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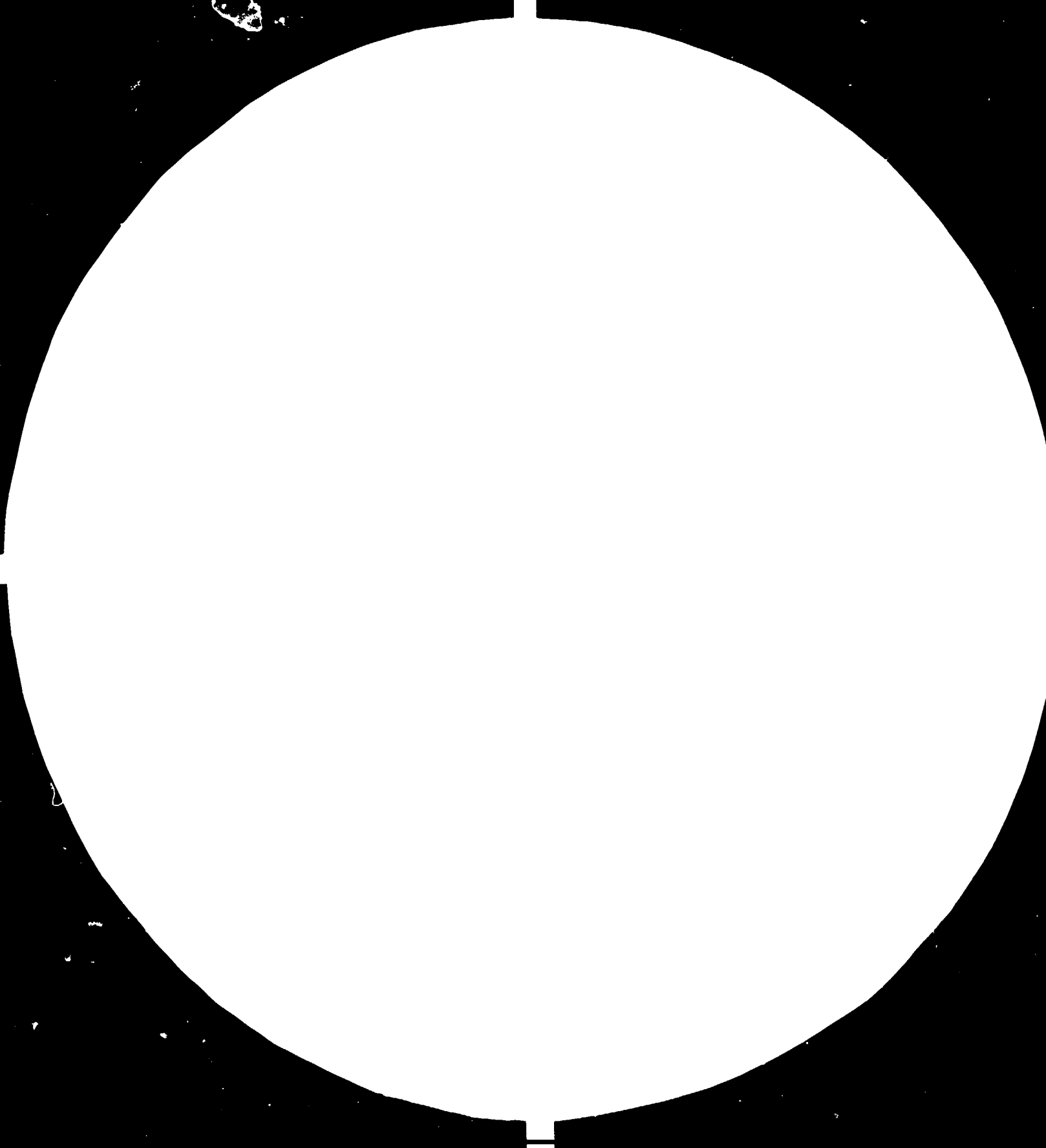

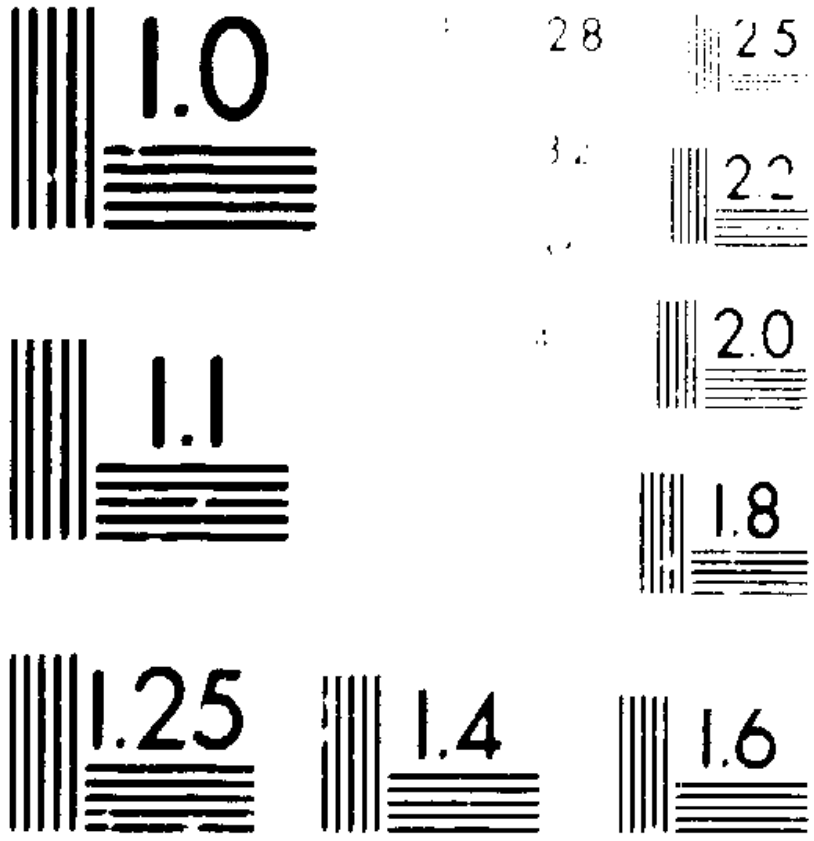

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COMPLEX UTILIZATION OF BIOMASS FOR FOOD, ENERGY AND RAW MATERIALS

January, 1984

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C O N T E N T S

I N T R O D U C T I O N

Food, Energy and Raw Materials are among the most crucial problems of all countries. Indigenous supply of food, energy and raw materials, in this order, has first priority especially for developing countries as a necessary basis for a sound economy.

Food supply, adequate in dietary energy and nutrition quality, is indispensable for survival and well being of mankind. Food is a renewable commodity, supplied entirely from biomass produced from inorganic materials with the aid of solar energy through photosynthesis. The production requires arable land, estimated at a quarter of the global land area. It is estimated that the global resources are such as to allow for an order of magnitude larger production on a sustained basis, providing an adequate energy supply is assured.

Energy, then, is also indispensable as it also assures protection against the environment and runs the wheels of the entire economy. Not only is the level of development proportional to energy consumed but no development and even no existence is possible without adequate energy supply. At the present energy is mostly a non-renewable commodity, supplied for the most part by fossil fuels. However, those fossils have been biomass a long time ago. Also, even now more than 10% of the primary energy in the world is supplied by biomass and about a half of the global population depends on biomass for energy. It is true that these are the poor of the world and that their energy supply is inadequate. Nevertheless renewable production of biomass on a global scale is in energy content ten times greater than the present total energy consumption.

