and bank paper
  kernel: carbohydrates--food
  oil (7-10%)--cocobutter substitute

Project 5: Cashew Fruit (India, Malaysia, Tanzania and many others):

- Fruit: pulp; jams and jellies; alcoholic and non-alcoholic beverages; liquor
- Nut: food, condiments
- Shell: oil, lacquers, resins, varnishes
- Nut skin:
  Tannin extracts, soil stabilizers

Project 6: Cassava Plant (countries in Africa, Asia, South America; X: 1, 2, 3, 5, 19, 21, 22, 26, 30, 44, 48, 50, 58, 63, 64, 69, 75, 77, 79, 80, 86, 87, 89, 91, ,108, 136; Y: 013467/1984, 011709/1982, 012323/1983, 013430/1983):

- Leaf: (10-13% protein) vegetable, soup, livestock feed, leaf meal (caution: poisonous hydrogencyanide must be removed)
- Stalk: Plant propagation, animal feed (with leaf), particle board
- Root: cooked, boiled, baked, shredded, grated, fried and fermented foods, pellets, juice, animal feed
- Chips: meal, flour, pellets, starch; fermented (Fufu)

- Meal or flour:

  Bakeries, fortified, enrich- foods etc; fermented (Eba, Gari) foods, beverages
- Starch: modified starches and related products such as glucose, dextrose, fructose, dextron, alcohol and related chemicals, e.g. adhesives etc.
- Cassava:

  ethanol

Project 7: Sugar cane (X: 1, 3, 5, 8, 15, 16, 26, 30, 44, 47, 48, 49, 50, 53, 58, 60, 63, 64, 67, 75-77, 89-92, 114, 129, 131, 136, 138, 140, 145, 150)

Twenty-five Industries are centred around sugar cane, using the leaf, rind, fibre, begasse, molasses and sugar to produce feed, fodder, paper, alcohols, ch- cals, etc. This list can be exetended to several other plants, such as rice plants (about 70 industries), cotton (about 10 industries), e.g. castor and ground nut.

PROGRAMME II--PILOT PLANTS THAT NEED SCALING UP AND PRODUCT MARKETING

Project 8: Gassification of several agricultural forest and other residues such as corn cobs, rice hulls, peanut shells, coconut shells, coffee husk, forest and wood wastes, waste tyres for producing gas and generating electricity (X: 3, 6, 7, 8, 13, 20, 22, 26, 28-36, 60, 62, 90, 92, 94, 17, 33, 40, 46, 53, 75, 135, 136, 142-46, 99, 101, 102, 108, 121, 133)

Project 9: Pyrolysis and liquifaction--agricultural residues like rice hulls for gaseous and liquid fuels, hydrocarbons, phenols, polysacharides etc.--by catalytic, flash, ultra flash, vacuum and hydropyrolysis (X: 3, 20-22, 26, 32, 33-36, 43, 48, 49, 50, 52, 69, 77, 79, 88, 89, 90, 92, 94, 97, 103, 125, 133; Y: 011957/1982, 012397/1983, 021916/1983, 012974/1983)

Project 10: Biogas digestors--OLADE/BORDA/CEMAT/IREN, INDIAN/CHINESE/MEXICAN/TANZANIAN. (Interested institutes: X: 27, 48, 53, 55, 57, 61, 86, 91, 105, 107, 120, 133, 142)

Almost every country is involved in biogas production, particularly using animal manure, household and community wastes and lignocellulosis. And yet, much more needs to be done to give a package of micro-organisms, a good gasholder and a good delivery system that is socially acceptable.

Project 11: Leaf Proteins:

from cassava leaf (6)*
maize (121)
and others not listed in the Directory

Project 12: Fuller utilization of water Hyacinth plant (X: 66, 99, 100, 133)

- Leaf: animal fodder, paper, cardboard, fertilizer, biogas, chemicals, hormones etc.

