DOE/RA/50316 - -T1
Attachment V

METHANOL PRODUCTION FROM EUCALYPTUS WOOD CHIPS

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The Florida Eucalyptus Energy Farm Environmental Impacts

MASTER

June 1982

Prepared by
Biomass Energy Systems, Inc.
Lakeland, Florida

For the
U.S. Department of Energy
Office of Alcohol Fuels
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METHANOL PRODUCTION FROM EUCALYPTUS WOOD CHIPS

Working Document 5

The Florida Eucalyptus Energy Farm - Environmental Impacts

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June 1982

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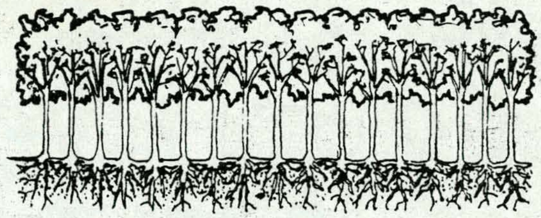
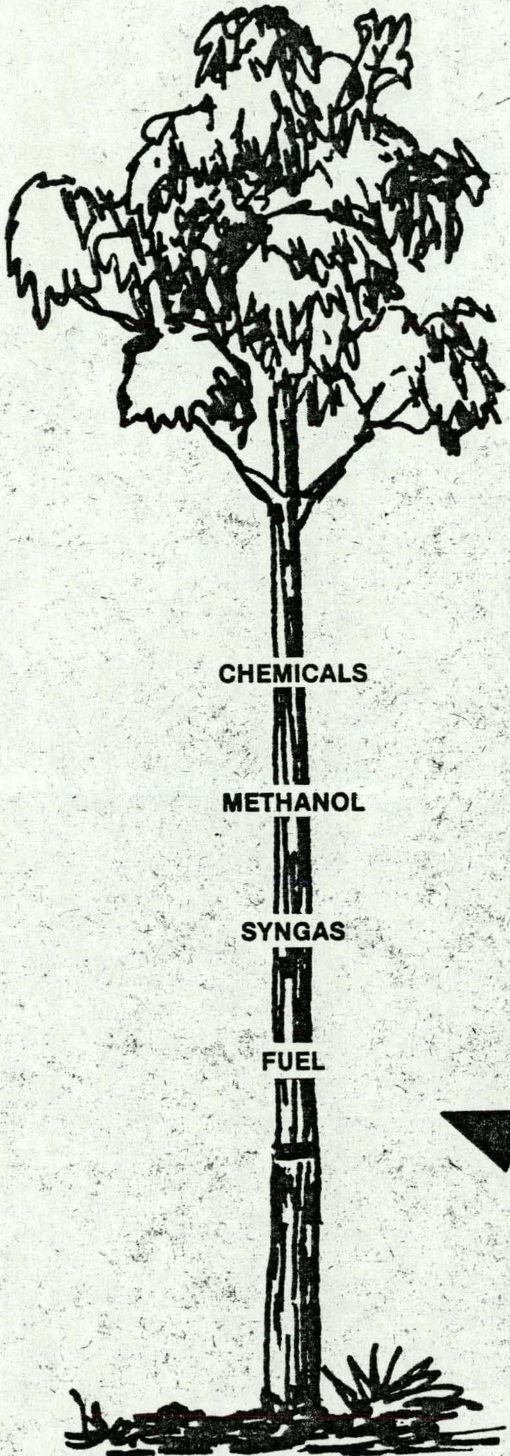
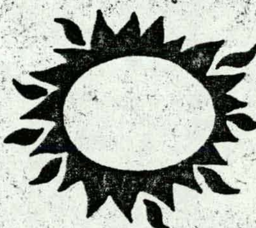
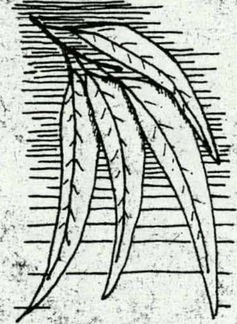




THE FLORIDA EUCALYPTUS ENERGY FARM--
ENVIRONMENTAL IMPACTS





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"HARVESTING RENEWABLE ENERGY RESOURCES NOW"

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1.0 INTRODUCTION AND OVERVIEW

Floridians have the opportunity to install a eucalyptus wood energy system in the regional environment south of Orlando which offers a viable alternative to the ongoing and planned expanded use of coal. Of all the alternative energy technologies, the wood biomass approach incorporates renewability, recycling of carbon, and relatively benign environmental impacts when compared to the fossil fuels. It will be necessary in the next few years for many of Florida's industrial and utility energy consumers to choose between coal and wood. We believe the environmental balance weighs heavily in favor of wood. As more coal is burned in Florida over the next decade, the air and water quality data will become available to document or refute our interpretation. Because we perceive the wood energy system is in direct competition with coal, we have frequently made comparisons between the coal and wood impacts on the environment. Since we are not experts on coal impacts, we have relied heavily on the literature and cited the sources relied upon for the conclusions reached.

There are many uncertainties in projecting the environmental impacts, even on the generic scale used herein, of both the eucalyptus energy forest and the methanol refinery. No one has installed a eucalyptus energy plantation of the type conceptualized by us; hence, there are no data available for analysis. Reasonably accurate extrapolations from our collective experience with silvicultural and agricultural ecosystems have formed the backbone of our analysis. Likewise, no modern wood to methanol plant is in operation. This points to the need for temporally staged environmental impact studies and expanded research as wood energy systems begin to come on line. We regard this current environmental assessment as no more than a beginning of an ongoing environmental assessment process. Knowledge is accumulating rapidly on the twin problems of acidification and carbon dioxide accumulation typically associated with increased consumption of fossil fuels. Better research is currently being done on possible silvicultural impacts. Knowledge about methanol use as an automotive fuel is advancing rapidly, as is wood gasification technology. Five years from now the data base will be much stronger and therefore will permit environmental impact assessments with increased credibility.

Biomass Energy Systems, Inc. (BESI) launched its wood-to-methanol project in 1980 on parallel tracks, assessing the feasibility of both a 100 MGY methanol refinery and a 100,000 acre eucalyptus energy plantation to provide an assured and constant feedstock for the methanol refinery. Changes in the world energy matrix rather suddenly have made wood fuel technology economically competitive with fossil fuels, especially coal and foreign petroleum distillates. Thus, what is new about today's wood biomass technology is the scale of wood fuel production necessary to meet exploding market demands.

Wood biomass energy is the most environmentally benign of all the large scale energy systems and has an ecological soundness absent from the fossil fuel systems. Fundamentally, it is a solar technology where the leaf is the collector of solar energy which it converts and stores in the form of cellulose via photosynthesis. Wood and its byproducts are converted into energy and conventional fuel equivalents by combustion, gasification, pyrolysis, methanol synthesis, fermentation, or a combination of these processes.

Biomass is a renewable resource. In a renewable, biomass energy system, there is no net release of carbon dioxide. That is, fuel is not taken from a carbon "sink". By the same token, nutrients and minerals to a major extent are recycled in the biomass energy system. Compared with nonsolar or nonrenewable energy systems based on fossil fuels, biomass production systems require less environmental control. Fortunately, wood offers more of the advantages of coal in terms of density and fuel value than most forms of biomass. Not only is the environment at less risk in the wood energy system, but so is the work force. Exposure to carcinogenic materials and toxic substances is far less when compared with coal and oil shale technologies.

Bioenergy programs must be designed to exploit the unique regional resource base. Because of the favorable climate and available lands, Florida south of Orlando is perhaps the most ideal region within the United States for creating a new, large scale wood energy system. Forest planting is a land use highly compatible with the increasing human population which characterizes Florida's growth. The "organic" appeal of a renewable energy source from trees should result in public and political support, in contrast to the negative attitudes widespread in Florida toward strip-mining, industrialization, and other high density developmental uses. Indeed, planting a million acres of eucalyptus energy forest on pastures, rangeland, and former flatwoods is a type of reforestation that would significantly enhance the regional environment, particularily in terms of water quantity and quality, air quality, and wildlife.

Establishment of additional woodlands is an environmentally desirable alternative to pasture and row crops, particularly on soils marginally suitable for agriculture. The installation of commercial wood fuel plantations is the only economically viable means of increasing forest acreage in the region. Although wood fuel plantations cannot compare with undisturbed native forests in biological values, they are ecologically benign compared to other more intensive land uses in Central and South Florida. In fact, fuel production forests still provide many of the benefits attributable to natural forest ecosystems--soil and water conservation, air quality improvement, climatic control, wildlife habitat, and esthetic and visual enhancement. Furthermore, wood fuel systems offset the adverse environmental effects of alternative fossil fuel systems.

The regional abundance of available and suitable lands is crucial to the development of a large scale, wood fuel system. There are well over a million acres of suitable land that might be converted to an energy plantation use. A commitment by landowners must occur before plantations can be established. Educating landowners to the exploding demand for wood fuel is necessary before they will incur the cost of installing the energy plantation. Most of the present land-uses are of a low intensity/profitability and will be easily displaced by uses with higher economic returns. The dominant present use is for cattle grazing, primarily cow/calf operations, an industry under severe economic stress.

On an ecospheric scale, man's continued release into the atmosphere from storage of carbon dioxide not now part of the global cycle, through the burning of fossil fuels, threatens to bring about catastrophic worldwide climatic changes. The continued ravages of acid rain cannot be sustained. Burning of sulfur containing fuels must be cut back. In a renewable biomass energy system, there is no net release of new carbon dioxide additive to the cycle. By the same token, nutrients and minerals are cycled from the energy farm to the gasification plant and then back to the energy farm or otherwise into the environment at large. Since wood contains a negligible quantity of sulfur, acid rain resulting from the release of sulfur oxides into the atmosphere will not be a problem in biomass energy systems. A flag of caution is the concern over the increase in particulate polycyclic organic matter associated with wood combustion.

Biomass Energy Systems, Inc. developed an interest in the wood to methanol technology in the belief that an increasing percentage of the nation's vehicular fleet will operate on methanol instead of gasoline. Methanol is used neat to fuel automobile engines, and as a gasoline additive to improve octane. Methanol currently is used as an octane booster in unleaded gasoline, a use that will expand rapidly in this decade. Methanol in the neat, undiluted form can be used in an internal combustion engine with relatively minor modifications. Methanol in automotive engines is extremely clean burning and is rated the preferred fuel by EPA (Pers. Comm.) among the field of all synthetic alternate fuels.

Fluid fossil fuels will remain either in critically short supply, or will be exceedingly costly in the foreseeable future. The biomass energy system represents a way of using solar energy to produce fuels, solid, liquid, and gaseous, which will displace a significant segment of fossil fuel consumption over the long term. One ton of green eucalyptus biomass is equal in equivalent Btu's to one barrel of #6 fuel oil. Most importantly, the wood biomass equivalent is renewable. We do not believe that the economic success of the eucalyptus energy plantations is linked in any way to the construction of a methanol refinery. A sufficiently large acreage of energy forest, capable of providing a sustained, dependable, and predictable yield, will prove attractive to most users presently dependent on coal, oil, and natural gas.

The purpose of this document is to assess the overall environmental impact of the eucalyptus to methanol energy system in Florida. It is not ment to be a site-specific environmental impact statement, but a generic description of positive and negative environmental impacts of the system. We shall consider the environmental impacts associated with the following steps of the process: (1) the greenhouse and laboratory; (2) the eucalyptus plantation; (3) transporting the mature logs; (4) the hammermill; and (5) the methanol synthesis plant. Next, we will compare the environmental effects of methanol as an undiluted motor fuel, methanol as a gasoline blend, and gasoline as motor fuels. Finally, we will compare the environmental effects of the eucalypt gasification/methanol synthesis system to the coal liquefaction and conversion system.

2.0 A GENERALIZED SCENARIO OF THE EUCALYPTUS-TO-METHANOL ENERGY SYSTEM

Biomass Energy Systems, Inc. vision is that of a eucalyptus energy plantation, with 871 trees to the acre, each a cloned replicate of a proven superior parent tree, growing in the Florida sunshine and rainfall, producing a yield of hardwood fuel which far exceeds man's experience with most other natural or planted forests. Some eucalypt species have an astonishing ability to convert sunlight, water, and nutrients into stored energy. Individual E. camaldulensis, the river redgum in Australia, planted on mined lands in Polk County have grown to 90 feet in height and 14 inches in diameter in less than seven years! One measured tree added 10% in volume during the winter months between December 1980 and March 1, 1981; a period of expected slow growth and cold temperatures. Our mensuration studies of this existing stand show a yield of 15 cubic meters per hectare per year, about one-sixth of the estimated potential production of intensively managed, cloned eucalypts planted on better sites under more favorable growing conditions. This ability of eucalypts to rapidly produce such a great volume of wood fuel with virtually no management costs between planting and harvest, makes them the outstanding candidate tree choice wherever the climate and environment permits.