The bulk volume of raw-material supply is at the present non-renewable, although some industries, like wood-, pulp- and paper-industries depend entirely on biomass for raw materials. Not a long time ago, before the advent of cheap

oil, much of the chemical industry raw-material supply came from biomass. With the changing patterns of economy going away from heavy metal industry, many new materials could be produced on the basis of biomass.

Thus, there is a sound foundation for the statement that indigenous, renewable biomass production could in many aspects be possible solution to critical problems of food, energy and raw-material supply, for many countries in the world, in the long run. After all solar energy is by far the greatest primary energy source on Earth. Furthermore, photobioconversion is an ideal way of harnessing solar energy resulting in chemical energy stored in biomass which could be used whenever and wherever needed for energy supply and also as food and raw-material.

The resources exist while the appropriate technology is in development. In fact Biotechnology, which could be defined as application of scientific and engineering principles to the processing of materials by biological agents to provide goods and services, is amongathe fastest developing technologies at the present. Among the modern technologies in which spectacular breakthroughs are expected Biotechnology is considered as the technology of the future. Developments in biotechnology open some new possibilities esspecially for developing countries as a technology in which human resources and ingenity have a principal role. Research and development in biotechnology does not require excessive funding and the applications do not involve extremly large investments necessary in some other new technologies.

In the long run, therefore, the perspective of biomass and biotechnology playing an important role in indigenous supply of food, energy and raw-materilas on a sustainable basis looks very promissing. In changing the objective to the present situation looks different.

On a global scale for the last 30 years production of food doubled for an increase of 76% in population while the production of food is by 10 to 30% greater than needs there are about 450 million undernourished in the world due to poor distribution and overconsumption in industrial countries. All available land is therefore needed for food production. High productivity in industrial countries is being paid by extensive energy inputs

in form of oil for fertilizers and fuel. Increase of productivity in developing countries is often prevented by the lack of oil already imposing an overburden to national economies. The FAO estimated that by the end of the century food production in developing countries would have to double with a modest increase of the arable land area. This then requires an increase of oil consumption by a factor of four which would double food prices in these countries.

As far as energy supply from biomass is concerned by far the most part of renewable biomass comes from forests. Forests have an important ecological equilibrium and soil conservation role. In developing countries heavily relying on fuelwood for energy a serious deforestation is already taking place endangering ecological equilibrium. In industrial countries all available forests are needed for the supply of raw-material for wood and paper industry.

It is obvious then that at the present there is a number of important problems in biomass production and utilization to be dealt with. The problems concern poor resource management, inefficiency of production and processing, utilization of various residues and waste. These problems could be grouped under several items:

- Improved resource management: better land use through land reclamation and environmental control, better cultivation procedures and increased plant productivity through selection and breeding.

- Improved energy economy through conservation, better energy management and substitution of deficient hydrocarbons by renewable sources of energy.

- Increase of biomass resources for further processing by making full use of residues and waste and by cultivating alternative cultures.

- Decrease of waste by wider application of post-harvest technologies and by complex processing of biomass, and esspecially waste, into food, energy and raw materials.

While dealing with the described urgent problems it is at the same time necessary to make preparation for the advent of new biotechnology methods. In fact a number of the mentioned problems could be dealt with through application of some forms of biotechnology providing for a necessary experience for the further development. In addition, however, research and development basis has to be prepared. However, for this it is necessary to have a clear definition of the research and development strategy in order to concentrate available resources.

These are then the objectives kept in mind in proposing this study, the outline of which is proposed in the text. The study should provide for an inventory of the existing resources and the present situation in the biomass production and processing in a given country. A critical analysis of the resource management and energy economy should follow on the basis of which possible improvements should be proposed. A review of the state of the art in the application of new technologies in production and processing should be given also providing for a necessary technical and economic data for the subsequent analysis of possible development directions. Finally a Program of Action should be defined.

The present outline for the study is made on the basis of a project being realized by the Serbian Academy of Sciences and Arts in Yugoslavia. Therefore, it should be directly applicable to European and Mediterranean countries. However, the general approach is valid for all countries. Of course, depending on the development level of a given country, the outline could be modified in details various levels of complexity in dependence with the given situation and available means.

1. EVALUATION OF RESOURCES

Biomass production in a region depends on many factors such as: climatic conditions, available land and its quality, plants being cultivated and animals being grown, methods of cultivation, nutrient and energy supply, etc. However, under the optimum cultivation methods and nutrient supply there is for the given region an upper limit of biomass production depending on available land, water and prevailing climatic conditions. This upper limit, or potential biomass productivity should be evaluated in order to be able to assess present biomass production from the point of view of possible improvements in the future.

At the present stage of agricultural and forestry production energy input appears also as a limiting factor due to the dependency of energy supply on defficient hydrocarbons, mostly oil. It is therefore advantageous to substitute for defficient energy sources by indigenous renewable sources whenever this is economically feasible. From this point of view an evaluation of potential resources in renewable energies - solar, wind, geothermal and hydro - is necessary.

A country or a region in question is more often than not inhomogenous with respect to soil condition and prevailing climate. It is therefore necessary to divide available land area into subregions with similar climatic and soil conditions. Activities involved are concerned with the evaluation of potential bioproductivity and potential in renewable energy sources in each of the subregions.

1.1 CLIMATE, LAND AND BIOPRODUCTIVITY

1.1.1 Solar Radiation

Intensity and quality of solar radiation received are among the most important parameters for the evaluation of bioproductivity. Only a part of the solar spectrum between the wave lenghts 380 to 710 nm is photosynthetically active and the relative importance of this part in the total amount of solar energy received depends on the ratio of direct to diffuse radiation, i.e. on atmospheric turbidity, cloud cover etc. On the other hand solar radiation could be used for the energy supply in different processes of biomass utilization.

It is therefore important to gather all available data on solar radiation and its regional and seasonal distribution and to review these data from the point of view of completness. As available data are usually incomplete, especially in developing countries it is necessary to apply different methods for the estimation of missing data as well as to propose a program of improved data collection, storage and evaluation.

Activities involved:

- - Data collection. Regional and seasonal distribution based on statistical evaluation of following parameters:
  - Total amount of solar radiation received;
  - Diffuse radiation;
  - Reflected radiation;
  - Radiation balance;
  - Spectral distribution of solar radiation or photosynthetically active radiation;
  - Duration of sunlight;
  - Cloud cover and atmospheric turbidity.
- - Application of approximate methods for the estimation of missing and incomplete data;
- - Evaluation and mapping of regional distribution of principal data such as total and photosynthetically active radiation;

- - Programme for the improvement in data collection, storage and evaluation.

1.1.2 Climatic Conditions

Under sufficient nutritional conditions bioproductivity depends, in addition to solar radiation, on other climatic conditions, the principal among them being water balance and temperature as well as their seasonal variation, i.e. duration of plant growing period. Gathering necessary climatic data and their statistical evaluation on the regional basis is therefore needed for the evaluation of potential bioproductivity. As a result available land should be divided in a number of climatic subregions.

Activities involved:

- - Data collection. Regional and seasonal distribution of statistically meaningful data of following parameters:

- Air temperature,
- Air humidity,
- Precipitation,
- Potential evapotranspiration and water balance,
- Soil temperature,
- Wind,
- Other parameters of importance for the determination of the plant growing period.

- - Regional climatic analysis. Regional determination of climatic types based on different climatic indexes such as global humidity and continentality indexes, degree-day, and durations of plant growing periods, including elaboration of suitable mappings.

- - Air pollution could act as an inhibiting factor so that evaluation of available data on a regional basis should be worked out.