- Root: fodder

An interrelated project would be the utilization of aquatic biomass.

Project 13: Mushroom production (X: 28, 92)

Conversion of cellulose into edible protein mushroom is an age-old practice and a mul^imillion-dollar business, apart from providing the much needed nutritious protein to the poor. Several institutions in the world are involved in this business. It could be a major project of interest.

Project 14: Manufacture of fructose/syrup (X: 69, 137, 142, 63, 83)

Fructose is 120-150 times sweeter than sugar and is already replacing the use of sugar of to 60% in the softdrink manufacture in the United States of America and other countries. Fructose from cassava root starch, sweet potato (69), molasses (109), Jerusalem artichoke (137, 63) and other carbohydrate sources would be of interest.

Project 15: Protein sweeteners (See UNIDO/IS.397/1983)

- Miraculin from Richardelia dulcifera (Synsepalum dulcificum)
- Africa . Morellin from Dioscoreohylum cuminsii
- Thanmatin from Thanmatococcus danielli
- Faraguay. Leaves of the Shrub Stevia rebandiana
- Glyerine from root of licorice plant Glycyrrhiza glabana

Project 16: Ne·/ methods of extraction of sugar cane:

The process involves first separating rind from the pith (X: 8,59), then easily extracting sugar from the pith and high-quality stalk fibre from the rind for building materials, paper etc. Yet another process is the Ex-FERM process for a continuous fermentation in a mixed-phase solid liquid system (X: 59)

Project 17: **Production and utilization of high proteins, high oil seeds:**

For both food and fuel production (Australia, Fiji, France, Thailand, United States of America). (X: 4, 17, 19, 20-23, 50, 53, 102, 126, 140, 141, 144)
Substitutes for diesel oil (vegetable oils extended with methanol.

Vegetable oil extraction

- Byproducts--green manure, insecticides, pharmaceuticals
- converting inexpensive lipids such as lard and fallow by enzymes into valuable food lipids or industrially useful fat derivates;
- valorization of palm-oil wastes
- cloning of oil palms
  Jojoba oil potential for food, fodder, nutrition, protein, waxes, cosmetics, drugs, lubricants (Y: 01408/1981, 011016/1982)

Project 18: **Production of improved woodstoves:**

A saving of energy up to 50% and housewife-friendly technologies for smokeless stoves have been the subject of serious study by several institutions in the world (X: 9, 30, 48, 88, 106, 144). Several others could be added.

The present need is to select a few designs for each region or sub-region, get them field tested for techno-economic evaluation and social acceptance. The most acceptable wood stove may then be manufactured in the small-scale sector and supplied to the rural households.

Project 19: **Medicinal and aromatic plants for industrial development:**
(Y: 011709/1982, 012323/1983 (Zambia), 0131430/1983 (Zambia), 011751/1982, 011742/1982; 010802/1981, C11235/1981

Extraction of essential oils, perfumery components, drug components that fetch high returns from sun-belt resources will be of great interest to a number of developing countries.

PROGRAMME III--RESEARCH AT LABORATORY LEVEL

Some of these projects, now at the stage of laboratory-level, research that are of mutual interest are listed below:

Project 20: Industrial chemicals from indigenous carbohydrate raw material resources

Sucrose based

Starch based: citric acid, glacial acetic acid, dextron, fructose, alcohol, yeast, single cell protein, biodegradable polymers, ethanol,

butanol, butanediol; acetone, glucose, xylose, arabinose, mannosse, galactose, biodegradable films, starch copolymers with ethylene, acrylics, highly absorbent polymer derivates, foam and solid rubber copolymers etc.