Our data documenting the growth of a sample of select Eucalyptus camaldulensis trees in two plantations mined for phosphate, showed volumetric increases of 19% on sand tailings and 31% on overburden in the eighth year alone. Even to an experienced forester familiar with the voluminous eucalypt literature, this annual incremental growth increase is phenomenal! A one acre hypothetical stand of 522 of these super trees, vegetatively cloned by tissue culture propagation, on a site similar to the overburden plot, would have increased in wood fuel volume this past year by 80 green tons! While we don't predict real world yields of this magnitude now, we do believe 20 green tons per acre per year is a very conservative estimate of yield from clonally propagated trees in the 7th or 8th year planted on newly reclaimed, phosphate-mined lands. The same hypothetical stand of 522 of these actual select trees would have yielded 335 green tons per acre with a harvest at eight years. Few, if any, land uses can outcompete a renewable wood energy crop with potential yields like those demonstrated by the river redgum, growing in Polk County, especially if marketed as a fuel for its Btu content! This potential wood biomass productivity is at the very heart of the Biomass Energy Systems, Inc. scenario.

Florida plantings of eucalyptus are drawn from a very limited gene pool for most of the species planted. Florida plantations derived from seedlings have been characterized as "aces and spaces", in which many or most of the spaces are occupied by inferior trees. Vegetative propagation of the best parent trees available is necessary to provide a nearly uniform stand of high volume individual trees. Biomass Energy Systems, Inc. has perfected the laboratory techniques needed to mass produce plantlets cloned from superior parents by in vitro tissue culture propagation. We confidently predict minimum doubling of yield when clonal plantlets are used in place of seedlings. Seedlings of Florida grown Eucalyptus camaldulensis, the species we prefer and recommend, presently are not available in commercial quantities. Most mature individuals of E. camaldulensis in Florida fail to produce viable seeds. The use of clonal plantlets derived from superior parent trees is an essential element in the Biomass Energy Systems, Inc. scenario.

Genetically superior Eucalyptus plantlets will be cloned in the tissue culture laboratory and raised in greenhouses. These plantlets eventually will be installed on 100,000 acres of silvicultural biomass plantations in Central and South Florida at a rate of about 10,000 acres per year. After 6-8 years, the resulting mature trees will be harvested and transported to the hammermill. The mill and methanol plant might be an integral internal part of the plantation; or they might be as much as 50 miles distant. Coppice growth of the eucalypts will replace the harvested trees. Reworking the soil and planting new trees will occur once every 25-50 years. At the hammermill, the logs air-dried in the forest will be size-reduced to very small chips. The chips then will be converted into methanol by a Texaco gasification/methanol synthesis process yet to be tested in a pilot plant stage.

Conventional wood-fired boiler technology will power the hammermill and methanol synthesis plant. The wood feed, air dried to a 15-20% moisture content, will be injected into the Texaco gasifier, which will be operated at approximately 2,600°F and 800-1,000 psi in a nearly pure oxygen environment. The residence time of an average wood particle will be approximately eight seconds.

This high temperature and pressure eliminates the production of olefins, phenols, tars, and heavy metals. The relatively small amount of ash remaining will be returned to the plantation soil after each cutting.

The gasification process produces almost pure carbon monoxide (CO), carbon dioxide (CO_2), hydrogen gas (H_2) and some ash. Some trace of hydrogen sulfide gas (H_2S) may be produced. The H_2S will be "scrubbed out" and the CO_2 separated from the H_2 and CO by a standard Benfield process. The CO_2 may be vented or routed to a greenhouse to enhance growth of commercial plants.

The H_2 and CO will be combined in the proper ratios in the shift reactor to form methanol gas in the presence of a catalyst. The methanol gas will be condensed to form liquid methanol. Paul (1978) and Reed (1981) describe these processes in greater detail.

The liquid methanol then can be used as an automotive fuel or additive, in fuel mixes for industrial and electrical utility boilers, and as a feedstock for further chemical synthesis.

A portion of the eucalyptus wood produced can be expected to flow into markets other than methanol, such as pulp and paper manufacturing, residential heating, direct boiler feeds, gasification into a gas boiler feed, and as a feedstock in chemical processes. A decade from now, phosphate mining companies can be expected to cogenerate much of their electrical energy requirement from eucalyptus grown on their own lands. Therefore, Biomass Energy Systems, Inc. must own or control by lease enough eucalyptus plantation acreage to assure a feedstock supply for the methanol plant.

3.0 ENVIRONMENTAL EFFECTS OF THE LABORATORY AND GREENHOUSE

The primary direct impact of the tissue culture laboratory and greenhouse complex will be the physical occupancy of the land by structures, parking lots, plant beds, and associated facilities. A very large greenhouse complex is anticipated requiring 50-100 acres of land near the methanol plant site.

The primary purpose behind the greenhouse facility is to make a productive use of the excess CO_2 released by the methanol plant. The CO_2 enriched atmosphere within the greenhouse can produce increased out-of-season yields of high-value, specialized food and ornamental crops. Waste heat from the methanol plant likewise will be used to warm the greenhouses and laboratory when ambient temperatures require heating. Thus, the energy demands of these facilities will be minimal. Indeed, it is our intention to meet our electrical energy requirements with a wood-fired cogeneration facility, as well.

We do not expect the resource requirements and environmental impacts of the tissue culture laboratory and greenhouse complex to differ from numerous, similiar businesses now operating in Florida. When detailed plans are finalized, a more comprehensive assessment may be warranted. The water requirements of the greenhouse, for example, could be large. However, treated waste water from the methanol plant might be of sufficient quality and quantity to meet greenhouse irrigation needs.

Biomass Energy Systems, Inc. may contract with it's sister company, Clonal Resources, Inc., for all the eucalyptus plantlets required to install the energy forest. In this case, Biomass Energy Systems, Inc. would not build and operate a tissue culture laboratory. The conceptual planning now underway does not allow for other than a broad-brush treatment of these possible amendments to the primary scenario.

There are no anticipated, substantial adverse environment impacts from the tissue culture laboratory or greenhouse complex.

The use of pesticides, fertilizers, and other chemicals will be consistent with the state-of-the-art for the industry. All chemicals will be handled according to the manufacturer's specifications on the label and in the literature. All appropriate federal and state rules and regulations will be followed to safeguard the environment and protect the work force.

4.0 ENVIRONMENTAL IMPACTS OF THE EUCALYPTUS PLANTATION

4.1 Introduction. Silvicultural practices can have both positive and negative effects on the soils, wildlife, water quality, and other environmental components of both the forest ecosystem and adjacent lands. The magnitude of impacts in any situation depends almost entirely on management practices and on the physical characteristics of the site. Significantly, most negative impacts generally are short term and last only a few years, or less, over each rotational cycle, which in the case of eucalypts is at least 25 years.

Individual perceptual differences about forests, and particularly silvicultural forests, make an evaluation of the environmental effects of wood-for-energy plantations difficult. Obviously, those who view a forest mainly in terms of product output have different imperatives than those who find merit in both perspectives. Hence, it is likely that a wood-for-energy strategy that increases the areal extent or intensity of forestry management will promote a wide range of reactions - even if the physical impacts are fully predictable and if forecasts of these physical changes are credible to all parties (OTA, 1981).

Lack of impact assessment credibility, however, is commonplace and stems largely from the history of U. S. logging activities and the negative impact it has had on public perceptions of logging and silviculture. Reversing emotional bias concerning the establishment of eucalypt energy plantations in Florida may prove to be a more formidable task than actual stand establishment, since implementation, no matter how feasible, beneficial and economically sound, will languish without support. A fact largely unperceived by opponents is that biomass energy plantations can lessen harvesting pressures on wilderness areas and other more ecologically valuable natural forestlands; and, that eucalypt stands may have relatively short harvesting intervals (6-8 years) but long rotation periods (25-50 years), equaling or exceeding less productive softwood plantations in the Southeast.

The future of ecologically invaluable tropical forests will be determined by broad policy decisions on rural development, food production, energy, land use, and population growth. Principal direct causes of tropical forest loss are the intense and increasing needs of people seeking food, fuelwood, wood products and shelter. Underlying these needs are fundamental problems of unequal land tenure, lack of employment, lack of advanced agricultural methods and rapid population growth (Council on Environmental Qaulity, 1980). Biomass plantations, such as those envisioned by Biomass Energy Systems, Inc., can contribute to relieving the pressure on the Earth's natural forest treasures. Our biomass stands are to be established on mined lands, pasture lands, abandoned agricultural lands, and so-called "marginal" lands, with no contemplation of displacing Florida's existing wetland and hammock forests. The natural system damages to land, water, and living resources perpetrated by natural forest removal and cattle ranching, for example, are far greater than the potential impacts of establishing eucalyptus energy plantations on previously disturbed lands.

Enlightened biomass silvicultural practices aim to optimize yields while attempting to minimize the loss of biological diversity. For example, clear-cutting of the eucalypt plantations only will occur at 25 to 50 year intervals, except for initial site preparation, due to the advantages of repeated coppicing after harvests. Since eucalypt insect pests are few, integrated pest management can be implemented in place of pesticide spraying. Depending on specific site-preparation needs and because of economic realities, herbicide applications are not anticipated beyond establishment of the plantlet in the first months after planting. No reasons exist for discouraging wildlife from eucalypt plantations. We envision energy forests where wood fuel is the principal product, but where biological elements not inconsistent with biomass production are welcome and encouraged.

Based on intensive research of existing Florida eucalypt plantations and the realities of production through harvesting processes, there is no indication that our program will significantly contribute to the environmental problems of water availability, pollution, or topsoil or nutrient loss. Two years of continuous study allow a confident prediction that serious ecological impacts to the regional ecosystem will not be incurred. The biomass stands will not damage land and water resources through increased erosion, runoff of fertilizers, and chemical pesticides, or salination and waterlogging from large-scale irrigation. They will not reduce existing plant and animal ranges, increase risks to endangered species, or eliminate any ecological communities. In short, we predict no long-term or significant short-term adverse ecosystem impacts from biomass fuel production of E. camaldulensis in Central and South Florida.

4.2 Land Use. We propose the use of 100,000 acres for eucalyptus plantations. Therefore, the scale of land use conversion to eucalypt production will be relatively limited, especially compared to improved pasture and other agricultural land uses. Greater use of mill wastes offers land use benefits through the reduction of accumulated wastes. At some sites, waste materials deposited over many years now occupy large areas (Braunstein, et al., 1981) and the use of these wastes will allow more productive use of waste sites.

In most cases, the collection of forestry residues for energy use would cause no major change in land use (Braunstein, et al., 1981). But, land requirements for the eucalypt plantations will compete for other uses. Much of the land presently available in South and Central Florida is rangeland. In particular, pasture creation is associated with surface mine reclamation in Central Florida. This is a low intensity, low profitability use of the land, with minimal esthetic and wildlife values.

According to Salo, et al., (1977), land for silvicultural energy farms must satisfy three criteria: (1) it must be arable, (2) it must receive at lease 63.5 cm (25 in.) of precipitation per year, and (3) it must have gentle to moderate slopes (<30%).

Reclaimed phosphate mining areas and waste clay settling areas are foreseen as ideal for eucalypt plantations. They represent large, contiguous tracts of land which, in Florida, satisfy the above-described land criteria.

Intensive silvicultural farms will be linked to the methanol plant and the methanol plant will be provided with a continuous supply of eucalypt biomass feedstock. Land requirements of the eucalypt plantations will compete with other uses. However, much of the land presently available in the appropriate Florida district is in range and is marginally productive. There are vast areas of unreclaimed, strip mined land on which eucalyptus could be planted following reclamation. Strip mine overburden soils are particularly suited to eucalypt plantations (see Biomass Energy Systems, Inc. Working Document 1, Section 3.1). We perceive the future of the eucalyptus energy system to be closely linked with reclamation policy and the productive use of reclaimed lands following mining.

4.2.1 Cattle Vs. E. camaldulensis. By far the greatest single land use impact of the eucalyptus energy system is that it will reforest tens of thousands of acres of range and pasture lands now committed to cattle production. In Polk County alone, 430,000 of the county's 1.3 million acres are used for ranching (Lakeland Ledger, 1981). We estimate that 90% of the acreage not subject to mining reclamation that moves into eucalyptus plantations will have been in a ranching-related use. Per capita beef consumption has dropped drastically, beef markets are weak, and a typical Polk rancher with 100 head of cattle was expected to lose $14,000 in 1981 (Lakeland Ledger, 1981). Probably, many cattle ranchers would prefer growing eucalypts if the profit were higher and the work less demanding. Many owners lease their lands to ranchers at rates comparable to the annual tax assessment for agricultural lands.

If 50,000 acres of Biomass Energy Systems, Inc.'s 100,000 acre eucalyptus plantation were in a ranching use at planting, that would remove from 10,000 to 16,500 cattle from the plantation's watershed(s). One 1,000 pound beef animal produces yearly: 1,614 gallons of urine and 6.7 wet tons of manure containing 61 pounds of nitrogen, 18 pounds of phosphorus, 39 pounds of potassium, and 1,510 pounds of chemical oxygen demand (COD) (Gilbertson, et al., 1979). Since livestock often concentrate in streams and adjacent aquatic systems, surface waters receive the full thrust of livestock grazing. Many of the surface water quality issues in Florida interface with non-point source pollution from cattle populations in the watershed. The overall environmental impacts of cattle ranching on Florida's aquatic ecosystems has yet to be addressed.

We feel confident that the eucalyptus energy forest will have a very positive impact on surface waters wherever it displaces large numbers of cattle. Reducing the substantial erosion of sediments from grazed lands into water courses also will accompany reforestation. Other positive hydrological benefits can be expected and are addressed elsewhere in this section

It well might be in Florida's environmental and water management interests to offer cattlemen and ranchland owners a tax credit for every acre of range and pasture they reforest instead of graze.