- - Programme for the improvement in the collection of principal data, its storage and evaluation

1.1.3 Soil Conditions

The adequacy of nutritional conditions for plant growth depends on the soil type and condition. The configuration of available land is related to the suitability of cultivation of different plants. Of importance for the land use are also present and future land occupancy for other uses such as habitats, communications, mining and industry, rivers and lakes, etc. A part of the land might be or could be unsuitable due to chemical and mechanical degradation. It is therefore necessary to classify available land regionally from the standpoint of bioproductivity and adequacy for cultivation. An adequate system of land categorization should result from these evaluations.

Activities invloved:

- - Regional classification of land area from the standpoint of:

- Occupancy i.e. non-productive land,

- Pedology, i.e. geologic and genetic structure,

- Configuration from the point of view of height, slope and orientation,

- Chemical and mechanical degradation (air pollution, fertilizers and pesticides, mining etc.),

- Average area of a land-piece with the identification of large land complexes.

- - Regional categorization of the available land from the standpoint of cultivation of principal plant cultures such as:

- Forestry,

- Pastures,

- Agricultural arable land.

1.1.4 Hydrology

Hydrology of surface and ground waters could influence plant productivity and land availability both favourably and infavourably. In flat-land, permanently overmoistured land due to high ground water, seasonally overmoistured land due to poor permeability of the ground and land exposed to river flooding are

restricting land use. In high-slope land configurations flood erosion directly threatens soil conservation. On the other hand surface water availability is favourable from the point of view of irrigation and corresponding upgrading of land productivity. In any case water conservation is important for many countries and water quality could be endangered by extensive utilization of fertilizers and pesticides.

Activities involved:

-- Hydrology of surface waters from the standpoint of:

- Seasonal water availability and uses;
- Water quality;
- Tendency for flooding.

-- Regional classification of available land from the point of view of:

- Permanent overmoisture,
- Seasonal overmoisture,
- Flooding,
- Soil conservation due to erosion,
- Potential for irrigation,
- Exposure of ground water to chemical pollution.

1.1.5 Potential Bioproductivity

For a given culture, or family of cultures, potential plant productivity depends on the solar radiation, climatic and soil conditions. Potential bioproductivity could be limited by land configuration as well as chemical, mechanical or hydrological degradation. It could be improved by the availability of water irrigation. Actual productivity depends on the degree of cultivation, directly related to energy, labour and capital input. Comparison of actual and potential productivity is a measure of land use efficiency.

Activities involved:

- Regionalization of the territory in areas having similar solar radiation and climatic conditions.

- *Land categorization with respect to soil conditions, land configuration, chemical, mechanical and hydrological degradation.*

- *Review of different existing methods for the evaluation of potential bioproductivity aiming at choosing a particular method most suitable for the predominant climatic conditions.*

- *Evaluation of potential bioproductivity in each region and land category for forests, pastures and agriculture.*

1.2 POTENTIAL FOR RENEWABLE ENERGY USE

1.2.1 Solar Energy

Direct use of solar radiation could be made for the supply of heat and even electricity in a number of agricultural and biomass processing activities. So far direct thermal utilization of solar energy is mostly made in greenhouses, including soil warming, drying of hay, fruits and grains and animal husbandry, including water heating. Solar photovoltaic electricity is potentially interesting for irrigation pumping, depending on the costs of photovoltaic modules.

Activities involved:

- Assessments of energy needs at present and in the future in the most promising areas of solar energy utilization in agriculture, such as: greenhouses, crop drying and animal husbandry as well as electricity needed for irrigation, especially in areas where electricity grid extension is necessary.

- Regional characteristics of solar radiation parameters necessary for the evaluation of solar energy utilization.

- Techno-economic evaluation of typical solar installations for most promising areas of utilization.

- Assessment of possible energy supply from solar energy which is economically justified.

- Programme of research and development activities aiming at wider solar energy utilization in biomass production and processing.

1.2.2 Wind Energy

Wind energy is already economically viable for the irrigation pumping and other electricity needs in certain areas.

Activities involved:

- Assessment of the wind energy potential, including collection of necessary data and regional mapping of wind energy or mean wind velocity.

- Technical and economic evaluation of typical wind power plants for irrigation pumping and electricity supply.

- Assessment of economically justified potential utilization of wind energy in different areas.

- Programme of exploratory and development activities.

1.2.3 Hydroenergy

Mini- and micro- hydropower plants could be very well adapted for the supply of electricity for rural areas if available hydro-potential exists, and especially in combination with irrigation schemes.

Activities involved:

- Assessment of the hydropotential of mini- and micro hydro power plants on existing rivers.

- Techno-economical evaluation of small hydropower plants.

- Assessment of economically justified potential for hydropower utilization in rural areas.

- Programme of exploratory and development activities.

1.2.4 Geothermal Energy

Low grade geothermal heat (below 60 to 80°C) is already being effectively utilized for agricultural purposes in a number of countries. Especially suitable for utilization are greenhouses, soil warming and drying of some crops. Economy of geothermal energy use depends on a number of source parameters, such as: temperature, depth, permeability, flow rate, etc. Most of these are difficult to estimate without extensive exploration efforts. Some kind of estimates are however necessary to justify these costly explorations.

Activities involved:

- Preliminary assessment and regional mapping of geothermal resources and their principal characteristics based on geological prospecting, natural geothermal sources and existing explorations.

- Techno-economical evaluation of different utilization schemes of geothermal waters in agriculture and animal husbandry depending on water quality.

- *Preliminary assessment of economically justified potential uses of geothermal energy on the regional basis.*

- *Programme of exploratory and development activities aiming at improved basis for the evaluation of potential geothermal energy uses.*

2. EXISTING BIOMASS PRODUCTION

The present biomass production in a given country is the result of the historical development, cultural and social conditions and the degree of development of the country. The assessment of the existing biomass production is necessary in order to compare it with the potential bioproductivity evaluated in the preceeding chapter. The subsequent analysis should be aiming at explaining the difference by the degree of introduction of modern agricultural, forestry and animal husbandry methods. It should also point out to the adequacy of the existing land use and the efficiency of the energy uses. Therefore, the analysis should be done on the regional basis corresponding to climateic regions and land categories established earlier.

In all areas of biomass production a large amount of residues is left over unused or more or less inadequately used. Roughly the amount of residues is equal to the amount of biomass used for food or industrial raw material. Therefore, the importance of the assessment of different residues and the adequacy of their use at the present. It is believed that improvements in use of residues and wastes could result in appreciable increase in useful biomass providing also an additional energy source often capable of substituting for deficient fossil fuels.

A rough estimate of the present uses of produced biomass for food, industrial raw material and as an energy source, as well as how much this production satisfies existing needs is necessary in order to assess the importance of the improvements in biomass production for the national economy.

2.1 CROP FARMING

Analysis of the present crop production is necessary for the assessment of potential improvements through:

- *adequate land use;*
- *increased productivity;*
- *energy economy; and*
- *potential use of residues and wastes.*

It is therefore important to collect and analyse available information on a regional basis on: crop cultures raised on different land categories; their corresponding yields in function of climatic conditions and the application of fertilizers, pesticides, irrigation, greenhouses, etc; direct and indirect energy inputs; and the priduction and present utilization of wastes. On the basis of the information collected an adequate data bank should be established in the frame of complex information system.

2.1.1 Land Use

Activities involved:

- For different land categories and climatic regions defined earlier (Ch. 1.1.5) collect information on land area cultivated by principal crop groups:

- *cereals;*
- *vegetables;*
- *fruits;*
- *industrial plants;*
- *animal-feed crops;*

as well as by principal crop cultures cultivated inside groups. Also information on average land-piece areas are necessary. Special attention should be given to land areas on which catch crops and mixed crops are grown.