Project 21: Improvement of traditional fermented foods by enhanced protein/amino acid/vitamin content to increase the nutritional value:

Gari food, a poor man's food from the cheap source starchy cassava needs fortification. Growth of microorganisms in controlled media will enhance the protein content as well as vitamin B12. Indonesian tempeh is a fermented food with a mold mycellium grown on low-cost starch. It contains as much protein or more than meat, contains vitamin B12, and was one of the world's first, cheap, quick-cooking foods. Indonesian Tape Ketalla is based on cassava and has 2-4 times more protein content. Tape Ketan--there is a selective increase of lysine by 15 per cent and thiamene content three times, doubling the protein content of rice. Only the surface of this "gold mine" of traditional knowledge of fermented food has been investigated. Further investigations and introduction of biotechnology into this traditional fermented food industry will yield rich returns.

India, Indonesia, Nigeria, Thailand on one side with traditional knowledge and Sweden and the United States of America could join together to devise suitable commercial production methods for improving traditional fermented foods such as Gari food.

Project 22: Production of Chitin and Chitosan as a by-product of shellfish wastes (X: 36)

Very costly chemicals such as chitin and chitosan can be produced from shellfish wastes. This project should be of much interest to several countries with coastal shorelines.

Project 23: Protein from Spirulina Algae (X: 39, 54, 55, 72, 74, 100, 125; Y: 010174/1980, 010176/1980)

For animal fooder/food etc.

Project 24: Particle and fibre board from agricultural residues and non-woody fibrous material

From begasse, coconut fibre, grasses, bamboo, banana stalk, rawmit, cassava, cotton stalks, kenaf, jemp, jute, flac, sisal, rape, rice husk, straw, maize stalk etc. (Y: 011514/1982--a bibliography).

Project 25: Low-cost bvioding materials from agricultural and industrial wastes (Y: 013309/1983)

Mention has already been made of the use of leaf, fibre stock, stem, trunk and roots of several agricultural and forest plants as well as the wastes converted into boards and panels to be used as building materials. Fibre composites of natural and synthetic fibres and agricultural and industrial wastes acting as fillers for polymeric materials would also prove to be good building materials.

Project 26: Decomposition of lignin, hemicellulose and cellulose in lognicellulosis:

Several countries are actively engaged in this important area of research. Several methods of physical. chemical, thermo-chemical and biological techniques are being developed individually or in combination to separate lignin and cellulose. Also catalytic (X: 32,35), flash (X: 15,31), ultraflash (X: 34), vacuum (X: 34), hydropyrolysis (X: 32, 133), and micro-wave treatment techniques (X: 143) are being developed. Networking in this area would prove fruitful.

Project 27: Lignin and cellulose as chemical feedstock

Conversion of lignin into BTX fuel, and benzene, toluene, xylene and related products will become the feed stock for a number of chemical compounds.

Cellulose can be converted into microbial protein

- methane--fuels
- glucose--alcohol--chemicals like ethylene, ethyleneglycol, butanol, butanediol, acetone, acetic and citric acids, glucose, xylose, arabinose, mannose, galactose, fructose, CO_2
- suppressed methane fermentation to obtain pentanol, octane, decane and BTX fuel together with organic chemicals such as ethylacetate etc. (X: 33, 63, 83, 113, 125, 136)

Project 28: Production of enzymes, proteases, amylases, cellulases, yeasts and thermofibric tolerant enzymes (X: 7, 92, 130, 132; Y: 021847/1983)

Biotechnology and genetic engineering is pressed into industrial fermentation; separation and conversion of lignocellulosis into food, fodder, fertilzer, fuel, chemicals, drugs etc. Identification, isolation and supply of an individual or a mixture of micro-organisms, genetically cloned micro-organisms is an important area for joint research.

Project 29: Utilization of aquatic biomass

For food, fodder, fertilizer, fuel, chemicals etc. (X: 1, 8, 22, 30, 33, 36, 39, 43, 48, 50, 55, 56, 60, 61, 63, 66, 72, 74, 78, 81, 87, 88, 92, 100, 107, 108, 133-136)

Project 30: Methanol, paper pulp and mushrooms from straw (X: 6; Y: 010918/1980)

PROGRAMME IV: EQUIPMENT AND MACHINERY

For industrial conversion of biomass into usable products, equipment, machinery, process control and monitoring tools are needed. Several of these may be simple and suitable for decentralized production. Some of the projects at the idea stage are listed below, which could attract the attention of the different institutes toward a network.