4.2.2 Reversibility by Removal of the Energy Forest. Some Florida adversaries of the eucalyptus energy forest have pointed to the tree's ability to coppice (sprout) from the cut stump as making their future eradication more difficult. The apparent assumption is that for some future unforeseen cause, *E. camaldulensis* will become a threat to man or the environment. If for some improbable reason this tree should start to eat people, or perform some equally despicable act, the wood energy plantations easily could be removed by physical and chemical methods. The stumps, if uprooted by a bulldozer and burned, will not sprout. The stumps and leaves, when treated by any one of an array of herbicides, cause the trees to wither and die. Perhaps, Koalas and other Australian predators would be imported as biological controls? If the trees do pose a future problem, put them to an economic use, and man will destroy them for profit. Indeed why not use them as a source of energy, along with the "pest" trees melaluca, Australian Pine, and even Brazilian pepper? Let man become the predator of the "pest" trees for personal economic gain and they will become an instant over-exploited resource.

4.3 Soil Considerations. The primary ecosystem impact concerns regarding wood energy systems are interrelated and include erosion, residue removal, sedimentation, and loss of topsoil. Increased erosion leads to higher sediment loads in runoff and loss of soil nutrients and organic matter, which degrades water quality and changes watershed yields. Our eucalypt plantations will occupy level to nearly level terrain with a soil substrate of coarse, mineral sands which have high to moderate percolation rates. There will be ground cover and understory vegetation, a high density of tree roots in the upper soil horizons, an abundance of woody and foliar detritus, vegetated buffer zones, and complete forest turnover and replanting only once in every 25-50 years. Therefore, the erosion potential is extremely limited and not projected as an adverse impact of this energy producing use of land. Indeed, we expect a substantial increase in detritus and organics as the topsoil values increase from reforestation. Wind and water will have minimal opportunity to transport soils off-site, or redistribute soils within the stand.

From a historical perspective, all land forms undergo natural erosional cycles that produce high rates of soil loss. Such rates are often driven by natural catastrophic events, including wildfire and storms. Undisturbed forests generally have small erosion rates, frequently less than 75 pounds of soil/acre/year (EPA, 1978). In fact, tree planting often is used to protect erosion-prone land. Erosion has always been a concern in silviculture, especially in logging operations and particularly in road construction (Stone, 1973). Increased erosion over natural conditions typically is negligible under favorable conditions such as occur in Central and South Florida. The increase from poorly constructed roads is greatest; therefore, special care will be taken in selecting the location and methodology for logging road construction within the eucalypt plantations.

Erosion danger increases sharply with the steepness of the landscape. Most locations projected for eucalypt biomass stands in Florida vary from level to 2-5% slopes; hence, the threat of sheet, gully, and mass movement erosion is minimal to nonexistent. The coarse, permeable nature of the mineral sand soils at most candidate plantation sites do not offer conditions under which the use of heavy machinery can reduce the porosity and water-holding capacity of the land. On such soils, erosion is not typical, nor is vegetative colonization usually restricted. Large areas of forest land served by roads on stable topography with gentle slopes draw little attention or criticism (Stone, 1973). Log "skidding" also can create some erosional problems, but most eucalypt stock is anticipated to be handled by relatively benign feller-bunchers, usually on tires rather than tracks. Erosion caused by the actual cutting of trees will be minimal, and post-harvest vegetation will regenerate quickly in the Florida climate. Intensive mechanical preparation of land prior to planting can cause serious erosion problems, but only on steep gradients with low permeability soils using careless practices, none of which will be inherent in our operations.

Topsoil is considered to be a nonrenewable resource over the short-term. The loss of topsoil in short-rotation energy farms, with a consequent loss of productivity and impairment of the ability of land to support future woodlands, is an assumption not tied to the realities of the eucalypt plantation. Coupled with the foregoing reasons for disputing the traditional environmental concerns associated with the proposed land use, the stability and quality of eucalypt stand soils will maintain their integrity due to an intrinsically high detrital output and an unusual degree of ground cover throughout the 25-50 year life of the stand. Unlike the matted pine straw duff and closed canopy of pine plantations, eucalypt detritus is more easily oxidized and incorporated into the soil matrix such that soil accretion actually occurs, rather than soil depletion.

The loss of ground cover by collecting forest residues from logging for use as a fuel potentially leads to faster runoff, increased soil erosion, laterization, decreased water quality and destruction of ecosystems sustained by the decaying organic material. Whole tree harvesting procedures for our eucalypt plantations will <u>not</u> remove residue and detritus from the forest floor, nor will it destroy the understory. However, most of the living biomass contained in the tree will be exported. Erosion-related sediment loading, including deposition of organic material and soil nutrients which accelerate eutrophication, will not be a significant cause for concern due to the stated factors controlling erosion. In addition, a 50' vegetated buffer zone will be maintained between the biomass stands and any local aquatic systems. This buffer is extremely important along riparian ecosystems and serves as a biological reservoir that permits reinvasion of the plantation and maintains a higher diversity of species.

As a group, eucalypts are adapted to growing well on poor soils, which reduces their dependence on nutrient enrichment by man. High levels of nitrogen and phosphorus in Florida's rainfall and existing soil conditions on reclaimed lands should be sufficient for most plantation locations after the initial planting. An initial treatment of 0.5 tons of coarsly ground rock phosphate will be required on most unmined sites with native soils at the time of establishment. No trace element or nutrient deficiencies have been found in Florida's eucalypt forests. Ash from the methanol synthesis plant will be spread back on the plantation soil, providing for a recycling of minerals, and potash. Wood ash, as opposed to coal ash, is not toxic and not a disposal problem. Wood ash represents a valuable fertilizer. It will be recycled through the biomass eucalypt plantations during site preparation and after harvesting if experimentation documents an economic increase in productivity. The deciduous eucalypt leaves, which decompose rapidly in the soil, will provide additional nutrients. Soil nutrient depletion is not foreseen as a consequence of eucalypt biomass production.

The critical operational stages for erosion will be during initial site preparation and harvest. Approximately 14,000 acres per year will be prepared for planting and harvested after the first seven years. Newly site-prepared fields will experience their highest erosion potential following clearing and during the first year after planting. Contour ditching to intercept water flow down long slopes is effective in reducing gully formation and will be utilized as site conditions dictate. Most plantation sites, however, will have a level or nearly level topography. All water bodies adjacent to plantations will have vegetated buffer zones to reduce soil transport into water bodies.

The coppicing ability of the trees leaves the root systems intact, which mitigates the effects of erosion, runoff, and siltation when the biomass energy farm is harvested. Best management practices will be employed to reduce runoff and nutrient loss. Nutrient removal from the biomass system can be compensated by additions (Cromer and Raupach, 1975) when necessary; but, problems in this area are not anticipated. The coppicing system also leaves soil microbiota and the soil itself stable and basically undisturbed (Mitre, 1981).

Modern tree harvest machinery, when properly used, can avoid significant or permanent deleterious effects on the forest soil in terms of compaction or on the roots (Bateman, 1963; King and Haines, 1979). Harvest of the eucalypt biomass crop has a much reduced potential to accelerate nutrient loss, by exposure of litter and soil, through erosion (Cole, et al., 1980).

The highest erosion potential is associated with the construction and use of service roads on the plantation. Potential damage can be mitigated by proper road siting and implementation of erosion control techniques. Light-duty roads requiring minor cut-and-fill operations can be covered with wood chips to help stabilize slopes and slow the rate of runoff. On those roads used only for harvesting, vegetative cover can be encouraged immediately after planting. Such roads would only be used by heavy equipment every 6-8 years.

The proposed wood energy system allows for reforestation with a hardwood species of previously forested land that has been denuded and placed into uses that are far more disruptive of the native soil and offer a far greater potential for soil degradation and erosion than would the same areas clothed with an energy forest.

4.4 Nutrient Depletion and the Value of Residues. Long-rotation logging generally does not deplete nutrients from forest soils. The most common use of fertilizers on commercial forestlands is on soils that are naturally deficient in nutrients or that have been depleted by past farming practices (EPA, 1978). Fertilization will not be an on-going practice in eucalypt biomass production, especially since phosphorus-rich reclaimed mine lands are contemplated for a large percentage of the stands. Other factors mitigating against soil nutrient depletion in eucalypt plantations will be the relatively high woody and foliar detritus (mulch) output of the stand and the spreading of potassium-rich ash from the methanol synthesis process back on the harvest sites. A policy of not removing most harvesting residues - tops, limbs, leaves, and understory - would lessen the possibility of nutrient depletion. If experience demonstrates that whole tree harvesting does reduce subsequent yields, the tree crowns might be left in the plantation.

Data by Attiwell (1972) on the distribution and movements of nutrients within an *E. obliqua* forest in Australia indicate that phosphorus is a particularly critical element. A very high proportion of the phosphorus in the biomass (to 60%) was found to be transported off-site in stem wood and bark. Phosphorus in wood and bark also is thought to comprise a high proportion of the available phosphorus present in at least the surface soil horizons (Attiwell, 1972). Since phosphorus is an essential element which is becoming increasingly expensive to replace, it is the element most likely to be troublesome in the long-term maintenance of productivity (Hillis and Brown, 1978). Eucalypts grown on reclaimed, phosphate mined land probably will be exempt from this constraint, at least for several harvest cycles, since measurement of soil phosphate levels in 7-8 year old stands on Central Florida overburden and tailings sites have remained extremely high (M. Moorman, pers. comm.). A soil treatment of coarsely ground rock phosphate at about 0.5 tons per acre is strongly recommended for most Florida eucalypt sites that have not been mined and reclaimed.

Residues serve a number of ecological functions in addition to nutrient replenishment. In serving wildlife needs, they provide shelter and food to small mammals, birds and herptiles, and provide a temporary food supply for deer and other larger mammals. Post-logging benefits to the harvest site include moderating soil temperature increases that normally occur after logging, provide some protection to the forest floor against erosion, and are a source of organic matter for the forest substrate. Thus, removal of all residues will reduce certain wildlife habitats and may expose the forest floor to some additional erosion above that which may be caused by conventional logging (OTA, 1981). Retaining logging residues on-site may be necessary if declines in soil organic matter are detected and accompanied by declines in nitrogen-fixing capacity, soil microbial activity rates, and cation exchange capacity, all of which are important determinants of long-term forest health (Stone, 1979; White and Harvey, 1979). There will be ample opportunity for this type of research and development of appropriate management practices when the eucalyptus energy forest is operational.

Allelopathy is the ability of a plant to inhibit competing species through organic toxicants produced in its leaves. Delmoral and Muller (1970) isolated 10 phenolic toxins from the soil litter of E. camaldulensis in California. These water soluble toxins are leached from the leaf litter into the soil where they inhibit, often severly, annual herbaceous vegetation. This remarkable property is of obvious competitive advantage to the eucalypts and favors high productivity in the plantation as well as no need for herbicides once the establishment period of about 18 months has passed. Conditions for allelopathic interference are most favorable where the soil is high in colloidal content, poorly drained, and poorly aerated. Generally, these conditions prevail only on former phosphatic clay settling areas in the study area. Conversely, on sandy soils little inhibition was observed in the California study, and little has been observed in existing Florida plantations (see Working Document 6). Because the toxins are water soluble, they will have no long term inhibitory effect on vegetation once the eucalypt forest has been removed. Similar allelopathic inhibition has been reported for E. globulus (Baker, 1966).

4.5 Hydrology and Water Consumption. Maintaining good water quality and conserving water quantity are important goals recognized and accounted for in biomass plantation planning. The eucalypt plantation should not adversely impact the surface or ground water resource, especially when compared to agricultural systems now in place. Runoff should not be increased from background conditions due to canopy interception, detrital accumulation, ground cover vegetation, tree root soil stabilization and bedding. The eucalyptus plantations will not require irrigation, and therefore, will not impact the aquifer resource as a consumptive user.

Forests are particularly important as areas for the storage and controlled release of water. The non-capillary porosity of surface soils, and consequently the rate of infiltration of water, normally is higher in forests then under pasture (Harrold, et al., 1962). Litter layers of the forest hold considerable volumes of water (Dyrness, et al., 1957). The establishment of forests on former grasslands and croplands can increase soil infiltration rates such that stormwater runoff will decrease and storage will increase. This would have a significant regional impact on surface water quantity and quality.

By establishing forests on non-forested land, the amount of water "lost" from a watershed (hydrologic yield) is decreased. Clear-cut harvesting tends to reverse this condition. Forest cutting reduces both evaporation and transpiration. Thus, the cutting of trees increases the amount of water moving into soils, reduces the amount of water removed by plants from soils, and increases the amount of water moving from soils into streams. The hydrologic yield from a watershed increases after cutting in proportion to the reduction in forest canopy. Stream flows return to normal as forest regeneration occurs. Forest cutting apparently has only minor effects on the timing and magnitude of flood peaks, provided that good logging practices are used and that cutting does not affect a large proportion of the watershed (Braunstein, et al., 1981).

The overall hydrologic effects of reforesting a large acreage of the rural lands in Central and South Florida would be positive and highly desirable to most Floridians. Flooding from the rapid discharge of stormwater runoff would be diminished. The delayed release of rainfall via surface runoff and subsurface groundwater would augment stream flows to maintain higher base levels during the dry periods. Water quality of surface runoff would be substantially improved over current conditions, with less nutrient enrichment of lakes and streams. The increased organics in the topsoil would allow the forest soils to store more water for longer periods. Evapo-transpiration discharges to the atmosphere could trigger regional increases in rainfall.