- In addition collect information on land area:

- *irrigated;*
- *under green-houses.*

2.1.2 Plant Productivity

Activities involved:

For given land categories and climatic regions, and principal plant cultures collect information on:

- Average, maximum and minimum crop yields per unit land area, depending on climatic conditions, and with particular attention to mixed cropping and catch crop growing;

- Commentary on the influence of selection and breeding on average yields of different crops;

- Use of different fertilizers and pesticides per unit area;

- Average quantity of residues and wastes per unit area as well as their quality, energy content and possible uses;

- Different agricultural machinery and their average use per year and per unit area;

- Crop yields in greenhouses and corresponding energy supply;

- Application of crop drying and corresponding energy supply.

2.1.3 Energy Analysis

Activities involved:

- Development of the adequate methodology of energy analysis for different crop groups as well as for the application of irrigation, green-houses and crop drying. The analysis should include not only direct energy consumption in fuels for machine drive, heating, and electricity, but also indirect energy consumption in fertilizers and chemicals as well as in machinery and buildings. Two levels of analysis are involved - a detailed analysis of a number of different typical large farms as well as a simplified analysis for principal crop cultures.

- Choice of a number of typical large farms on which methodology is being tested and preliminary data obtained.

- Preliminary energy analysis of principal crop cultures involved.

- Preliminary energy analysis of irrigation systems, green houses and crop drying.

2.2 LIVESTOCK BREEDING AND FISHERIES

Analysis of the present situation in livestock breeding and fisheries is interesting from the point of view of land use, assurance of animal feed, biomass productivity, energy economy and possible uses os animal wastes. For this it is necessary to collect, sort and analyse information on animal feeding, animal husbandry, fisheries, product yields and available wastes. Data collected should form a part of a data bank to be used in complex information systems.

2.2.1 Land Use

Activities involved:

- Determination of land areas for pastures in different land categories and different regions defined earlier with the assessment of yields and quality of biomass produced.

- Determination of land areas under natural waters and artificial fisheries with corresponding catch of different fishes and other biomass, and equipment use.

2.2.2 Animal Husbandry and Fisheries

Activities involved:

- Regional distribution of number and structure of principal livestock (cattle, pigs, sheep, poultry, horses, etc) with the corresponding annual production of food and wastes, waste uses, consumption of different animal feed and definition of the type of shelter.

- Commentary on the influence of selection and breeding on production.

- Regional characterization of livestock farms with respect to the number of animals with the inventory of large animal farm complexes.

- Regional characterization of artificial fisheries.

2.2.3 Energy Analysis

Activities involved:

- Development of appropriate methodology of energy analysis as applied to different livestock breeding in small and large farms, including direct and indirect energy consumption and potential use of wastes.

- Application of the methodology on the level of typical large farms as well as on the principal livestock breeding.

- Energy analysis of large fisheries.

2.3 FORESTRY

By far the largest amount of biomass is in forests. Biomass productivity in forests differ very much over the world, even for the same type of forest, and not only because of the different climatic conditions but often because of the inadequate forest maintenance, as well. Forest biomass is already important industrial raw material. However, a large part is being used as energy source, very often inefficiently. Careless deforestation is also taking place in some countries, with adverse effects to ecology and soil conservation. Finally, large amount of biomass is left unused in form of forest and wood residues.

Analysis of the present forest biomass inventory and productivity is important for the assessment of adequate land use, improved productivity, energy economy and potential use of residues.

2.3.1 Land Use

For the given land categories and climatic regions defined earlier activities involved include:

- Inventory of forest biomass by major types of forests and principal forest cultures including not only large forests but also small private woodlands. The inventory should provide land areas under different forest cover as well as the estimate of the standing biomass.

- Inventory of the land under forest cover from the point of view of land ownership, average areas of the woodlands and final use of produced wood.

- Commentary on the state of maintenance of the different types of forests.

- Inventory of the unused land, land under bushes and shrubs as well as land which is being used inadequately and would be better used under the forest cover.

2.3.2 Productivity of Forests

For given land categories and climatic regions activities involved include collection of available information on:

- Average annual biomass being cut for different types of forests in function of the adequacy of forest maintenance. Care should be taken to define the quality of wood cut from the point of view of wood parts (stem and other), moisture and energy content.

- Amounts of forest biomass being used for different purposes (lumber, pulp and paper, fuelwood etc.). Care should be taken to include fuelwood cut in small private woodlands, as well.

- Average amount of forest residues (tops, branches, stumps, roots) for different types of forest with the commentary on the use of these residues for different purposes (including thinnings).

- Use of different machinery for forest exploitation and transport.

2.3.3 Energy Analysis

Activities involved should provide for a complete mass and energy balance of forest biomass from forest to different final uses as well as for a rough energy analysis of forest exploitation including direct and indirect energy supply.

- Evaluation of energy content of different forest biomass products for different types of forests (stems, residues, etc).

- Regional and overall balance of forest biomass uses in mass and energy units.

- Energy analysis of forest exploitation.

2.4 FINAL USES OF BIOMASS

Raw biomass produced normally undergoes complex processing in food industry before being used as food. In some countries, however, at least a part of the production is being used directly without further processing. Some industries, such as wood-industry and pulp and paper industry, depend entirely on biomass while in others biomass represents an appreciable part of raw material supply. On the other hand biomass production and processing depend on the supply of energy, chemicals and machinery. The whole complex of biomass processing for final use is mostly outside the scope of the present analysis. However,at least a rough assessment and simplified analysis of principal routes of biomass processing is essential for a number of reasons.

First af all it is necessary to evaluate nutrition quality and dietary energy supply of the population as well as to which extent needs in food supply could be met by existing indigenous biomass production. This goes also for the principal industrial products depending in raw materials from the biomass production. On the orher hand it is important to know to which extent indigenous biomass production depends on the import of fertilizers, fuels and mechinery with the corresponding influence on the national economy. Finally, at least simplified overall energy and matter balances of biomass production and processing are important from the point of view of the assessment of biomass being left unused, as residues and wastes, as well as of the efficiency of energy uses.

2.4.1 Food

Activities involved:

- Food consumption

Special attention should be given to the consumption of different food commodities per capita and corresponding dietary energy supply and nutrition quality.Of special interest is also proportion of unprocessed food supply as well as import and export of different food commodities.

- Food processing

Attention should be given to biomass and energy input, end product output and amount of residues and wastes in princi-

pal food industries. Of interest are also quality and possible uses of residues and wastes as well as a simplified energy analysis in principal industries.

- Animal feed: supply and processing

Attention should be given to direct use of raw biomass for animal feed as well as biomass and energy inputs, end product output and amount of residues and wastes in biomass processing. Of interest are also import and export of animal feed.

2.4.2 Industrial Commodities

Acitivities involved should be concerned with the evaluation of biomass and energy inputs, end product outputs and amounts of corresponding residues and wastes in principal industries depending on biomass as raw material. Of special interest are wood, pulp and paper, textile, farmacentical and some chemical industries. Quality and the present uses of residues and wastes and simplified energy analysis are also of interest.

2.4.3 Energy

Attention should be given to:

- Direct use of biomass and residues for energy supply

Activities should be aimed at the evaluation of fuelwood, forest and agricultural wastes for the energy supply including the ways and efficiencies of the utilization.

- Supply of fertilizers and chemicals

Activities should provide for the evaluation of consumption of different fertilizers, pesticides and herbicides, ways of supply as well as energy costs of these commodities

3. POSSIBILITIES FOR INCREASED BIOMASS PRODUCTION

Increased biomass production for the given land area could be achieved either through better land use or by improved biomass productivity. The task involves efficient management of available resources, application of new techniques and usually increased direct and indirect energy input. It is therefore necessary to consider energy economy together with possible means of increased biomass production.