<u>Project 31</u>: <u>Biomass harvesting, drying, pelletising, briquetting, handling and storage</u> (X: 18, 30, 33, 52)

<u>Project 32</u>: <u>Biomass gasifiers</u> (X: 17, 27, 48, 55, 57, 61, 63, 86, 107, 120, 142)

<u>Project 33</u>: <u>Methane gasholders</u> (X: 95)

<u>Project 34</u>: <u>Rapid compost machines</u> (X: 137)

<u>Project 35</u>: <u>Tiby machines to remove rind from sugar cane</u>

<u>Project 36</u>: <u>Experimental devices to control several parameters</u> (X: 143, 52)

<u>Project 37</u>: <u>Reactors</u>

- Extruder-type reactors for lignin hydrolysis (X: 21)
- Fluidized beds (X: 63)
- Pulse column beds (X: 63)
- Nitrogen columns
- Fixed film digestors (X: 142)
- Fixed beds
- Continuous reactors with encapsulated micro-organisms (X: 140, 142)

Project 38: Fermentation processes and reactors

- Bacterial fermentation (X: 5, 19, 21, 75, 80, 83, 91, 136, 150)
- Cell recycle fermentation (X: 63, 114)
- Continuous fermentation (X: 5, 15, 19, 58, 83, 91, 114, 127, 142)
- Extractive fermentation (X: 58, 75)
- Flash fermentation (X: 127)
- Vacuum fermentation (X: 80, 110, 127)

PROGRAMME V--BIOMASS POLICY AND MANAGEMENT

It was stated earlier that each country should have a National Bio-resource policy integrated with the national industrial policy. This would involve the following projects:

Project 38: Information on biomass generation, mobilization, conversion and utilization: awakening, awareness, intelligence

Project 40: State-of-the-art reviews; survey of literature, techno-economic feasibility studies (X: 104, 110)

Project 41: An equation between food, energy and industry requirements for biomass generation and use: optimal pathways

- To optimize phytoplankton and biomass production (X: 52)
- Direct biomass conversion of solar energy to hydrocarbons via the cultivation of unicellular algae, fast-growing energy forests, oilseeds and hydro-carbon plants for substituting diesel fuels; biomass-derived hydrogen fuels (X: 54)
- Bacterial chemosynthesis using waste hydrogen sulfide as a mode of bacteria/biomass products used for fodder (X: 52)

- Unconventional marginal land crops as sources of fuels and chemicals: analysis, appraisal and evaluation.

Project 42: Blending of traditional and modern technologies

Project 43: Evaluation of processes (chemical and biological: process engineering, economics, marketability and profitability

Project 44: Ecology, hygiene

Project 45: Socio-economic aspects

Economic and social costs and benefits, employment, cultural compatibility, acceptability, alteration in the demand pattern of skills, shifts in regional economic and industrial activity, decentralized small-scale production etc. (X: 101, 103).

IV. A NETWORK OF INSTITUTES OF BIOMASS TECHNOLOGIES (NIBT)

It is in clear recognition of the importance of biomass for industrialization that UNIDO is taking the initiative to promote regional networks of institutes of biomass technologies in Africa, Asia and Latin America. These regional networks could form an international network. While scientific research is global in character, the technology, its applications and its delivery systems are site-specific and region-specific.

It is imperative that every country build its local competence to utilize biomass from the initial stage of awareness to policy response, from formulating plans to successful implementation and from assessing and evaluating the resources and technologies to matching them to the needs and socio-economic conditions. The need for local competence is all the greater because the biomass resource is largely country- and site-specific.