As reported in Working Document 1, the amount of water transpired by E. camaldulensis is dependent on the water available in the root zone. It will behave hydrologically much as a mesic hardwood forest with respect to its impact on the shallow water table. The eucalyptus forest will not lower the shallow water table beyond its periphery. During wet periods of high rainfall, ET will be high. During dry periods, ET will be low. E. camaldulensis is shallow-rooted, so its water withdrawal from the upper soil horizons will not reach deep enough to effect the water table in wetlands and aquatic systems beyond the forest edge. Within our plantations, aquatic systems will have a 50 foot buffer of natural vegetation.

It is extremely naive and misleading to predict as environmental fact, as has been done by opponents of the energy forest, that upland plantings of eucalypts will impact adversely on the water table so as to dry out adjacent marshes and wetlands. We have seen no data that supports such an inference. Certainly, in Glades County the eucalyptus plantations coexist nicely with neighboring marshes and swamps.

A water-loving eucalyptus species, if one could be found, planted on a reclaimed clay settling area where the soil moisture is always high and flooding with rainfall is a major management problem, might help to dry out such a soil to a more mesic condition. This has yet to be proven by research and is not related hydrologically to the conditions in upland eucalyptus energy plantations.

4.6 Water Quality. The major cause of impaired water quality associated with logging is sediment resulting from erosion (USDA, 1977). Sediments are directly responsible for water turbidity, destruction of stream bottom organisms by scouring and suffocation, and the destruction of fish reproductive habitat. They also carry nutrients from the soil, and nutrient loading of waters may have a variety of effects, including accelerated eutrophication and oxygen depletion. Fortunately, sediment loading from the eucalpyt stands is predicted to be minimal since adequate buffer zones will be maintained between all stands and any adjacent wetland or aquatic system, and for the same reasons that erosion will be minimal on such sites. The rapid revegetation following land disturbance on our sites will have the effects of slowing runoff and leaching, increasing nutrient uptake, and slowing the decomposition of organic material and consequent nutrient release by shading and cooling the soil (Rice, et al., 1972).

Surface and riparian water quality impacts of the eucalypt energy system will be somewhat dependent on the siting and construction of the logging roads. Roads can contribute the largest portion of an erosion problem, perhaps as great as 90 percent in many cases (Magahan, 1972 and Braunstein, et al., 1981). As a result, our plantation concept will encourage appropriate, site-specific planning and the use of best management practices and techniques.

We do not expect any negative impact on water chemistry resulting from the establishment of plantations. Rock phosphate fertilizer will be applied only at initial planting and again at harvest. Fertilizer runoff is thus expected to be nil or insignificant due to the infrequency of application and flatness of the terrain. Eucalyptus are extremely resistant to defoliating insects. We will not use insecticides unless we find insect populations which are causing substantial defoliation or tree loss. These conditions are not anticipated.

Herbicides, if used at all, will be applied only once at initial planting establishment. Without irrigation, there will be no mixing of deep aquifer waters with surface waters. Conservation of water is a major concern with water quality implications. Many alternative land uses, particularly cattle grazing or row cropping, require more water per hectare than the eucalypt plantation. They also have a far greater pollution impact on water chemistry.

Eucalypts are well adapted to dry, sandy areas in Australia. We do not anticipate the need for irrigation. From a regional water quality perspective, we doubt that any knowledgable environmental regulator would oppose reforestation of large areas as a desirable ecological goal in peninsular Florida.

4.7 Air Emissions. We expect air emissions and fugitive dust from the heavy equipment used for planting and harvesting. Estimates of the air emission factors for heavy duty construction equipment, similar to those used in these activities, are published by USEPA (1977). These emissions are time-based, (i.e., based on annual operation in hours per year). For example, the emission estimates for wheeled dozers and off highway trucks are based on 2000 hours per year operation. This is quite reasonable for our operation. A future detailed environmental impact statement will include calculations of these emission factors.

According to Inman, et al. (1977), vehicle and utility engine emissions are not expected to pose a serious air pollution problem on silvicultural biomass farms. It is assumed that all vehicles that are in use will be equipped with pollution control devices and be properly maintained. The vehicles will be operating in rural areas where background air quality should be good.

Fugitive dust will be generated by pulverization and abrasion of soil by blades and discs, or by entrainment caused by the air currents produced by moving vehicles or wind. Some palative treatment of the service roads as a dust control measure may be necessary.

Forest ecosystems act as sinks for subtoxic levels of air pollutants (Lindberg, et al., 1980). This is one of their most important and positive exchanges with the environment. Once pollutant levels toxic to some species in the forest ecosystem have been reached, the pollutants no longer are exchanged between the atmospheric compartment, the available nutrient and soil compartments, and various elements of the biota (Smith, 1981). When toxic levels of a pollutant have been reached, tree species or individuals within any given species may be effected by nutrient stress, impaired metabolism, increased susceptibility to disease or direct disease induction. Until such toxic levels are reached, however, the forest ecosystem acts as a sink. Depending on the nature of the pollutant, it could have an innocuous effect, or even a stimulatory or fertilizing effect (Turner, et al., 1980; Smith, 1981; Abrahamsen, 1980). It has been suggested that forest buffer zones be used around sulfur-oxide producing power plants to scrub the air of sulfur particulates.

The biomass forest soil will be a sink for a variety of air pollutant species. Particulate lead retention by organic materials on the forest floor is quite effective. Other trace metals may also become immobilized in the forest soils. Zinc, cadmium, copper, nickel, manganese, vanadium, and chromium; all products of coal combustion, may find a sink in the soil of the biomass forest. Forest soils can remove pollutant gases through various microbial chemical and physical chemical processes. Sulfur dioxide, ammonia, and some hydrocarbons and mercury vapor may be removed by forest soils (Smith, 1981; Cronan, 1980; Abrahamsen, 1980). Forest soils also play a dominant role in regulating the concentration of carbon monoxide in the atmosphere (Smith, 1981).

Forest vegetation is an important sink for airborne particulates. Particulate contaminants from coal combustion include many carcinogenic compounds (Wilson, et al., 1980). Particulates are deposited on plant surfaces by settling out from the air mass, impaction through air currents, and in precipitation (Smith, 1981). Biomass energy forests could be an efficient air pollution filter because of the extremely high surface to volume ratio. Also the biomass energy forest will tend to still wind speeds, therefore particle sedimentation from the air mass will be increased in the forest. Quantification of the filtering capacity of forests, however, is not possible with the data presently available (Smith, 1981). The capacity of the biomass forest to remove gaseous pollution from the atmosphere will be discussed.

4.8 Insecticide Use in the Eucalyptus Energy Forest. There are no known serious insect pests of eucalypts in the continental United States at this time. However, should such pests become established, the use of insecticides must be guarded. Insecticide usage tends to cut down predator species of insects while allowing the damaging herbaceous consumer insects to flourish. Primary consumer insect populations rebound after insecticide application much faster than their predators. In one pertinent California study, predaceous insects averaged only 45 percent and 9 percent of their former numbers in low and high dose applications, respectively. Corresponding figures for herbivorous insects were 108 percent and 206 percent, respectively. The application of insecticides clearly created an ecological imbalance that favored the pest species (Hurlbert, 1972).

Pest species have been known to develop resistance to various insecticides. Resistance in pest strains develops most rapidly with heavy applications of insecticides. Since a total kill of the insect population is never achieved, resistant individuals are selected out more rapidly with the higher levels of insecticide usage. Long before DDT was actually banned, its use was dwindling because of resistance formation in the targeted insect pests (H.E.W., 1963). For these reasons, as well as economic imperatives, insecticide usage is not contemplated for our eucalypt biomass stands. Evidence suggests that pestiferous epidemics will not occur; but, if controls are necessary, an integrated pest management approach will be the preferred course of action.

4.9 Impacts on Wildlife and Natural Systems. All types of replanting are accompanied by major changes in habitats available for wildlife. In the short term, any wood-harvesting operation, other than large area clear-cutting, usually increases wildlife populations because mature forests often do not support as great a total population of wildlife as do young growing forests (Rice, et al., 1972). This may be especially true for the rangeland and mined land sites of Central Florida contemplated for a majority of the eucalypt plantation sites. Many species require both cleared and forested habitat for survival, and thus the "edges" created by planted forests and logging are particularly attractive to these species. We envision a majority of the eucalypt stands having a rectilinear configuration that will be beneficial to both planting and harvesting operations and wildlife populations preferring subclimax habitat. In spite of some obvious habitat limitations, biomass plantations can increase the structural diversity of an ecosystem and thereby serve to attract and support many types of resident and migratory wildlife.

There is a significant lack of knowledge of the habitat requirements of wildlife in eucalypt forests (Hillis and Brown, 1978). Forest operations effect wildlife habitat by changing the species and structure of the vegetative complex, which consequently effects food chains, cover and nesting sites. Such alterations are most dramatic at the time of harvest, and populations of animals in native eucalypt forests may be most altered by clear cutting (Tyndale-Briscoe and Colaby, 1975; Suckling, et al., 1976). The long-term consequences are minimized when populations are maintained in surrounding areas. Recolonization of coppice growth stands should be proportionately rapid, indeed almost immediate. Many vertebrates and invertebrates should benefit from the high plant productivity of the mid-successional growth stage. Harris (1976) found the insect diversity in eucalypt stands was greatest in 2-5 year old stands.

Establishing a eucalypt plantation can create new habitat for tree squirrels, perching and ground-dwelling birds, and perhaps deer by creating forestlike conditions and "edge" habitat (Segelquist and Rogers, 1975; Blymyer and Mosby, 1977). This capability is especially true for pastureland and surface mining systems. Stands of Eucalyptus camaldulensis have open canopys which allow considerable sunlight transmission to the forest floor, which in turn stimulates a diversity and abundance of understory and ground cover plants typically not found in nature pine plantations, for example. A comparative Florida eucalypt field survey with plant and animal species lists is provided in the natural system interface document (Working Document 6).

Management of plantations would include controlling competing plant species during the first 18 months. In addition, E. camaldulensis can have an allelopathic effect on understory vegetation (DelMoral and Muller, 1970). Conditions for allelopathic effectiveness are good on poorly drained, poorly aerated, shallow, clayish soils, but poor on sandy soils such as those scheduled for biomass production in Florida (DelMoral and Muller, 1970). Plantations located on the sandy, native or mined overburden Florida soils will coexist with a variety of grasses and herbs, as well as some shrub species if establishing a moderate understory for improved wildlife habitat is a management objective.

Wildlife species diversity can be increased on plantations by increasing environmental heterogeneity. Our plans to provide buffer strips along highways, property boundaries, and aquatic systems will provide natural systems habitat and refugium for native plants and wildlife, as well as travel corridors for wildlife. For example, the impacts to wildlife from wood energy operations can be mitigated to some extent by leaving some snags standing, especially large ones. In stands that have had snags removed, some trees could be left and/or killed for snags (Raphael and White, 1978; Braunstein, et al., 1981). Animal diversity can be influenced by limiting the area and varying the pattern of clearcuts when and if possible.

Eucalyptus camaldulensis in Florida generally aborts its seeds in a premature fruit drop due to a fungal pathogen. The propagules, in addition, are not well-dispersed by wind, water, or wildlife. The supporting natural systems interface document (EcoImpact, 1982) details the reasons for the lack of naturalization potential of E. camaldulensis in Florida's wildlands.

Anyone who visits Florida's Eucalyptus camaldulensis plantings becomes aware of the amount of sunlight penetrating to the forest floor, the several layers of understory and ground cover vegetation, and the evidence of use left by a variety of nesting and feeding birds, deer, rabbits, burrowing mammals, predators, herptiles, etc. There is an indisputable array of wildlife species who use these plantations as habitat. Nonetheless, what other private Florida landowners growing agricultural or silvicultural crops are constrained by environmental regulators and told their croplands must provide good habitat for wild plants and animals? None. Why then is this demand being placed on the eucalypt plantations to be established on reclaimed lands?

4.10 Stability of Crop Yield. The eucalypt plantation's productivity will generate relatively predictable sustained yields over several cutting cycles. Short-term vagaries of climate should not affect the rate of biomass production, and yields per unit of time should be reasonably constant for several coppice cuttings. New growth every 6-8 years should be able to acclimate to possible changes in temperature and rainfall trends. The short time-frame between harvests will allow for periodic improvements in the stock line without altering timbering schedules or productivity. Select clonal stock eliminates much of the inherent uncertainty of other systems.

4.11 Fire Hazards. Fire does not pose a serious threat to eucalypt plantations in Florida when compared with natural pine or hardwood forests. The accumulation of litter and fuel in the understory is not as great as natural system stands, and a thick, matted duff layer does not accumulate as it does in pine plantations. Crown fire is less likely since the canopies are sparse and higher from the ground when contrasted with planted pines. Grass and other competing vegetation initially are controlled by site preparation. Control burning, while unlikely, may become a part of the management strategy if sufficient fuel accumulates prior to harvest in 6-8 years. The site may be burned off prior to tree harvesting to enable access by machinery (M. Moorman, pers. comm.). Due to the coppice potential of *E. camaldulensis*, an established stand could be harvested after a deleterious fire without a significant loss of production capacity or biomass standing crop.