The aim of this part of the study is to:

i) Review possible means of increased biomass production, appropriate for the given land, currently being applied or developed in the world, in view of expected yields and corresponding energy costs, as well as of necessary development efforts involved.

ii) Review corresponding research and development efforts currently active in the country as well as indigenous potential for starting new development activities.

iii) Propose a priority programme of medium and long term research and development activities leading to increased biomass production, substantiated by expected gains and corresponding costs.

3.1 IMPROVED LAND USE

Previous analysis provided for an appraisal of the present land use and corresponding biomass yields. Some of the land is left unused due to overmoisture, flooding, errosion or degradation. This land could be made useful through appropriate land reclamation. Some land is inadequately used due to lack of water or adverse environmental effects and its productivity could be increased through irrigation or adequate environmental control. Yet another part of land is inadequately used due to inefficient cultivation methods or inappropriate cultures being grown. It is necessary to identify all inadequately used land, propose appropriate means of increased biomass production and evaluate corresponding investments and energy costs.

3.1.1 Land Reclamation

Activities in question involve identification of land that could be made arable by adequate means evaluate expected biomass production and corresponding costs. In particular it is necessary to consider:

- Drainage of permanetly and/or seasonally overmoistured land;
- Flood control;
- Prevention of soil errosion.

3.1.2 Environmental Control

Inadequate water supply could be controlled by appropriate water conservation and irrigation, wind errosion, withering or other adverse effects could be controlled by windbreaks or shelter trees and in some cases soil warming could lead to better land use. Raising biomass under greenhouses comes also in this category.

Activities involved:

- Identify land susceptible to improved biomass production through application of:
  - water conservation methods;
  - irrigation;

- wind control;
- soil warming.

- Apply appropriate energy analysis and evaluate expected biomass yields from such land with corresponding investment and energy costs, taking into consideration possibilities of renewable energy supply.

- Analyse possibilities of wider application of greenhouses through appropriate energy analysis, taking into consideration possibilities of renewable energy uses.

3.1.3 Crop Management

By tradiation some crops are grown on inadequate land or in inadequate climate while some other crops could produce better yields and therefore improve land use. Land use could often be considerably improved by growing catch crops in afterseason or growing mixed cultures on the same land. Such opportunities should be identified and evaluated.

Activities involved:

- Identify land areas on which inadequate crops are grown, propose crop replacement and evaluate improved land use.

- Identify land areas susceptible to growing but not growing catch crops and evaluate possible improvements in biomass production.

- Review present practice of mixed cropping, identify and evaluate possibilities of its wider application and corresponding effects on land use.

3.2 IMPROVED BIOMASS PRODUCTIVITY

Plant selection and breeding has already provided for appreciable increase in biomass production and in particular in food production throughout the world. Rapid development of biotechnology opens wide new possibilities in this area through genetic engineering, in-vitro techniques, etc. However, basis understanding of fundamental processes, such as photosynthesis and plant physiology, necessary for the definition of goals to be achieved by breeding and biotechnology is still unsatisfactory and requires increased research efforts. This includes understanding of the response of plants to different environmental influences and behaviour of plants in communities in the fields.

In all these areas it is necessary to:

- Review main directions of research and development and principal results expected or achieved so far on the global scale.
- Evaluate areas of special interest for the land and climate conditions in question and identify principal activities already existing as well as existing manpower and equipment resources on the basis of which new activities could be initiated.
- On the basis of these evaluations propose a research and development medium and long range programme with corresponding requirements in researchs and funds.

3.2.1 Basic Physiological Processes

Particular attention should be given to:

- Photosynthesis

Activities involved concern photosynthetic activity in plants and its relations to environmental factors as well as to differencies in CO_2 formation among species and varieties (C_4, C_3 and CAM types) with the aim of possible improvements of photosynthetic activities in plants by breeding or genetic engineering.

- Plant physiology

Activities involved concern physiological mechanisms of translocation, conversion and accumulation of photosynthate in plants with the aim of obtaining higher yields of a certain crop organ as well as of increasing the amount of useful components converted into sugar, lipid or protein.

- Crop adaptibility to the environment

Difference in growth environment affects solar energy conversion efficiency of a plant as much as the difference in species. Activities involved concern physiological and ecological response mechanism of plants against the environment, particularly temperature, with the aim of enhancing plant adaptability.

3.2.2 Selection and Breeding

Activities involved:

- Conventional selection and breeding

Inventory of the present efforts in the region including research teams and equipment and the evaluation of the results achieved, in particular as it concerns different crops, percentage of harvested crop involved as well as programmes for the future and expected results.

- Genetic engineering

Review of the activities in the world with expected results and possibilities of application of particular techniques in the region on the basis of existing research and development potential.

3.2.3 Productivity of Plant Populations

Activities involved concers:

- Productivity of plants in the field

Due to density effects of the plants in populations and their dimensional arrangements of leaves as well as effects of soil moisture and temperature the difference in growth exists in function of the geometrical structure. Activities involved include a review of activities in the world concerned with the flow of energy and matters in different crop populations as well as of the related existing or potential activity in the region.

- *In-vitro techniques*

Lately in-vitro techniques have produced spectacular results with some kind of plants. A review of this activity in the world and in the country should be made giving results achieved and expected and a possible development programme.

3.3 ENERGY ECONOMY

Land reclamation and environmental control aiming at better land use usually involve large energy inputs. Productivity of the available land depends on plant productivity but only under the condition that sufficient nutrients are available and that adequate land cultivation is applied. These processes are directly energy dependent. Finally, much of what is gained through better use and improved plant productivity could be lost if adequate post-harvest technology is not applied to conserve harvested crops. Post-harvest technologies, mostly drying, is also energy intensive.

Thus, sufficient energy supply is prerequisite for the increased biomass production. Moreover, by far the most of the energy supply is required in form of deficient, usually imported hydrocarbons for fertilizers and engine fuel. Adequate efforts should be put therefore in the areas of energy conservation and substitution of deficient hydrocarbons by available, indigenous renewable energy sources.

The activities involved should therefore provide for:

- Evaluation of possibilities of energy economy in most energy-intensive processes and technologies.

- Evaluation of possibilities of substitution of deficient hydrocarbons by indigenous renewable energy sources.

In this respect following areas are of particular interest:

3.3.1 Fertilizers and Chemicals

Increased crop yields are closely linked to nutrient (NPK) supply by fertilizers. As a consequence a substantial part of the energy input in modern agriculture comes indirectly through uses of fertilizers as well as pesticides. A part of necessary nutrients is provided from the residues left in the field or from animal manure, which could be also utilized for other purposes by adequate processing. Different kind of fertilizers are needed (nitrogen, phosphorus, potassium), the

production of which is energy intensive to a different degree, mostly relying on energy supply on petroleum products. A better management of fertilizer supply as well as substitution of petroleum products by other sources could improve energy economy.

Activities involved should include:

- Analysis of the present use of biomass residues and wastes for the supply of nutrients, including biotechnological means for improved efficiency of such utilization.

- Analysis of the present use of artificial fertilizers and chemicals, aiming at adequate management and possible substitution of deficient raw materials for their production.

3.3.2 Biological Nitrogen Fixation

Nitrogen is an indispensible nutrient in biomass production supplied by an appreciable part by energy intensive nitrogen fertilizers. Nitrogen could be supplied also by nitrogen-fixing microorganisms. Curtailment of artificial fertilizer consumtion through efficient use of biologically fixed nitrogen by microorganisms is therefore greatly improving energy economy. However, biological nitrogen fixation is still in development stage.

Activities involved should include a review of related development in the world leading to a research and development programme aiming at the understanding of the interrelation between microorganisms and plants as well as at the increase in nitrogen-fixing capacity of microorganisms by biotechnological means.