Each country should consider providing the necessary infrastructure and trained personnel. Each country could establish a "centre of excellence" to develop one or more biomass technologies, or the existing institutes could be encouraged to take up biomass technology development as a priority programme. Such national centres could join in a regional network to exchange information, experience and expertise in order to supplement and complement the indigenous competence of an individual country. Such a collective co-operative endeavour might attract the attention of international funding agencies for funding potential research projects and for training personnel. Several United Nations agencies are keenly interested in biomass and its profitable utilization, particularly for rural development in developing countries.

The Directory of Industrial Technological Research Institutes: Industrial Conversion of Biomass (UNIDO/IS.372) will prove very useful in this regard. From this limited survey, it was learned that in 1982 there were 154 research institutes in 47 countries of which 60 were located in 31 developing countries, spending about $US 12 million on research and development. It is interesting to note the diverse nature of these institutes, ranging from an oceanographic institute to a jet propulsion laboratory and a rural innovation centre. This Directory gives a brief diagnostic glimpse of the current research efforts, the types of biomass and the technologies, processes and products under development or already developed. Greater coverage is needed to include other research institutes involved in the same areas as well as those involved in biomass generation, policy, planning, management, monitoring, information and awakening awareness.

The UNIDO Directory is envisaged as a starting point for the promotion of international co-operation in the industrial conversion of biomass. There is a great need for pooling this knowledge and sharing the experiences of these and other institutes in order to achieve rapid development and utilization of biomass technologies for the alternate pathway of rural industrialization. Although the conversion processes may be largely global in character, biomass and micro-organism resources are site-specific and, therefore, a sharper focus on regional co-operation could be considered.

A. Goals and objectives

The major goal of the network would be to establish and facilitate regional and international co-operation and collaboration throughout the Network of Institutes of Biomass Technologies.

The main objective would be to supplement and complement each country's competence in biomass generation, mobilization and utilization and to bring about an alternate pathway of industrialization in developing countries.

The Network would help to build a peak point in developing one or two technologies in each country. Each country has a peak to give and yet to receive from the peak of the other country. Therefore, each country is independent and yet interdependent. In this way a collective, self-reliant development could be ach eved rapidly and at a lesser cost.

B. Activities

To achieve the set goals and objectives, the activities and programmes would include:

- Training of personnel within and outside the Network;
- Identifying and defining specific industrial projects and the degree of progress;
- Initiating and organizing joint research projects and development;
- Setting up joint task forces;
- Organizing workshops, seminars and symposia on interrelated subjects of mutual interest in conjunction with concerned, competent institutes;
- Collecting, assessing, and analyzing information and providing awakening and awareness intelligence and alternative choices to decision-makers and researchers;
- Generating state-of-the-art reviews on specific projects;
- Spotlighting successful technologies, policies, strategies, approaches and management systems;
- Preparing technical and economic studies of available conversion technologies;
- Assisting in the commercialization of processes and products;
- Transferring and disseminating technology;

- Testing, evaluating and verifying the claims about technologies and equipment and designing evaluative criteria for monitoring;

- Assisting individual countries in formulating policies, programmes and projects;

- Building linkages with related institutions; and

- Enlisting co-operation und support from the various regional and international development funding and scientific agencies.

C. Organization, structure and management

- The membership of the Network would consist of the participating Institutes and Centres for Biomass Technologies engaged in biomass-generation, mobilization, conversion, utilization and management. These may be governmental, non-governmental, private and/or publicly funded institutions. Other organizations interrelated and interested in this activity, e.g. funding agencies, could become affiliated members;

- The Network would have a General Body and an Executive Board. All the participating members and affiliated members would constitute the General Body, which would meet once or twice a year to approve the overall policy guidelines.