4.12 The Biomass Forest as a Sink for Fossil Fuel Pollution--Carbon Dioxide. Florida's environmentally aware citizens are showing increasing concern over the twin spectares of carbon dioxide accumulation (greenhouse effect) and acidification of surface waters and soils (acid rains). Since the eucalyptus energy forest is a formidable weapon in society's hands to offset these impacts, we have closed this environmental impact of the forest section with what might be the greatest positive effects of a large scale energy forest.

Forest ecosystems are important sinks for anthropogenic carbon dioxide. Carbon dioxide releases from man-made sources are becoming an important global pollution problem. Carbon dioxide released from burning fossil fuel deposits such as coal and oil is increasing the carbon dioxide concentration of the global atmosphere (Budiansky, 1980). This carbon dioxide concentration has been estimated as approximately 290 parts per million in the middle of the 19th century. Today that concentration has increased up to 335 parts per million. One-fourth of this increase occurred between 1967 and 1977 (Wilson, et al., 1980). Evidence for this increase has come from carbon dioxide monitoring stations in Hawaii, Alaska, New York, Sweden, Australia, and the South Pole. Data have been intensively collected over the last 20 years (Smith, 1981). At the current rate of increase, in the year 2020, the carbon dioxide content of the global atmosphere may be nearly twice the present value.

Carbon dioxide emissions are not under regulatory scrutiny at this time. There is a growing recognition of possible global effects resulting from the massive output of carbon dioxide through the burning of fossil fuels (Wilson, 1980). Recent correlation of calculations of the greenhouse effect with observations made by NASA's Venus space probe have underlined the reality of the greenhouse effect resulting from increased atmospheric carbon dioxide (Budiansky, 1980). Forests, also declining drastically in area and age, ameliorate the problem by putting carbon atoms into both short-term and long-term storage. Coal deposits once were ancient forests and marshes.

4.12.1 Greenhouse Effect. Increased concentrations of carbon dioxide in the atmosphere apparently accelerate the global warming trend. An increase of 1 to 5 degrees Kelvin is theorized for each doubling of carbon dioxide concentration. These predictions must be viewed in light of present global temperatures that are only 6 degrees Kelvin higher than temperatures during the last Ice Age. Temperature changes due to increased carbon dioxide levels are liable to be more extreme at higher latitudes (Wilson, 1980).

The greenhouse effect operates through carbon dioxide's transparency to ultra-violet ratiation. Solar energy is transmitted through the atmosphere to the Earth's surface. When the Earth's surface reflects the incoming radiant energy in the infra-red band, carbon dioxide reflects this energy back to Earth. The atmosphere of carbon dioxide is an effective energy trap; the result is atmospheric heating. If the warming trend melts the polar ice, decreased albedo will accelerate the greenhouse effect. Albedo is a measure of the reflectivity of the Earth's surface to incoming solar energy. Less reflectivity means more radiant energy is absorbed, resulting in higher ambient temperatures (Odum, 1971).

Release of carbon dioxide into the atmosphere by burning fossil fuel has increased exponentially over the last century. We emit $5x10^9$ metric tonnes of carbon per year, as carbon dioxide. Fifty percent of this carbon can be accounted for as an increase in atmospheric levels. The remainder interacts with green plants and in the carbonate equilibrium of the oceans. Projected fossil fuel use estimates for the next century indicate an increase in atmospheric carbon dioxide concentration of two to five times the value of the middle 19th century. This model is based on an increase of two percent per year until 2025, when fossil fuel use may decrease as alternate energy resources become available. The high fossil fuel use case predicts a four percent increase per year. In both cases, ocean and land biota continue to remove fifty percent of the carbon dioxide released per year. In the above models a one to five degree Kelvin temperature warming for the low use case, and a two to ten degree Kelvin warming for the high fossil fuel use case are theorized. While a one to two degree Kelvin increase in global temperatures may be acceptable, a ten degree increase would have catastrophic effects (Nowacki, 1980).

4.12.2 Control Measures. While carbon dioxide emission control measures are theoretically possible, as in the acid gas clean up, they may not be economically or technically possible on such a large scale. The control of the carbon dioxide emission problem must be solved at the source; that is, the burning of fossil fuels. If the burning of fossil fuels were cut back or controlled, so would the atmospheric increase of carbon dioxide be controlled (Budiansky, 1980).

While concentrations below 100 parts per million do not produce toxic effects in plants, the overall impacts of increased carbon dioxide levels could be fundamental (Smith, 1981). The pH of oceans and fresh water ecosystems could be lowered by increased levels of dissolved carbon dioxide since the atmosphere-water equilibrium would be shifted. Changes in temperature, precipitation, pH, or concentration of carbon dioxide could have drastic effects on the stability of ecosystems. Environmental stress and the resultant ecosystem instability would lead to irruptions of pests and diseases in agricultural regions. Changes in temperature and patterns of precipitation could also have direct effects on agricultural crops (Johnson, et al., 1980).

4.12.3 Silviculture and Greenhouse Effect. Silvicultural energy farms will not contribute to the atmospheric buildup of CO_2. In fact, green plants fix carbon dioxide from the atmosphere during photosynthesis. Hence, the storing of energy for later gasification and synthesis of methanol. While the burning of methanol will release carbon dioxide once again, there will be no net increase, as no geologic sink of carbon has been tapped in producing the methanol from wood. Carbon dioxide will cycle from the atmosphere to the biomass energy plantation, to the gasification plant, which will emit carbon oxides, thence to the methanol product. Finally, the consumer burns the methanol, releasing carbon dioxide to the atmosphere once again. There should be no net increase in carbon dioxide contributed to the atmosphere through the biomass energy gasification system. George M. Woodwell of the EcoSystem Center Marine Biological Laboratory, has hypothesized that forest destruction, along with fossil fuel burning, contributes to the increasing atmospheric carbon dioxide levels. The wood energy system will not be destroying forests but creating forests and harvesting the fixed atmospheric carbon dioxide. Once the methanol fuels are burned,

CO_2 - GREENHOUSE

WORLDWIDE CO_2 EMISSIONS BY SOURCE*

Source	1970	1971	1972	1973	1974	1975	1975	1976	Distribution %
Coal	1497	1479	1499	1527	1550	1626	1676		33.2
Lignite	237	239	243	246	246	249	260		5.1
Crude Petroleum and NG Liquids	1803	1907	2011	2203	2213	2107	2224		44.1
Natural Gas	545	583	614	646	659	665	675		13.4
Natural Gas Flared	90	94	100	110	113	105	113		2.2
Cement	82	88	93	95	95	100	99		2.0
Total Carbon As CO_2	4254	4390	4560	4827	4876	4852	5047		--
Incremental ATM CO_2 Conc. (ppm)	2.00	2.07	2.15	2.27	2.29	2.28	2.38		--
U. S. Emissions Contribution	0.58			0.64		0.64			--

*All entries in 10^6 metric tons carbon as CO_2 except where indicated

SOURCE: DOE CY-76-C-02-0016

no net increase in carbon dioxide levels will result (Budiansky, 1980). Indeed, forest biomass is a pathway for long term storage of carbon atoms.

4.13 The Biomass Energy Forest and Acid Rain. Airborne sulfur compounds can have major impacts on ecosystems. Metallic sulfates, ammonium sulfates, and in particular, sulfuric acid in precipitation cause widespread ecological problems, particularly in the areas of the country where acid rains occur (EPA, 1980; Klopatek, et al., 1980; Abrahamsen, 1980). Traditional models of the sulfur cycle attribute fifty percent of the sulfur in the atmosphere to biological transformations of sulfur in soil and water ecosystems (Meagher, 1980; Adams, et al., 1980). Most of these transformations are mediated by microbial activity. The sulfur is released from the microbial processes in the form of hydrogen sulfide. Zinder and Brock (1978) have proposed that most of the sulfur volatilized from soils through microbial activity, is actually in the form of compounds with carbons, such as carbonyl sulfide, dimethylsulfide, dimethyldisulfide, and methylmercaptan (Aneja, 1980). Ambient air contains concentrations of sulfur dioxide, hydrogen sulfide, and carbonyl sulfide, carbon disulfide, dimethylsulfide, and sulfur fluoride (Newman, 1980; Bandy, et al., 1980). Microbial sulfate reduction and organic matter decomposition are the two main pathways by which microbes cycle sulfur. The sulfate reducers desulfovibrio and anaerobic bacteria are found in oxygen deficient soils and benthic muds. They employ sulfate as a terminal electron acceptor (Adams, et al., 1980; Bandy, et al., 1980).

In addition, other microorganisms, including aerobes, anaerobes, thermalphiles, and fungi decompose sulfur containing organic molecules and release hydrogen sulfide. The maximum estimated dimethylsulfide release, 5.5×10^{12} grams of sulfur per year, is small when compared with anthropogenic release estimated at approximately 65×10^{12} grams of sulfur per year. The release of dimethylsulfide however, could be less than one-tenth of the total biogenic emission of sulfur. Therefore, biologic processes may account for fifty percent of the sulfur released to the atmosphere. Dimethylsulfide is also released from marine algaes, fresh and senescent leaves, and soils (Smith, 1981; Bandy, et al., 1980).

Sulfur oxides go through complicated chemical reactions in the atmosphere, catalyzed by sunlight radiation. Sulfuric acid results come down in precipitation events causing acid rain and acidification of surface waters and soils. Acid rain can damage property, fish, soil, and crops (EPA, 1980; Evans, et al., 1980). The acid component of acid rain is mainly sulfuric and nitric acid. The atmospheric input will come increasingly from conversion industries, power plants, burning coal, and automobiles (Meagher, 1980). Sulfuric acid pollution can travel hundreds of miles from the source to the place where it comes down with precipitation. Some rain events is the United States at this time do not meet EPA criteria for aquatic life. Fish would die in a bucket of this rainwater. With less drastic pH changes, fish fail to reproduce (EPA, 1980).

Acid rains are responsible for massive leaching of nutrients from soils. Fish kills in U. S. lakes in the northeast are caused by acid rain. The problem is even more acute in parts of Canada. Aluminum acids have been found to be a toxic material. Strong nitric and sulfuric acids come down in the rain, and are rapidly replaced by aluminum acids in the soil. This replacement of cations in the soil is also the mechanism of leaching and depletion of soil nutrients by acid rains. Slow chemical reactions occur between the aluminum acids and the alkaline minerals, mainly sodium and calcium in the rock beneath the soil. If the rain stays in the soil zone for very long, most of the aluminum acidity is neutralized. However, if the rain is heavy and the water does not remain in the soil long enough, the aluminum acids produced in the rock beneath the soil zone reach rivers and lakes and poison the biota (Schofield, 1980). Not only does the lower pH from direct runoff effect ecosystems, but the leaching depletes soil reserves of nutrient capacities, and produces toxic chemical species which poison ecosystems (Cronan, 1980; Schofield, 1980; Abrahamsen, 1980). Increased use of coal will increase these effects (N.S.F., 1981).

The pH of precipitation measured in North and Central Europe and in the Northeastern United States and parts of Canada is commonly in the range of 3.0 to 5.5. Individual storm events have been recorded having pH values as low as 2.0. The hydrogen ion concentration of acid precipitation has been observed to be sixty percent due to sulfuric acid, thirty-four percent due to nitric acid, and six percent the result of organic acids (Smith, 1981).

Acidifying substances in precipitation such as rain, dew, mist, and fog wash out other substances from plants through leaching. Essential macro- and micro-elements are leached from plants. These inorganic chemicals include potassium, calcium, magnesium, and manganese. A variety of organic compounds also are leached, including sugars, amino acids, organic acids, hormones, vitamins, and other substances. Nutrient losses increase as leaves increase in age. Nutrient losses peak at senescence of the leaf. Leaves under stress are much more liable to leaching than healthy leaves. Stresses could come from injury, infection, or infestation with insects (Smith, 1981; Abrahamsen, 1980). The removal mechanism of leaching is the replacement of cations with hydrogen. Precipitation with a pH of 3 or below visibly damages leaves (EPA, 1980; Abrahamsen, 1980).

4.13.1 Soil Nutrient Leaching from Acid Rain. Similarly, soil nutrients are leached by acid precipitation (Cronan, 1980). The mechanism is the same as in leaves, with the cations replaced in the cation exchange sites by hydrogen. Cations are leached from decomposing litter. Sodium is more mobile than potassium, which is more mobile than calcium, which is more mobile than magnesium. These nutrients are taken up by trees and are absorbed as cations. They exist as three forms in the soil: slightly soluble components of mineral or organic material; absorbed onto the cation exchange complex of clays; and in small quantities of soil solution in the pore water. As the pore water migrates through the soil profile, the movement of the cations is called leaching (Smith, 1981; Likens, et al., 1970; Cronan, 1980; Abrahamsen, 1980).

4.13.2 Acid Rain and Weathering of Forest Soils. Acid precipitation also may change the weathering characteristics of soil. When soils weather, hydrogen ions in solution replace cations in crystal lattices of minerals. Soil acids are the primary source for hydrogen ions in soil weathering. It is possible that accelerated weathering due to acid rain could significantly change the geologic process of soil formation; particularly when increased inputs of potassium and magnesium are released into the pore water and are then leached away (Cronan, 1980).

4.13.3 Nitrogen Oxides. Nitrogen oxides are an important constituent of acid precipitation (EPA, 1980). Nitrogen oxides are involved in the formation of ozone, another air pollutant with far reaching health effects (Wilson, et al., 1980). Combustion of fossil fuels at high temperatures, in transportation, energy generation and manufacturing of petroleum products create nitrogen oxides (EPA, 1980). High combustion temperatures increase the formation of nitrogen oxide. Higher combustion temperatures are probable in the more efficient burning of fossil fuels in the future (Wilson, et al., 1980).