3.3.3 Soil Preparation

Most of the direct energy input into agriculture is used in fuelling various machinery and in particular tracktors for soil preparation. Activities involved are aimed at the evaluation of number and size of different machinery, efficiency of their use and corresponding fuel consumption per unit area of arable land. An analysis of the rational use of machinery should follow. In particular a review of advanced, less energy intensive

methods of soil preparation should be provided with corresponding suggestions on the possibilities of their development and utilization.

3.3.4 Post-Harvest Technology

An appreciable amount of energy is used in agricultural product conservation and in particular in drying. An evaluation of the extent of post-harvest technologies employed with corresponding energy analysis is of interest. Proposals concerned with energy conservation and substitution of deficient energy sources by renewable energies leading to wider and more efficient use of post-harvest technologies should follow.

4. POTENTIAL BIOMASS RESOURCES

A large part of the biomass produced is left unused. This goes for all kinds of agricultural and forest residues, animal and municipal waste as well as for residues and wastes of various industries, in particular food-processing, wood and paper industries. Residues and wastes still have useful nutrient and energy content and at the present state of economy represent a large potential of biomass which could be processed and used. Problems of their use come from inappropriate knowledge of energy and nutritional characteristics of this biomass as well as from still not well developed means of their collection and processing.

Changing trends in the world economy, marked by the necessity of reliance on indigenous and renewable resources, influence the objectives of the biomass production from principally a source of food and a limited number of non-food commodities to a more complex utilization for food, energy and raw materials. Some plant and forest cultures being so far neglected gain in importance with this change in objectives. Therefore a need of revalorization of some alternative biomass production such as energy plantations or for other purposes. Again, problems arise with insufficient experience in cultivation, harvesting and processing.

The objectives of this part of the study are to:

- Identify all significant biomass residues and wastes, evaluate their nutrient and energy content and assess possible collection methods.

- Examine possibilities of raising alternative crop and forest species contributing to a better available land use through a complex utilization for food, energy and raw materials.

4.1 RESIDUES AND WASTES

Residues and wastes amount to as much as 50% of the produced biomass and therefore represent a large potential resource for processing into useful products. Some of the residues are already being used as animal feed, fertilizer or energy source. However, this is mostly done in a traditional way and often inefficiently so that reevaluation of the uses could lead to better economy. Still, a large part is left unused so that efficient ways of collection and processing have to be developed and are being developed in many countries. These developments being costly a careful economic evaluation of different possibilities has to be performed on the basis of nutrient and energy content as well as the value of end products to be obtained.

Activities involved should concentrate on:

- Inventory of all agricultural and forestry residues as well as animal, municipal and industrial wastes on the basis of evaluations in preceeding chapters with the assessment of their nutrient and energy content.

- Evaluation of the efficiency of the present uses of residues and wastes.

- Assessment of the economy of different ways of collecting and transporting residues and wastes for the final processing.

Categories of residues and wastes to be considered are given below.

4.1.1 Forest Residues

Tops, bark, roots and wood-shavings are often left over after stems are taken away. Residues of forest thinnings are in the same category as well as residues of fruit-yards and vineyards. Amounts of these residues have to be evaluated together with their corresponding quality and efficient ways of collection and transport have to be assessed.

4.1.2 Agricultural Residues

Post-harvest residues in the production of cereals, vegetables, fruits amd wines have an appreciable nutrient and energy content. A part of these residues is left over on the fields retaining some nutrients to the soil. Ancther part is used in animal husbandry as feed or filler. Yet another part is used as an energy source in rural areas. These traditional ways of utilization have to be re-evaluated. Quantities and quality of different residues have to be assessed and corresponding ways of collection and transport have to be evaluated from technical and economical standpoint.

4.1.3 Opportunity Crops

Appreciable land areas of some countries, mostly in arid regions, are covered with natural vegetation in form of bracken, shrub, weed or reed. Due to their energy content attempts in some countries are being made at their utilization or even enhancement of their productivity. An inventory of such natural vegetation has to be made together with the evaluation of the corresponding energy content and possible ways of collection and transport.

4.1.4 Animal Waste

Wastes in animal husbandry, especially in large cattle, pig and poultry farms, contain appreciable amount of nutrients and energy. In addition this waste often presents serious environmental problems. A part of this waste is being used as fertilizers. These ways have to be reconsidered from environmental point of view. Available amounts and quality of wastes have to be evaluated for principal sorts of animals with due consideration of the size of farms.

4.1.5 Wood and Paper Industry Residues

An appreciable part of residues in these industries is being used in many countries as raw material for further processing or as an energy source. These uses have to be evaluated

from the efficiency standpoint. Amounts and qualities of all residues have to be evaluated.

4.1.6 Alimentary Industry Residues and Waste

Residues in these industries have usually high nutrient and energy contents. Some parts of these residues are being used for further processing or as animal feed. Amounts and quality of residues and wastes have to be evaluated together with the existing ways of utilization at the present.

4.1.7 Other Industrial Wastes

Wastes in some other industries may also have appreciable nutrient or energy content. Wastes in some industries represent considerable environmental hazard and corresponding sewage has to be treated before disposal. Lately, biotechnological ways of treatment with corresponding output of energy rich gases are being employed. Potential resources in waste or waste treatment of principal industries have to be evaluated for possible use.

4.1.8 Municipal Waste

Large amounts of biomass are found in solid municipal waste. In case of sewage biotechnological treatment is being employed more and more. Corresponding amounts of waste and their energy content have to be evaluated for the large municipalities and existing as well as possible ways of use assessed.

4.2 ALTERNATIVE BIOMASS PLANTATIONS

In some cases biomass resources from specially grown energy plantations could be used for substitution of fossil fuel. Plants grown for energy purposes require different characteristics than plants grown for human or animal food or industrial raw material. This leads to interest in alternative species which so far have not be cultivated on a larger scale so that experience has got to be gained.

Special interest exists for the biomass obtained from algal and other aquatic plants, not only for the energy supply but also for the supply of food and industrial raw material. This interest comes from theunusuallyhigh productivity of aquatic plants which is several times higher than in case of other plants. The experience with growing such plants is still modest.

The aim of this part of the study is therefore:

- Inventory of alternative plants being investigated in the world capable of being cultivated in the climatic conditions of the country in question with the identification of available land areas for their cultivation, preferably unsuitable for other purposes.

- Review of the present state of the art in the development of plantations of the plants identified as suitable from the standpoint of expected yield and quality of products.

- Evaluation of cultivation and harvesting means from the technical and economic standpoint.

Special attention should be given to plantations of the plants listed below.

4.2.1 Forest Plantations

Plants in question should have considerably shorter rotation period than conventional forests while having interesting enough energy content. They are usually divided into two groups:

- Single stem
- Coppice trees such as poplar, birch, larch, salix, etc.

Special attention should be given to required soil conditions, water and nutrients as well as to procedures of cutting and collection of biomass.

4.2.2 Sugar and Starch Crops

Some plants of this kind, traditionally grown for food - such as sugar cane, sugar beat or corn - have been used in some countries to obtain alcohols as substitute engine fuel. In such cases there is always the question of food versus fuel. In other countries less traditional plants such as turnip, sweet sorghum, chicory or Jerusalem artichoke are being investigated for the production of liquid fuel. In some cases mixed use for fuel as well as [illegible] food is being considered. An inventory of all such crops should be made giving expected yields under the climatic conditions in question.

4.2.3 Oil and Hydrocarbon Plants

Vegetable oil from some traditional or less traditional crops such as sunflower, soybeans, rape, etc., could be used as substitute for diesel engine fuel after appropriate thermochemical treatment. Some less traditional plants are capable of producing some hydrocarbons, such as latex, which could also be used as fuel substitute (Euphorbia). An inventory of such crops should be made with the evaluation of coresponding yields under the given climatic conditions.