- The Executive Board would consist of 7 to [illegible] members who would be elected to the Board on a rotational basis by the General Body. The Executive Board would consist of a Chairman, two Vice-Chairmen and 4 to 6 members;

- The Executive Board would approve the plans, programmes, projects and budgets for the co-operative endeavours and would set guidelines for co-operation, the generation, transfer and utilization of technology and training. The Board would meet 3-4 times per year by rotation in each participating country;

- The Executive Board would be assisted by a very small (1+1 person) Secretariat. This Secretariat could move with the Chairman from year to year or be located in one place as agreed by the General Body. It must be clearly understood that all the work would be done in individual institutes. The job of the Secretariat would be only to assist the Executive Board and individual institutes in joint endeavours.

D. Funding

- Each participating institute would fund the accepted programme;
- Sponsored research would be accepted by each institute;
- Donors would be encouraged to support programmes and projects that are of mutual interest to countries, on a subregional or regional basis;
- Bilateral science/technology co-operative agreements could include biomass programme as a priority programme;
- Exchange of senior and junior scientists could be organized between the countries on an equal basis (not on the donor-acceptor basis), e.g. two countries could agree to have a 900 man-day exchange programme, or each country could send and receive 30 scientists for 30 days or 10 scientists for [illegible]0 days, totalling 900 man days. Budgets would be provided for the local expenses of visiting scientists. In this way no foreign exchange problem would be involved.

E. International Co-operation

No doubt, such a network will readily attract the attention of UN and related agencies as well as international funding agencies, and scientific bodies such as the International Council of Scientific Unions and national academies. A Bioenergy Users Network is already being established with primary participation by developing countries interested in development of bioenergy resources and systems. ICSU and UNESCO are promoting an International Biological Network involving African, Asian and Latin American regional networks. UNEP, UNESCO and ICRO sponsored a Microbiological Resource Centre (MIRCENS) to form a network. UNCSTD, CASAFA, IDRC and others are promoting several activities in the area of biomass generation and utilization.

NIBT could establish firm linkages with such regional and international institutions to avoid duplication and to take advantage of the skills and knowledge available within such institutions.

The aim of NIBT is broad-based industrialization using biomass as industrial raw material. This should be kept in view when forging links with other institutions.

F. Programme/Project Formulation and Implementation

1. Programme

A programme is an overall area and each programme area has a number of well-defined projects which are generally interrelated.

2. Project formulation:

At the beginning of the year each institute participating in the Network would present suggestions and ideas for the programmes and projects based on their own resources, needs and priorities. The Secretariat of the Network would match similar interests, bringing together two or more institutes interested in the same or similar projects who would then jointly formulate the projects in detail. Such projects would be further evaluated by an Executive Board consisting of technical experts, perhaps assisted by competent experts in the field. Such an evaluation would ensure that the project is well defined, indicating the inputs and outputs, rights and responsibilities of each participating, involvement of the likely end-user of the research results, the terms of technology transfer and the priorities.

The project task could be split into sub-tasks or technical components. The inputs for each component, such as specialists, scientific disciplines, infrastructure facilities and funds would be clearly indicated. Each participant undertaking a sub-task would accept the responsibility to complete his part on time.

The outputs for each project could be a paper for publication, a patent, a process or a product. It is important that the project document clearly define how the results of research would be shared before the project begins. Even in a simple matter such as the publication of a scientific paper, the authors should determine whose name will appear first. Similarly if it is a patent, the bench researchers who invent the idea, the pilot plant people who contribute to the scaling-up of results, the information scientists and the techno-economic and social scientists will all have a claim on the money realized through the sale of a patent. One component of the project might require more inputs, including funds, than another. Do they get a greater share of the profits? Even such minute detail should be thought of at the very beginning of the project formulation.

3. Task forces

Once the project is defined, clearly indicating the technical sub-tasks (each sub-task would be assigned to the institute with such competence), a task force would be formed with a competent leader who would be given the necessary funds, authority and responsibility (administrative and financial) to get the job done on time; he would monitor, collate and co-ordinate the work of the different participants. It would be the duty of the leader to ensure at the very beginning that each participant had clearly understood his rights and responsibilities.