Under reducing conditions, however, such as in biomass gasification, nitrogen oxides are not formed, rather the N_2 molecule is formed. Abiotic and biotic processes of denitrification also release large quantities of nitrogen oxide to the atmosphere (Odum, 1971).

4.13.4 Effects of Sulfur and Nitrogen Oxides. In summary, carbon dioxide is increasing in the atmosphere at a rate of three percent every decade. The rate of increase is accelerating. The present rate of increase is approximately one part per million per year. There are currently seven hundred billion tons of carbon in the form of carbon dioxide in the atmosphere. Man's input of carbon dioxide from the burning of fossil fuel is on the order of 5 billion tons more carbon annually. The respiration of soil microbiota and the massive clearance of forests may contribute an equivilent or greater amount of carbon dioxide to the atmosphere.

About 75 percent of the carbon dioxide released into the atmosphere is removed by sink mechanisms. The ocean is theorized to be the most effective sink, although new vegetation makes important contributions to this process (Smith, 1981).

The use of fossil fuels, with their attendant release of sulfur oxides and oxides of nitrogen (Meagher, 1980), has increased the acidity of rain events 10-100 times their pre-industrial level. Acid precipitation can leach nutrients from foliage, and rain water pH less than 3.0 causes visible damage to foliage. With a precipitation pH of 4.0 or less, nutrients have been found to leach from tree seedlings (Smith, 1981). Acid rain events in the northeastern United States have pH values as low as 2.0 (EPA, 1980).

Acid rain can have a deleterious effect on the soil leaching process, and the weathering of minerals. pH ranges of 3.0-4.0 will increase the rate of movement of calcium, potassium, and magnesium through the pore water of soils.

Toxic levels of soluble aluminum, have completely erradicated fish populations in severely affected lakes of the northeastern United States. The soluble aluminum species are part of the leachate resulting from acid rain (Schofield, 1980). Recent studies have documented increasingly low pH levels in many of Florida's oligotrophic lakes (Brezonik, 1978), indicating that this serious ecological dilemma is not restricted to the Northeast.

4.13.5 Wood Energy Plantations - One Solution. Silvicultural energy farms will not contribute to the atmospheric buildup of sulfur oxides. Furthermore, forests are known to be a sink for sulfur compounds (Lindberg, et al., 1980).

Forests act as a sink for atmospheric sulfur compounds. Sulfate is added to the soil from acid rain precipitation and enters the pore water of the soil and remains as a soluble sulfur (EPA, 1980). It's effects on nutrient leaching will be discussed later. Soils have a large capacity to absorb sulfur dioxides in the atmosphere. Soil uptake of sulfur dioxide is enhanced by fine texture, high organic matter content, high pH, the presence of calcium carbonate ($CaCO_3$), high moisture content, and the presence of microorganisms (Turner, et al., 1980; Cronan, 1980). Soil moisture favors uptake of sulfur dioxide because of the high solubility of this gas and water. The exact mechanism of soil removal of atmospheric sulfur dioxide is not completely understood. It involves microbial and chemical (abiotic) mechanisms (Cronan, 1980). Fungi are capable of removing sulfur dioxide. Assessment of the relative importance of abiotic vs. biotic sulfur oxide removal by soils is not possible at this time (Smith, 1981). Abiotic removal processes appear to be acheived through the mechanism of sorption of sulfur dioxide through the formation of sulfide and sulfate, and sorption of hydrogen sulfide involving the formation of metallic sulfide and elemental sulfur (Chamberland, 1980). Estimates of soil removal of sulfur oxides vs. removal by vegetation, suggest that removal by vegetation is more important (Hicks, et al., 1980).

Increased use of coal will lead to increased levels of carbon dioxide in the atmosphere. Through the greenhouse effect, these levels of carbon dioxide threaten to stimulate a global warming trend. A rise in global temperatures could lead to catastrophic ecological events. The biomass energy forest can be an important factor in reversing this trend that is exacerbated in proportion to our reliance on fossil fuels.

The bottom line is that the accumulation of carbon dioxide in the atmosphere and the acidification of rainfall and surface waters no longer are theories. Rather, they are conclusively documented scientific reality with a growing data base that suggests the early alarms were not sufficiently strident. Burning as much or more coal, oil, and gasoline will only worsen the severity of the adverse effects. For Central and South Florida, the eucalyptus energy forest is a viable alternative that lessens the problem both by reducing the consumption of fossil fuel and by cleaning up the contaminants from burning fossil fuel. The only question remaining is whether Floridians are wise enough to formulate a land-use policy favoring wood energy systems.

5.0 ENVIRONMENTAL IMPACTS OF TRANSPORTING LOGS AND CHIPS

The effect of moving the woody biomass from the forest to the primary utilization plant will be directly tied to the distance between the standing tree and a drum of finished product. As the distance between the point of growing to the point of distillation increases, so must either the weight of the loads transported or the number of over-the-road wood hauling units. Transportation costs are a major limiting factor controlling the distance feedstocks can be hauled economically to the refinery.

State and federal regulations limit the weight of individual loads. Individual loads also are limited by the stackability of the raw material and the verticle height of obstacles along the route.

A typical whole-tree logging crew operation under field conditions should produce ten 25-ton (22.7 tonne) loads of wood per day. Using a 240 day annualized harvesting schedule, daily plant delivery will be about 6,000 tons (5,500 tonnes) and will require 30 operational logging crews, assuming an 80% effeciency rate. Thus, approximately 240 truckloads of wood per day will leave the plantation in a year. Using an average distance of 30 miles from plantation to plant, this would involve 24 trucks making ten 60-mile round trips per day, or 600 miles per day per truck for a year.

If and when truck traffic to and from the forest increases, present largely rural traffic patterns could be impacted by the increase in road usage unless the traffic moving capability keeps pace with vehicle increases by constructing additional traffic lanes or new routes of access to the final destination point of the traffic. Widening and/or repaving are options open to planners. The impact of the biomass facility probably will be minimal for at least three years after plant construction commences. It will be minimal for seven years after forest planting begins. These amounts of lead time, coupled with good and proper governmental planning and construction implementation far enough in advance of real need to assure timely completion, can make the transition to greatly increased traffic flows from the forest to in and around the methanol plant nearly painless. Preplanning and timely construction will provide access road systems which can avoid residental and urban areas. The accompanying absence of congestion will provide added factors of safety for all user vehicles.

The air emissions estimates for the heavy-duty diesel trucks that will be used to haul the logs and chips can be calculated with formulae published by USEPA (1977). In these formulae, the emission factor for a given air pollutant for a calendar year depends on the average speed and make of the truck. A site-specific and detailed environmental impact statement would include these calculations.

Plant location, yet to be determined, is the over-riding factor. If Site No. 1, 90,000 acres in Southwest Polk County, were selected, the refinery could be centrally located and most of the feedstock transport would occur on the internal roads.

Another site has immediate access to a commercial waterway connecting to the Gulf of Mexico, and barge transport becomes a possibility.

Many sites have excellent railline connections which might lead to development of a system using rail transport, tying in with the routes currently serving the phosphate industry.

Depending on final site selection, the transportation of the methanol product from the refinery can be expected to utilize a combination of highway, railway, and waterway routes. Planning needs to be much further advanced before we can more comprehensively address the transport issue. Methanol has been commercially transportable by all of the above methods for several decades, albeit an explosive chemical requiring special handling and appropriate caution.

6.0 ENVIRONMENTAL CONSIDERATIONS FOR THE HAMMERMILL FACILITY AND FEEDSTOCK STORAGE

6.1 Feedstock Storage and Air Drying. Eucalyptus feedstock from the plantation will arrive as logs and chips. During whole tree harvesting the crowns and branches will be chipped and loaded on chip vans with live-beds to aid in unloading. The chips will be stored in large piles at the plant site for several weeks to facilitate compaction and drying from the internal heat buildup. Front-end loaders will be used to move chips from the large piles to an auger feed system for movement to the steam boilers or hammermill. Most logs will be stockpiled in forest plantation yards for 2-3 months, during which time the moisture content is expected to fall to 20-25%. This will permit larger truck loads for the haul to the mill as well as greater combustion efficiency. Additional drying of the whole logs will occur in the wood yard over a storage interval of 2-3 months.

Chips have been stockpiled for long periods of time by southern forest industries without decay or loss of wood substance. Indeed fuel value is increased by drying within the pile. However, there has been only limited experience with whole tree chip storage. Fire is the primary hazard in chip storage. Internal pile temperatures should be monitored and adequate fire suppression equipment and water supplies be maintained in the yard area.

6.2 Ambient Conditions in the Wood Yard. Fugitive dust in the wood yard will not be serious enough to warrant control. The wood yard will be a noisy, dirty part of the site, with heavy traffic from logging trucks and chip vans. This is a highly sensitive area in the plant that will require close supervision and management to safeguard the environment and work force.

6.3 Hammermill Operation. At the hammermill plant, the logs will be chipped, dried and size-reduced along with those chips destined for the Texaco gasifier. The hammermill operation grinds the wood into small pieces (less than ¼ inch) to assure a more uniform feed into the gasifier. Because of the small size of the pulverized wood, combustion time in the gasifier is estimated to be eight seconds (Evergreen Energy, pers. comm.).

Fugitive dust is a probable impact from the hammermill operation which will be mitigated with baghouse technology. Dust levels could be explosive if not monitored and controlled, much as in grain storage elevators.

Noise is an unavoidable pollutant associated with the hammermill. Locating the hammermill away from residential areas, planting trees around the hammermill to muffle the noise, and designing the hammermill to minimize noise are all mitigating measures that will be taken. As mentioned in the supporting health and safety document, the workers will be protected as much as possible from noise, in compliance with OSHA standards.

Hammermills are a common element in the industrial environment and are not expected to interject any surprises or impacts that cannot be offset by current state-of-the-art design, operations, and management.

The hammermill plant and the adjoining methanol synthesis plant will be powered by wood-fired boilers generating steam power. The general environmental impacts of similar power systems are well documented (Golembiewski, 1980).

Deep wells will supply the water for the hammermill and methanol synthesis plant, and a consumptive use permit will be required from the Southwest Florida Water Management District. Boiler feed water consists of returned condensate from the methanol condenser plus demineralized make-up water, both of which are deaerated to eliminate oxygen. Consumption of water is a major concern in Central Florida, and every attempt will be made to conserve water in all steps of the process. Some water will be lost to evaporation, drift, and blowdown.

6.4 Wood Drying for the Gasifier. Efficient operation of the biomass gasifier requires that the green wood be dried before use as fuel for the gasifier. Drying continues once the tree is cut through the transportation and storage interval. Correct moisture content of the biomass feedstock to the gasifier enables the gasifier to be run at higher efficiencies, since the higher heating value of the biomass feed has been adjusted to optimum conditions (Reed, 1981).

Most drying will occur in the forest and wood yard. As currently planned, the pulverized wood will move from the hammermill through a flash dryer using exhaust gas as the drying agent before being introduced into the gasifier.

6.5 Drying the Boiler Feedstock. An alternative system which may be used on the wood boiler feedstock stream employes a rotary drum dryer commonly used by the forest products industry.

The rotary drum dryer system uses freshly chipped green wood. The wood is first screened and oversized pieces are rechipped. The green wood chips are then set into the rotary dryer. Dirt and fines are screened out of the rotary dryer and are used as fuel for the burner system. A cyclone separator and skimmer is used to recycle gas, dust, and fumes from the rotary dryer. Dry, coarse fuel is fed to storage facilities. Hot gases and greenwood chips are introduced at one end of the rotary dryer and are blown toward the outlet end of the dryer by induced draft fans. If the moisture content of the greenwood feed is high enough to absorb the heat, the hot gas inlet temperature can be run as high as 1600 degrees Farenheit. Operating the dryer at too high a temperature could cause the formation of blue-haze. Blue-haze is a mixture of organic material, including terpenes, that are distilled from the greenwood during drying. This condition will be avoided by the dryer operators.

As a variation of the rotary dryer system, green woodchips can be brought into contact with hot drying gases on a conveyer belt. Counter-current flow of the hot gases over the chips would be the most efficient use of energy in this type system (Karchesy & Koch, 1979). The production of hot gases for use in the dryer would consume about six percent of all the wood dryed (Earl Weber, pers. comm.) (Karchesy and Koch, 1979).

In either event, there will be no environmental impact beyond the plant environ from the drying of the chipped wood as part of the precombustion process.

6.6 Future Assessment Needed. Determination of the actual area needed for yard storage and drying facilities is beyond the conceptual scope of this assessment. The same is true of the actual management methods to be used in material handling. The primary factors that will dictate these requirements are:

1. The daily supply requirement of the methanol plant. Yard storage should be sufficiently large to operate the plant for 2-3 months.
2. More and better data on the extent to which the chips and logs will air dry in the plantation and at the yard.
3. Seasonal restrictions in cutting the trees.
4. Restrictions and limits on transporting logs and chips to the yard.
5. Actual distance between the eucalyptus plantations and the wood yard.
6. The design, dynamics, and management of log and chip piles in the yard.
7. Greater knowledge of the thermo-conversion process, feedstock handling, hammermill functioning, and other actual operating conditions as they optimize productivity, minimize environmental stresses, and maximize the safety of the work force and public.