4.2.4 Aquatic Plants

Some marine and freshwater aquatic plants, such as micro- and macro- algae, seaweeds and even reed, are capable of producing yields of biomass which are several times greater than in other crops. Interest in such plants comes also from the fact that land areas under water, normally unused, could be used for biomass production. In case of macroalgae biomass production in waste waters or warm efluent waters is advantageous so that double goal is achieved. An inventory of aquatic plants capable of producing interesting yields in available waters should be made.

5. BIOMASS PROCESSING

Conventional processing of biomass for food in alimentary industries or for non-food commodities in other industries such as wood or paper industry is outside the scope of this study.

This part of the study is concerned with:

- Processing of potential biomass described in the proceeding chapter;

- Non-conventional processing of biomass aiming at a complex utilization for food, energy and raw materials; or

- Processing of biomass for energy in form of heat or substitute for solid, liquid or gaseous fossil fuels.

Traditionally there are two ways of processing biomass for the above purposes: thermochemical or dry, processing and biotechnological or wet processing. Lately progress in biotechnology has led to new ways of processing in which solar energy is more or less directly converted into useful end products, sometimes called Solar Biotechnology.

Generally speaking thermochemical processing is done with the aim of obtaining energy in form of heat or fuel. However, methanol, as a possible end product could be used also as a feedstock for chemical industry. In case of biotechnological processing energy is usually only one of the end products, other end products being useful as food, fertilizers or industrial raw material. Solar biotechnology, or direct photobioconversion is more open as end products are concerned and could be designed in principle to satisfy any given goal.

Analysis in this part of the study should provide:

- A review of biomass conversion processes being developed in the world and in the country with corresponding definition of input biomass, end product quality, energy balance and costs involved.

- *A selection of biomass processing routes in principle promising for the conditions in the country in question.*

- *A coresponding programme of necessary research and development efforts needed to implement technologies in question.*

5.1 THERMOCHEMICAL CONVERSIONS

Wood and different forest, agricultural, wood industry and municipal solid residues and waste could be directly burnt in stoves and furnaces to produce heat for various uses. Alternatively, they could be converted by different thermochemical means into upgraded fuels: solid (charcoal), gaseous (producer and synthesis gas, pyrolysis gas) or liquid (bio-oil, methanol, phenols, heavy oils) for subsequent use either in furnaces or for the production of mechanical energy in engines (gas engines, methanol). Some liquid products could be used as chemical feedstock. Vegetable oils could also be used as substitutes for liquid fuels, after some thermomechanical treatment. These thermomechanical processes are in different stages of development and practical use. Some traditional processes such as burning of fuelwood or some agricultural residues, have been in use for a long time, usually with low efficiency. Some of them are in advanced stages of development while the other are only in the laboratory stage.

It is necessary to review states of the art in all promissing processes and to evaluate all necessary parameters for subsequent economic assessment. It is also important to establish the extent to which different processes are already being used in the region as well as to assess research, development and industrial basis for the development of these processes.

Thermochemical conversion processes of interest are given below.

5.1.1 Direct Combustion

Biomass residues include fuelwood from natural forests and forest plantations; forest, agricultural and wood-industry residues and municipal solid waste. Processes involved include mechanical pretreatment (compacting, pellets, briquettes) and furnaces for different uses. Special attention should be given to the evaluation of the efficiency of traditional uses in stoves and furnaces and possibilities of their improvement.

5.1.2 Gasification

Gasification of relatively dry wood or lignocellulotic material could be performed with air in which case low-BTU gas is obtained, or with oxigen with the synthesis gas as the end product. In case of gasification with air special care should be given to the elimination of tar (counter current design) if the gas is used in gas engines for mechanical drive or electricity production. Synthesis gas could be further processed into methanol. Advanced gasification methods include also catalyst gasification at short residence time.

5.1.3 Phyrolysis

Traditionally wood is processed by pyrolysis to obtain charcoal an upgraded fuel easier to transport which could be burned or gasified. Efficiency of traditional processing is low as liquid and gaseous by-products are not used. An evaluation of the extent and efficiency of traditional charcoal production has to be made.

Modern processing by pyrolysis of wood, straw and even rubbish, with moisture contents up to 50%, is done in kilns with the end products consisting of charcoal, pyrolysis or bio-oil which could be burnt and pyrolysis gas of medium BTU content.

5.1.4 Liquefaction

An interesting procedure for obtaining liquid fuel but also other raw chemicals from wood is wood liquefaction in the presence of hydrogen and a catalyst. In the integrated process cellulose yield sugars which could be further treated while lignin is depolymerized providing monophenols. Some other heavy fractions also appear as end products.

5.1.5 Vegetable Oil Derived Fuels

Vegetable oils could not be used directly as fuels. However with adequate processing by transesterification or catalytic cracking substitutes for diesel engine fuel could be obtained.

5.2 BIOLOGICAL CONVERSIONS

In biological conversions of biomass the principal role in the process is performed by microorganisms such as bacteria or yeasts.

Some biological conversions are as old as history, such as alcoholic fermentation. Alcohols obtained are used as beverage but have been used as engine fuel as well as industrial feedstock. For some time fermentation of biomass has been a main source for some organic acids necessary in the industry. With cheap oil petrochemicals have taken the market but with the rising oil prices there is a renewal of interest for alcohols as fuels and organic acids as chemicals obtained from biomass.

In the process of anaerobic fermentation or digestion the main product is methane rich gas called biogas. Interest in anaerobic digestion started with the possibilities of disposal of environmentally adverse organic waste. However, lately biogas became interesting as an alternative energy source esspecially as the residues in the conversion process could be used as fertilizers or processed into animal feed. Anaerobic fermentation is also a process esspecially suitable for the conversion of high moisture content biomass.

Fermentation, neither aerobic nor anaerobic, could not be applied to lignocellulosis materials such as wood or forest residues which represent the principal part of renewable biomass. Even agricultural residues are not sutable unless mixed with animal waste. However, with adequate pretreatment lignocellulosis material could be more susceptible to fermentation so that an appreciable research and development effort is oriented in this direction.

The activities involved should provide for a critical review of all processes being developed in the world and being of interest for processing of biomass available in the country. Corresponding technologies should be evaluated from the technical as well as economic standpoint. Of equal interest is to assess the extent of application of corresponding

technologies in the country as well as the existing research and development potential.

5.2.1 Biomethanation

Anaerobic digestion is a complex process in which dilution of urban, animal or other agricultural or agro-industry residues and waste are hydrolysed and then subjected to fermentation and methanogenesis by microorganisms. For each type of biomass input there is an optimum mixture of cultures of microorganisms to be developed and corresponding technological scheme to be applied. A high energy content gas obtained could be used as a heat source but also as an engine fuel. Liquid residues could be used as soil-conditioner with good fertilizer quality and solid residues could be used for further processing. All these ways have to be evaluated for different types of available inputs of biomass.

5.2.2 Alcohol Fermentation

Fermentation of sugar crops and molasses into ethil alcohol is a well established although somewhat energy intensive process mostly because of the energy required for distillation. Ethanol produced could be used as substitute for engine fuel but the process is of interest for only a few countries as the biomass resourse required is usually needed for food. Fermentation of starch crops like cereals, potato, etc., is also a well established process although with similar limitations regarding resources. In addition this process is even more energy intensive as hydrolysis pretreatment is required so that energy economy is marginal if by-products are not fully utilized. Continuous fermentation based on modern biotechnological procedures is advantageous in this respect while only in development. Some less traditional crops, like Jerusalem artichoke, involving butyl-acetone fermentation into acetone-butanol offer some advantages regarding non-competivness with food and better energy economy.