The Executive Board would assist and support the Task Force and its leader in every way. While the Network is a loose structure, the project formulation and implementation would be well defined; only then would it become more effective.

4. Project funding

The Task Force would clearly indicate the funding requirements for all sub-tasks of a project. The participating institute would generally fund its sub-task. The institute might also obtain a sponsor to fund its part of the project, maybe even the whole project. It is in this area that the Network Secretariat could be most useful by bringing projects of a regional nature to the attention of national, regional and international funding agencies. Development banks could also be involved in obtaining the risk capital for pilot plants or proving plant production. Whenever outside agencies or industry fund projects, either partly or fully, a set of guidelines for such sponsoring would be drawn up, or where favourable and necessary, the conditions would be set by the sponsor for funding the accepted research projects. The critical issues would be the terms and conditions for patenting the know-how, releasing the know-how for commercial utilization by the participants in the Task Force and selling the know-how to those belonging to the Network and outside the Network. Funds would be clearly earmarked for training, exchange of scientists, research and pilot production.

The following are illustrative programmes:

Programme area: Integrated utilization of cassava, leaf to root

Project 1: Leaf utilization

Sub-tasks:
1: Collection, handling, storage, and assuring uniform quality of raw material for industrial processing or for export as such.
2: Removal of highly poisonous hydrogen cyanide from leaves.
3: Extraction of leaf protein
4: Utilization of leaves as animal fodder, fertilizer, biogas, etc.

Task Force:

Participating Institute	Sub-task	Scientific discipline	Funds ($US)	Time schedule
Australia	1,3	chemical engineering, analytical	6,000	12 months
Thailand	2,4	chemical, biochemical	5,000	12 months

Expected outputs:
1. Publications
2. Technical know-how for production of (a) leaf protein, (b) animal fodder etc.

Technology transfer:
1. Between Australia and Thailand--no fee involved.
2. Between Australia and Thailand and others in the Network--2 per cent royalty on the sales or a lump sum amount of $US 5,000.
3. Between Australia, Thailand and others outside the Network--4 per cent royalty or a single down payment of $US 10,000.

<u>Project 2</u>: <u>Improvement of cassava-based traditional fermented foods</u>

Subtasks:
1. Identify and isolate micro-organisms involved in traditional fermented foods such as Gari (Nigeria), Tempeh, Tape Ketella (Indonesia) etc.
2. Study the biochemical changes in proteins, lipids and other components, including the flavours and textures produced.
3. Select and generate of essential micro-organisms for increased protein, vitamin content and improved nutritional value.

4. Improve the supply of standard quality raw material.
5. Improve the control of fermentation
6. Supply a standardized small package of micro-organisms at low cost for home use and small-scale production of improved fermented foods.
7. Apply microprocessor control of pH, temperature, oxygen, carbondioxide and humidity in the industrial processing of foods.
8. Pilot-plant production.

Task Force:

Participating Institute	Sub-task	Scientific discipline	Funds ($US)	Time schedule
Canada	3, 7, 5			
Indonesia	1, 2, 4, 6	industrial fermentation, genetic engineering	50,000	-
Nigeria	1, 2, 4, 6, 8	microbiology, biochemistry, chemical engineering	50,000	-
Sweden	3, 7, 5	genetic engineering	-	-
IDRC/SAREC	-	-	250,000	-

Expected outputs:
1. Publications
2. Patents
3. Technology for improved fermented foods
4. Technological competence to identify and clone micro-organisms

Technology transfer:

IDRC and SAREC might stipulate that technologies so developed would be offered (a) free to all developing countries since it can be considered as "technology for humanity"; (b` the know-how might be offered to companies at differential rates, e.g. least developed countries free of charge, other developing countries at 2 per cent royalty, and 10 per cent royalty for others etc. The countries that helped to develop it such as Indonesia and Nigeria might use the technology free of charge and share the royalties if the know-how is sold. Such technology development would attract the attention of funding agencies.