7.0 ENVIRONMENTAL IMPACTS OF THE METHANOL PLANT

Working Document 8, produced by Evergreen Energy Corporation (1982) offers a redesign of the gasifier portion of the methanol plant described in Working Document 7 by Davy McKee Corporation (1981). The Evergreen approach is to modify the feed train of the Texaco gasifier designed for coal gasification to accommodate a wood feedstock. Evergreen Energy Corporation is now scheduling pilot test runs on their wood gasification system; but, no data are available.

Little work has been done on which we can draw to characterize the environmental parameters associated with the wood-to-methanol system (Mueller Assoc., 1981). Currently no facilities exist in the United States for converting wood to methanol (U.S. Department of Energy, 1981). Virtually, all authors agree that the adverse impacts of producing methanol from biomass will be significantly less than from coal (OTA, 1980). Most of the useful data are from the exhaustive studies of proposed coal liquefaction plants and from comparisons between coal and wood feedstocks.

7.1 Gasifier Impacts. Environmental quality and the economical operation of the gasification plant go hand in hand. The more efficient a biomass gasifier design, the more environmentally clean the biomass gasifier. Woody biomass is an inherently clean feedstock, without the problems discussed later of both coal and oil shale (Reed, 1981). Inefficiencies in the gasifier design reported in working Document 7 lead to the necessity of Biomass Energy Systems, Inc. seeking the more efficient high temperature, high pressure gasification system reported in Working Document 8. Not only does this plant produce substantially more methanol fuel from the same unit of eucalyptus wood,it does so at a far lower environmental cost.

Biomass gasifiers can be classified into four categories according to the gas flow through the combustion chamber.

7.1.1 Theory of Operation. The theory of operation of the gasifier in the production of synthesis gas is that the biomass be broken down by combustion under proper conditions into a raw gas containing carbon monoxide and hydrogen. This gas stream is then cleaned and becomes the synthesis gas for use in methanol synthesis.

7.1.2 Updraft Configuration. In the updraft gasifier design, air or oxygen is introduced into the bottom of the reaction vessel under a grate which supports the feedstock. Combustion and reduction of these gases occur here. As the hot gases rise through the biomass feed, oils, and water are produced by pyrolysis and drying. Due to the relatively low temperatures of the exit gas stream, there are many tars and oils contained in this stream. This type of gasifier is generally coupled to some sort of power generation facility and the gas burned directly, thereby consuming the tars and oils (Reed, 1981). This type gasifier was used in the design reported in Working Document 7.

7.1.3 Downdraft Configuration. In a downdraft gasifier, air or oxygen is injected above the wood mass. Use of oxygen makes the system more efficient, since the nitrogen from air injection pollutes the raw gas stream. Oxygen injection produces a higher Btu gas. Use of oxygen will limit the amount of nitrogen available for the formation of nitrogen oxides. Nitrogen oxides are formed at high temperatures in an oxidizing environment (Wilson, et al., 1980). As the hot gases pass down through the char mass, pyrolysis of the incoming biomass is accomplished, producing char and oils. The oils then pass down over the hot char and are cracked into gases. Very little oil is produced in a downdraft gasifier. The temperature of the exit stream should be kept high enough so that complete decomposition of chars and oils is accomplished. (Reed, 1981). This is the type of gasifier we intend to use. It is described in Working Document 8.

7.1.4 Fluidized Bed Configuration. In the fluidized bed gasifier, oxygen and wood feed are introduced beneath a bed of inert material such as sand. The high throughput rate of the gases keeps the sandbed stirred up or fluidized. Fluidized bed gasifiers have high heat transfer rates and high throughputs. A wide range of feedstock sizes can be used. Because of the short contact time inside the reactor vessel, cracking of oils and tars and complete decomposition of the char is less efficient. Therefore, this gasifier type is not the most economical or environmentally most desirable (Reed, 1981).

7.1.5 Suspended Gasification. Suspended gasification involves high throughputs and small particle sizes. It is subject to the same inefficiencies as the fluidized bed. The gasifier design which accomplishes complete conversion of biomass to syngas without the residues of tars, oils, and other refractory species is far more desirable from an environmental and economical standpoint (Reed, 1981).

GASIFICATION REACTIONS OF BIOMASS FUELS[1]

S = Solid G = Gas

	REACTION	ENTHALPY CHANGE (KJ)/gm M
1.	$C(s) + O_2(g) = CO_2(g)$	-400
2.	$CO_2(g) + C(s) = 2\ CO(g)$	+160
3.	$2\ C(s) + O_2(g) = 2\ CO(g)$	-240
4.	$2\ CO(g) + O_2(g) = 2\ CO_2(g)$	-560
5.	$H_2O(g) + C(s) = CO(g) + H_2(g)$	+120
6.	$H_2O(g) + CO(g) = H_2(g) + CO_2(g)$	- 40
7.	$C(s) + H_2O(g) = CO_2(g) + 2\ H_2(g)$	+ 80

METHANOL SYNTHESIS

$$CO + 2H_2 \xrightarrow[250 - 300^{o}C]{50 - 200\ ATM} CH_3OH$$

SOURCE: Producer Gas Engines in Villages of Less Developed Countries
Rathin Datta, Gautam S. Dutt, Science, Vol. 213 14 August, 1981

7.2 Reducing Environment in the Gasifier. An important parameter in the design of gasifiers is their ability to operate within the proper reducing environment in the reaction chamber. A reducing rather than an oxidizing environment not only produces more carbon monoxide in proportion to carbon dioxide; but the troublesome oxides of nitrogen and sulfur are not formed. The production of carbon dioxide in the gasifier represents a waste of the biomass feedstock. Only carbon monoxide can be used in the production of synthesis gas. Any carbon dioxide produced in the gasifier must be removed from the raw gas stream before the syngas can be used for synthesis of methanol.

Molecular nitrogen and hydrogen sulfide are produced in a reducing environment. Molecular nitrogen is innocuous and not the problem; but, oxides of nitrogen should be limited. Hydrogen sulfide can easily be separated from the raw gas stream and elemental sulfur recovered. Biomass in comparison to coal has very little sulfur (Wilson, et al., 1980).

PRODUCTION OF NO_x SPECIES

$$N_2 + O_2 \rightleftharpoons 2\ NO$$

$$K = \frac{[NO]}{[N_2]\ [O_2]} = 10^{-31} \quad \text{AT } 25^\circ C$$

$$= \frac{1}{3000} \quad \text{AT } 1700^\circ C$$

LOW OXYGEN CONCENTRATIONS, AS IN A REDUCING ENVIRONMENT, SHIFT UPPER REACTION TO THE LEFT.

7.3 Proper Gasifier Operation. A properly designed gasifier completely decomposes the biomass feed into usable gases. Complete decomposition depends on gasification temperature. Above about 1000 degrees centigrade, the only stable fuel gas molecules are carbon monoxide and hydrogen (Reed, 1981). Energy efficiency demands that the gasifier be run under pressure. Contact time of biomass inside the gasifier is important to allow time for complete degradation. The reaction chamber should also contain a catalyst. The best catalysts are calcium oxide and wood ash. One of the chief components of wood ash, incidently, is calcium oxide. Removal of moisture from the biomass feed prior to placement in the gasifier allows the reaction to run at higher temperatures, thereby acheiving better decomposition of the biomass feed (Karchesy and Koch, 1979). Supplying the gasifier with a biomass feed at the correct moisture content eliminates the heat waste due to drying of the feed (Reed, 1981).

7.4 Environmental Impacts of the Biomass Energy Systems, Inc. Methanol Plant. The Texaco gasifier will be operated at approximately 2600°F and 800-1000 psi in a nearly pure oxygen environment. This high temperature and pressure eliminates the production of potentially hazardous particulates, olefins, phenols, and heavy metals. The gasification process produces almost pure carbon monoxide (CO), carbon dioxide (CO_2), hydrogen gas (H_2) and some ash. Some trace of hydrogen sulfide gas (H_2S) may be produced, governed by the relatively low sulphur content of the feedstock. The H_2S will by "scrubbed out" and the CO_2 separated by a standard Benfield process. The H_2 and CO will be recombined in the proper ratios in the shift reactor to form methanol gas in the presence of a catalyst. The methanol gas will be condensed to form liquid methanol.

7.4.1 Carbon Dioxide Emissions. We will use the Benfield process to remove excess carbon dioxide and hydrogen sulfide gases. In this process, a solution of carbonate becomes potassium carbonate when CO_2 is absorbed. The potassium carbonate is regenerated by heating, and carbon dioxide is driven off (Reed, 1981). The CO_2 byproduct will be routed to greenhouses at the facility where it will be used as an enriched atmosphere for photosynthesis for food and ornamental crops, resulting in major increases in productivity.

Carbon dioxide will be the only gas emission from the methanol synthesis plant. An important aspect in the design of gasifiers is their ability to operate within the proper reducing environment in the reaction chamber. Recall that a reducing rather than an oxidizing environment not only produces more carbon monoxide in proportion to carbon dioxide, but the hazardous oxides of nitrogen and sulfur are not found. The production of carbon dioxide represents waste of the carbon element in the feedstock. Only carbon monoxide can be used in the production of synthesis gas. Any carbon dioxide produced in the gasifier must be removed from the raw gas stream before the syngas can be used for the synthesis of methanol. Large releases of carbon dioxide to the atmosphere could equate biomass with fossil fuel in terms of the adverse climatic impact of the greenhouse effect. However, all such carbon dioxide is being recycled to the atmosphere rather than reintroduced from geologic storage deep in the earth.

7.4.2 Wood Ash. The ash will be recycled to the plantation soil. As mentioned, the ash will not contain potentially hazardous materials. Thus, we do not expect any leachate from this ash to contaminate groundwater. Water from the ash settling pond will pass through filters and be reused. Water from the methanol condenser will have a high organic content, and will not be reused. A waste water treatment system to remove these organics will be required.

The ash content of all eucalyptus species studied averages approximately one-tenth of one percent (Hillis, 1978). The exact elemental composition of wood ash varies; but, it contains about fifty percent calcium oxide, a large amount of silica dioxide and potassium oxide, and small amounts of magnesium oxide, oxides of iron, and aluminum. Sodium oxide and titanium dioxide are present in quantities of less than one percent. The P_2O_5 present in some wood ash is in concentrations as high as twenty percent (Reed, 1981). Wood ash is non-toxic. Wood ash from the proposed gasification system is a resource rather than an environmental problem (Levi,and O'Grady, 1980),in contrast to coal ash (Nowacki, 1980).

CHEMICAL COMPOSITION OF WOOD ASH[1]

	WT. %
SiO_2	33.8
Al_2O_3	2.6
TiO_2	.2
Fe_2O_3	1.6
CaO	56.5
MgO	4.7
Na_2O	.5
K_2O	.1
	100.0

SOURCE: Babcock & Wilcox Co., 1972

DRY WEIGHT ANALYSIS[1]

	C	H	O	N	S	ASH
UTAH COAL	77.9	6.0	9.9	1.5	0.6	4.1
PITTSBURGH COAL #1	75.5	5.0	4.9	1.2	3.1	10.3
PITTSBURGH COAL #2	73.3	5.3	10.2	0.7	2.8	7.6
WYOMING COAL	70.0	4.3	20.2	0.7	1.0	13.8
DOUGLAS FIR BARK	56.2	5.9	36.7	0.0	0.0	1.2
WOOD	52.0	6.3	40.5	0.1	0.0	1.0
PINE BARK	52.3	5.8	38.8	0.2	0.0	2.9

SOURCE: _Wood as an Energy Source_, Tillman, 1978

7.4.3 Methanol, a Hazardous Substance. The product methanol may pose a potential health and safety hazard to workers in the plant, due to fugitive leaks and spills as well as explosions. The toxicology of methanol and mitigating measures for leaks, spills, and explosions at the methanol plant are described in the health and safety document. The primary environmental impacts of methanol lie in its use as fuel, not in its synthesis.

7.4.4 Raw Gas Cleanup. There are several environmental disadvantages associated with gasifiers which do not accomplish complete breakdown of the biomass fuel feed (Davy McKee, 1981). The synthesis gas has to be cleaned before use, and this requires additional equipment, capital, and maintenance costs. Raw gas cleanup will also generate various waste streams. Tars and oils that are collected from the synthesis gas stream should be refluxed back to the gasifier. Among the tars and oils found in the raw gas stream of an improperly designed gasifier will be found halogenated aliphatic compounds, cyanide species, aromatic, and halogenated aromatics; and ethylene (Wilson, etal., 1980; Nowacki, 1980; Reed, 1981). Many of these compounds are carcinogenic, or are promoters of carcenogenisis (Walbott, 1978). Ethylene is especially toxic to plants (Wilson, et al., 1980).

Since we will be using the gasifier described by Evergreen Energy (1982), we do not expect a problem with raw gas cleanup.

7.4.5 Catalyst Poisons. Refractories, when separated from the syngas stream, should be refluxed through the reactor. If these refractories are not separated from the gas stream, the cyanide, ammonia, and unsaturated organics will act as catalyst poisons in the synthesis of methanol (Reed, 1981). These refractories, if not refluxed through the gasifier, will represent a net loss of effeciency and will also cause problems in the biological treatment of the waste waters. These compounds are likely to be refractory to biological breakdown for the same reason that they are refractory to pyrolysis. These molecules contain high energy covalent bonds in configurations which are difficult to break (Colwell, 1978). We expect to use guard beds to prevent the extremely costly poisoning of catalysts.