5.2.3 Fermentation of Lignocellulosic Materials

Lignocellulosic materials present a great interest as fermentation substrates for the production of substitute liquid fuels due to large resourses in biomass. There are, however, serious difficulties in their use for these purposes as pretreatment and hydrolysis techniques are necessary to decompose lignocellulosis into basic constituents before fermentation. Various mechanical, chemical and biochemical pretreatment procedures are employed before acid or enzymatic hydrolysis, or saccharification. Enzimatic hydrolysis is often employed lately, introducing novel biotechnological techniques like cell immobilization, as well. Solvent fractionation into cellulose, hemicellulose and lignin [illegible] aiming only partly at fermentation to alcohols but also at obtaining chemicals like furfural, phenol, etc. is also being used.

5.3 DIRECT BIOPHOTOCONVERSION

Biomass production available for processing by different techniques described previously is limited. Conventionally grown biomass due to its dependency on available arable land nutrients and rainfall and its limitations in low photosynthetic efficiency and climatic intermittency is at best capable of satisfying growing food and traditional material demand with only a small part of the production being available for conversions into energy and other deficient raw materials. Better utilization of residues and waste provides for additional raw biomass for processing, however, still not of the order required for instance for a renewable energy and raw material substitution on a large scale.

Biotechnology based on microbial photosynthesis, or Solar Biotechnology, opens possibilities of providing organic matter from minerals, CO_2 and solar energy on a scale to match large scale requirements in the future. Photosynthetic cells - plants, microalgae and photosynthetic bacteria - in especially designed photoreactors in controlled environment and supply of energy and materials -are capable of producing desired organic material in form of food, chemicals or energy, so far on a laboratory scale. Continous culture and immobilized cell techniques are being employed with different microalgae as well as phototrphic bacteria depending on the desired output. Close to theoretical maximum conversion efficiency is expected. At the present energy balances are usually less than one and the economy is such that only high value products, such as polysaccharides, are economically justified. However, there is a wide scope for the improvement of energy balance and economy with further research and development.

Activities involved should provide for a review of the state of the art and expected results in the world as well as in the country with corresponding recommendations of a research and development programme.

6. DATA BANKS AND SYSTEM ANALYSIS

There is no doubt that improvements in resourse management and the application of modern technologies, esspecially those based on developments in biotechnology, could result not only in the supply of more food, produced in a more rational way, but also in the production of energy, raw materials and even completely new products. As evidenced by preceeding chapters there are multiple ways to achieve these goals so that a decision making procedure has to be established. More often than not decisions are being made on the basis of qualitative or simplified evaluations which practice has to be avoided and replaced by appropriate system analysis.

There is no doubt, also, that positive results in the application of modern technologies could be achieved only through corresponding funding of research and development efforts, from the level of fundamental research to demonstration plants. There is a wide choice in development possibilities and only a limited amount of funds. It is, therefore, of utmost importance that the decisions are based on proper social and economic criteria, best available information and appropriate system analysis.

In the result of analysis under preceeding chapters of this study a great number of different data should be collected forming the initial basis for a corresponding Information System organized in a number of Data Banks. In general two types of data should be gathered together: data on resources and current biomass production and uses and data on different technologies dealing with the production and the processing of biomass, most of them being in the development stage . Collection of data in the first group has to be organized on a permanent basis. Data in the second group have to be permanently updated allowing for the input of new available information. The whole Information System has to be organized in such a way to make full use of available computational facilities in the country.

Analysis of the collected data should be made in accordance with the conterporary state of the art of system analysis. For this a framework of analytical tools has to be developed. The level of this analytical framework for decision making will depend on the country in question, complexity of the system in question and the availability of computational equipment and skilled personnel. However simple it should incorporate clear definition of goals and criteria as well as of all steps in process of decision making and should make use of best available information of technical as well as economic nature.

Full development of both the Information System and the Analytical Framework would require a lead time outside the time horizon of this study. However, the principal goal of the study being a first step towards a Program of Action, both systems should be developed to a stage allowing for first approximation decisions to be made.

Therefore, objectives of this part of the study would be:

- Conceptual design of the Information System with its development to a stage of handling data collected during the study.

- Conceptual design of the Analytical Framework and its development to a stage allowing for the decision making procedure aimed at the Draft Program of Action.

- Draft Program of Action tracing principal directions of research and development activities.

6.1 INFORMATION SYSTEM

Activities involved are concerned with the conceptual design of a complex Biomass Information System involving:

- collection and renewal of relevant data on a permanent basis; and
- Storage and sorting of information in corresponding data banks easily accessible for subsequent analysis.

Within the scope of this study Information System should be capable of handling all information gathered during the study so as to allow use of the data analysis. In addition a program of activities should be defined leading to the realization of the Biomass Information System in accordance with the conceptual design.

Information of interest could be grouped in the way given below.

6.1.1 Resources

Includes relevant data on a regional basis, on:

- Climate, solar radiation and other climatic data described in Ch. 1.1.1 and 1.1.2;
- Hydrology, data described in 1.1.4;
- Renewable sources of energy, data relevant to uses of solar, wind, hydro and geothermal energy as described in 1.2.

As all these data are usually collected and handled in already existing hydrometeorological services use of these data could be organized in forms of links with already existing systems.

However a special interest exists in a complex Land Resources system which would synthetize relevant data on available land, soil conditions, climate and resulting potential bioproductivity as described in Ch. 1.1 and in particular 1.1.5. The available territory should be divided in a given manner into a certain number of cells for each of which relevant data will be stored in the syster.

6.1.2 Production

Includes all relevant data on existing biomass production on a regional basis on:

- *crop farming (2.1),*
- *livestock breeding and fisheries (2.2),*
- *forestry (2.3), and*
- *final uses (2.4).*

These data are also usually collected and stored in corresponding services so that appropriate links could be organized.

Here again a special interest exists in a complex Land Use system, corresponding to the described Land Resources system, in which for each of the unit cells of the territory relevant production data could be stored for a given time horizon.

6.1.3 Production Technologies

Includes relevant technical and economic data on technologies leading to increased biomass production, needed for the evaluation of these technologies. These data should be permanently up-dated by acquisition of new information. These techniques could be grouped in the following way:

- *Land use, including land reclamation, environmental control, etc.;*
- *Land cultivation, including soil preparation, use of fertilizers and pesticides, etc.;*
- *Plan productivity, including selection and breeding, in-vitro techniques, etc.*

6.1.4 Biomass Processing

Two kinds of information are involved, those concerning nutrient and energy content as well as production costs of various biomass to be processed, including non-traditional cultures, residues and wastes, and those concerned with technical and economic data of possible processing technologies, necessary for their evaluation.

6.2 ANALYTICAL SYSTEM

A conceptual design should be provided of a framework of analytical tools needed in the process of evaluation of different available possibilities and subsequent decision making. The level and the complexity of this framework will depend on the existing situation in a given country. It should include:

- Prevision of future demands in food, non-food commodities and enery as a necessary basis for the definition of goals and evaluation criteria;
- Modelling of different systems, such as agriculture, agro-complex or energy, on different levels from the whole country to single large farms;
- Optimization and decision making procedures.

A development program leading to the realization of the Analytical System suitable for the country in question should be well defined. Within the scope of the study, however, it is necessary to arrive at certain decisions concerning future activities. Therefore, conceptual framework envisaged should be employed at a certain level in the process of decision making. Within this framework a certain number of analysis should be performed and the results presented.

6.3 PROGRAM OF ACTION

The final results of the study should be presented in the form of:

- Critical analysis of the present biomass production within the frame of existing potential resources and in comparison with advan[illegible] biomass production systems.
- Program of Action defining principal directions of possible developments and corresponding requirements in manpower, investments and research and development efforts.

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