Project 3: Utilization of stalk for particle board

Project 4: Cassava of starch for alcohol and other chemicals

A number of projects could be drawn up, centred around cassava: a large number of projects and institutes could be involved in this one area.

A second example of a different nature is also indicated here for clarity:

Second example:

Programme area: Utilization of lignocellulosis

Poject: Pyrolysis of lignocellulosic materials

Scientific approaches

1. Catalytic pyrolysis
2. Flash pyrolysis
3. Ultraflash pyrolysis
4. Vacuum pyrolysis
5. Hydro pyrolysis

Each institute could specialize in one of these approaches and complete the work early. The total information would be available between the five participating institutes in a short period at lesser cost, with a lesser number of scientific disciplines in each.

No attempt is made here to detail the projects. First and second examples are only indicative of how projects could attract the institutes to function under a networking system.

V. SUMMARY

In this paper, it is argued that the present pattern of urban-oriented, capital-intensive industrialization has produced severe imbalances in developing countries between the elite groups that monopolize wealth and power and the majority of rural people who are poor. A correction is called for.

It is urged that decentralized, rural industrialization based on the generation, mobilization and optimal utilization of biomass may well prove to be an alternate pathway for industrialization. Contrary to traditional thinking on cottage and rural industries, the coupling of local large, rich, renewable resouce biomass with technological advances, utilizing every part of a plant from "leaf to root" will help maximizing the returns for the resource, provide additional incomes employment and equity and keep people in the rural areas instead of bringing them to the city slums.

Biomass in its many different forms has many competing end-uses. There is a strong nexus between agriculture, food, energy and industry. It is therefore essential to assess the biomass potential for its competing claims and balance it in an integrated manner, matching emerging and alternative technologies and varied types of biomass with the needs, resources and socio-economic conditions of developing countries.

A national bioresources policy integrated with industrial and other policies, a bioresources survey, integrated resource manangement, development of technologies and building local competence to deal with biomass from the initial stage of awareness to policy response, to plan and implement plans. Some of the issues and constraints, the problems and prospects, the technology opportunities and options and the policy implications of biomass based strategy for industrialization have been discussed.

It is stressed that the need for local competence is all the greater because the biomass resource is largely country and site specific and the industrialized countries may not be interested in developing the required technologies. It is suggested that each country should consider providing the necessary infrastructure; trained personnel and also set up a research centre for biomass technologies. Such national centres or institutes may join in regional network, which in turn may become an international network of institutes of biomass technologies, to exchange experience, expertise, information etc. to supplement the competence of the individual country. A possible structure, organization and management of such a network (NIBT) is presented. The modalities and mechanisms for the operation of projects and programmes under such a NIBT have also been indicated.

Irrespective of the networking, for the benefit of each country and for UNIDO, to initiate, catalize and promote biomass based industrialization, an indicative list of groups of programmes and projects have been included to cover the projects that could be taken right away with proven profitability and marketability; those that require further testing in the laboratory, pilot and proving plant stages; in equipment, machinery and process control systems and the policy support needed. The institutes that could join in different projects and programmes in the network based on the UNIDO directory of institutes for industrial conversion of biomass have also been indicated.

It is earnestly hoped that this paper provokes discussion, debate and decisions on the implementation of an alternative pathway to industrialization with a biomass based strategy.

Acknowledgements

Several UNIDO reports on Technological Advances, particularly the excellent report by Dr. C. G. Heden, "The Potential Impact of Microbiology on Developing Countries" (UNIDO/IS.261/1981), and the UNIDO Directory of Industrial and Technological Research Institutes for Industrial Conversion of Biomass (UNIDO/IS.372) contain a mine of information on the generation and use of biomass. A report entitled "Integrated Application of Technologies for Complete Utilization of Agricultural Crops--Paddy Crop (CDA)" is very useful.