7.4.6 Combustion Control System. The percentage in the biomass feed of carbon, hydrogen, oxygen, nitrogen, sulfur, halogens, and phosphorus, as well as moisture content, need to be determined in order to adjust the stoichiometric composition of the combustion gases supplied to the gasifier and to predict the gas flow and composition of the raw gas exiting the gasifier. A recent EPA study (1980) estimated time and temperature regimes for a wide range of boiler designs. Size and zonal heat are calculated using information on the combustion chamber and the makeup of the fuel supply. There are numerous performance data to support a claim of environmental cleanliness of well-designed biomass gasifier when properly operated. In fact, incineration is the preferred method of handling toxic wastes. In cement kiln test burns using a fuel containing polychlorinated biphenols, no other high molecular weight compounds present in the fuel feeds were present in the stack emissions (Oppelt, 1981).

7.4.7 Combustion of Hazardous Substances. Hazardous substances introduced into the gasifier, or produced in the gasifier, can be completely degraded to carbon monoxide, hydrogen, and carbon dioxide. In fact, this use for industrial boilers was recommended in the Co-Firing of Hazardous Wastes. This recent EPA study concluded that the currently available data on the destruction of hazardous substances in coal-fired boilers indicate, that boilers with exit temperatures above 815°C or 1500°F and residence times above one second are the best performers in terms of complete destruction of hazardous compounds (Oppelt, 1981).

7.4.8 Fugitive Emissions. Operation of the lock hoppers could result in fugitive emissions from the gasifier. The lock hoppers enable the gasifier to be fed a constant supply of biomass fuel while the gasifier is kept at high pressure. The gasifier will run at between 100 and 1000 psig (Davy McKee, 1981). The fugitive emissions from the lock hoppers are likely to consist of small amounts of carbon monoxide, carbon dioxide, and hydrogen (Reed, 1981). Pyrolysis oils are drawn down into the combustion zone, and there should be no significant escape from the lock hopper operation (Nowacki, 1980).

The gasifier design recommended by Evergreen Energy Corporation (1982) will not require lock hoppers since a more fluid feed system is employed.

7.4.9 Heavy Metals. Any heavy metals in the biomass feedstock are likely to end up in the ash taken from the reactor. Biomass contains only trace quantities of these metals (Reed, 1981). In strong contrast to the situation with coal, the ash from the biomass gasifier will be much less in volume and non-toxic (Nowacki, 1980). In fact, wood ash is useful as a soil amendment and as a fertilizer and provides a mechanism to recycle essential nutrient elements back to the biomass plantation (Levi, et al., 1980).

7.5 Possible Pollutant Discharges and Clean-Up Technology. The gasification process and type of gasifier determines the nature and extent of pollutants that must be treated. Our first gasifier design (Davy McKee, 1981) produced a pollutant stream that was extremely difficult and costly to correct. This was a primary factor in our seeking a different gasifier design that was more acceptable ecologically and economically. The modified Texaco Gasifier (Evergreen Energy, 1982) operates at a sufficiently high temperature and pressure to cannibalize most possible pollutants rather than releasing them into the environment. It is a remarkably pollution-free gasification technology. Most of the possible pollutant problems discussed in this section are characteristic of the preliminarily gasifier design rather than the technology we intend to employ.

7.5.1 Air Quality. The only gas discharges expected from the gasification process are a trace of hydrogen sulfide and large quantities of carbon dioxide. These have been addressed in Section 7.1.4 of this report. Conventional wood fired boiler technology will be involved elsewhere in the plant, primarily for energy generation and steam production.

7.5.1.1 Fly Ashes. Fly ashes are airborne particulates which are pollutants in the gas stream coming from the gasifier and wood fired boilers. For a wood combustion process, control of particulate emission is accomplished by cyclone separators, scrubbers, baghouse filters, and electrostatic precipitators. Most wood-fuel boilers are equipped with cyclones; some have scrubbers. Besides the clean and useful ash byproduct from the gasifier, fly ash constitutes the only other significant solid waste stream from a wood gasification system (Reed, 1981). J. P. Wendlick (1978), in his article, Health Effects of Airborne Particulate Matter with Emphasis on Fly Ash, an in-house report by the Weyerhouser Company stated:

> "In the ambient particulate concentrations required for primary NAAQ's, particulate emissions from wood and bark fuels are not toxic, not carcinogenic, and not mutagenic."

Scrubner and Fisk (1978) noted the lack of mutagenicity of filtrates from hog-fuel fly ash. The wood gasifier we intend to employ will recycle the fly ash collected back into the gasifier, because the fly ash represents a valuable carbon source. There should be no fugitive emissions (Weber, pers. comm.).

7.5.1.2 Oil Mist Elimination-Mechanisms. The next step in gas clean-up after the removal of fly ashes is the elimination of oil mist. The required mechanisms may not be necessary with the development of a wood gasifier which can completely degrade the tar and oils. We expect the modified Texaco gasifier to eliminate oil and tar mist because of the high temperature (Evergreen Energy, 1982).

Since most of the oil droplets are assumed to be less than 10 microns, gravitational sedimentation will not be a useful means of elimination of oil mist in the raw gas stream. Impaction and interception of droplets on filter media represent a very effective method of mist removal. Changes in gas-flow direction are used in this system.

When a circular vortex motion is created in the gas stream, droplets impact the walls of the container through centrifugal force. This method is not effective for droplets less than five microns in diameter. Oil mist droplet size is assumed to be in the one to ten micron diameter range. Droplets which grow in size through condensation of additional liquid, or by collision with other droplets, are more easily collected by centrifugal force or inertial impaction. Electrostatic precipitation will collect droplets of all diameters and can achieve high collection efficiency. An electrostatic charge is induced on the droplets and a potential gradient then attracts the droplets from the gas stream and they are removed (Reed, 1981).

7.5.1.3 Mitigation of Possible Air Emmissions. Inefficient wood gasifiers operating at low temperatures can be expected to contain in their flue gas organic acids, tars, oils, aldehyds, vetones, ammonia, carbonyl sulfide, phenols, and polynuclear aromatic compounds. These compounds decompose under the high temperature and pressure conditions of the modified Texaco Gasifier (Evergreen, 1982) into CO, CO_2, and H_2 and become part of the product synthesis gas.

Many biomass gasifiers currently in use produce raw gas streams consisting mainly of carbon monoxide and hydrogen. However, minor amounts of methane and higher molecular weight hydrocarbons, sulfur compounds, tars, and oils are also produced in the raw gas stream. As has already been discussed in the gasifier design section, gasification units with vastly improved designs are presently possible. Proper gasifier design eliminates the tar and oil problem. These improved designs (Reed, 1981) result in the nearly complete combustion of the biomass feed, which greatly reduces or eliminates the formation of undesirable hydrocarbons (Reed, 1981; Wilson, et al., 1980).

Finally, because the product gases are scrubbed and purified, air emissions from the methanol synthesis process are extremely low and should not pose an environmental or human health hazard (Mueller Assoc., 1981).

Some air emissions can be expected from the wood preparation section involving milling and drying. These might include small quantities of CO, H_2S, COS, and methane (CH_4) (Mueller Assoc., 1981). There is no data base available to analyze or evaluate this possibility. Any air pollutants produced in this section of the process are not expected to be present in sufficient quantity to pose a hazard. Monitoring will determine if mitigation procedures are needed.

7.5.1.4 Raw Gas Clean-Up Sulfur Recovery. Highly efficient sulfur recovery is possible with the Stretford process. The Stretford process is a licensed proprietary system developed by the Northwest Gas Board of the United Kingdom. In this process, H_2S is absorbed from the raw gas stream through a solution of sodium carbonate, sodium metavanadate, and anthraquinine disulfonic acid. In this process the H_2S is first reduced to HS. The HS is then oxidized to elemental sulfur and can be removed as a marketable product. The scrubbed gas stream leaving the Stretford unit contained no more than 10 parts per million by volume of H_2S. The Stretford process would be the most efficient and economical for the low amount of H_2S that will be found in the gas stream from a wood gasifier. It is our current plan to use the Benfield process to recover the trace amounts of H_2S expected in the gas stream.

Solid iron oxide and zinc oxide have also been used for trace sulfur removal from gas streams. The solid iron oxide stream is relatively high in operating and capital costs, while the zinc oxide can cause halemorization of the settling pond (Reed, 1981). Neither are recommended for the wood gasifier.

After sulfur recovery, the sweetened gas can be passed over a bed of activated carbon. The gas leaving the activated carbon beds would contain less than 0.5 parts per million by volume of sulfur.

Chlorine can be removed from the gas stream by the use of promoted alumina. This process reduces the chlorine content of the outlet gas to less than 0.2 parts per million by volume (Reed, 1981).

The next step in synthesis gas clean-up is the removal of excess amounts of carbon dioxide, using the Benfield process. Here the passing carbonate becomes potassium bicarbonate when CO_2 is absorbed. The potassium carbonate is regenerated by heating, and carbon dioxide is driven off (Reed, 1981).

The carbon dioxide byproduct will be routed to the greenhouse atmosphere to increase plant productivity.

7.5.1.5 Gas Scrubbing. Oil, water, or a combination of the two are used in gas scrubbing. In spray scrubbers, the atomized scrubbing medium, whether it is water, oil, or a combination of the two, is sprayed through the raw gas in the contact chamber. A combination of spray trajectory and gas flow has been used. Properties of the sprayed droplets can be engineered through nozzle configurations and scrubbing medium make up. The efficiency of pollutant removal is governed by liquid spray to gas ratios and contact times. Nozzles, pumps, and piping are subject to corrosion and erosion problems. Nozzles can be plugged with circulating solids. Up to 100 gallons per 1000 cubic feet of scrubbing liquid might be required in a maximum use case (Reed, 1981).

Pressure drops increase the efficiency of oil mist separation devices that use wet scrubbing. There is an equilibrium between scrubbing media and pollutant oil gases. Some of the pollutants removed from the raw gas will reenter the gas stream from the oil-water mixtures of scrubbing medium. When oil is used as a scrubbing medium, the scrubber oil itself can be entrained and vaporized in the raw gas stream. The lower boiling components of the scrubbing oil will tend to saturate the raw gas stream at the operating temperature and pressure of the scrubbing device (Reed, 1981).

Plate scrubbers consist of towers with horizontal perforated trays. The trays are stacked and a counter-current flow of gas against scrubbing medium is established. The scrubbing medium falls from the top and through the perforations. The raw gas stream comes up through the bottom through these perforations. The rising gas stream keeps the scrubbing medium in a froth. The fine droplets of scrubbing medium thus generated absorb impurities from the gas stream. The gas stream is either humidified or entrained when cooling and condensation occur. A mist eliminator is used at the end of this process (Reed, 1981).

The packed bed scrubber uses rings or saddles in place of plates in the scrubber column. Again the gas flow is up from the bottom and the scrubbing media trickles down from the top in a counter-current flow. Collection efficiency for the packed bed scrubber rises as the packing size decreases for droplets larger than three-tenths of a micron (Reed, 1981). Packed bed scrubbers are subject to plugging and must be shut down for tar removal. Reentrainment of pollutant gases into the cleaned gas stream is also a problem (Reed, 1981).

High velocity of the raw gas stream is used in the Venturi scrubber. Gas velocities as high as 200 to 400 feet per second are used to atomize the scrubbing liquid added to the contact chamber. Oil mist in the producer gas stream coalesces with the scrubbing liquid droplets. The high gas velocities used in Venturi scrubbers make them subject to corrosion; however, they do not plug easily. As little as five to twenty gallons of scrubbing medium can be used per 1,000 cubic feet of gas scrubbed. All the scrubbing liquid is entrained in the gas stream and must be removed by subsequent separation. Venturi scrubbers are the smallest and simplest of the scrubbing devices. Ejector Venturi scrubbers use the high pressure of a spray to move the gas through the contact chamber and to collect the droplets of oil mist pollutant (Reed, 1981).

In baghouses, the raw gas is passed over beds of fibers. The oil droplets are collected from the gas stream by inertial compaction onto the fibers. The fibers are then flushed and the impacted material from the raw gas stream is collected. The fibers are often made of plastic, spun glass, fiberglass, or steel, and the packings usually have void ratios between ninety-seven and ninety-nine percent. While small fibers are highly efficient, they must be strong enough to reduce matting. Efficiency increases as fiber diameter decreases and as the gas velocity increases. Baghouse filters are subject to plugging and are susceptible to chemical, mechanical, and thermal attack (Reed, 1981).

Wet electrostatic precipitation (ESP) is a highly efficient means of scrubbing the raw gas stream. Some micron size particles can be collected using wet electrostatic precipitation. Electric power usage in this system is negligible. The pressure drop across and electrostatic precipitator is very low compared to the plate scrubber, which is more efficient with larger pressure drops. Essentially all droplets greater than or equal to one micron in diameter can be collected with the ESP (Reed, 1981).

In the ESP a negatively charged electrode produces a corona through which the raw gas is passed. Oil droplets in the raw gas stream are then electrostatically charged. A grounded collection plate on the inside wall of the pipe traps the droplets. Liquid flowing counter-currently with the raw gas stream collects the droplets stuck to the inside walls of the pipe and washes them out of the system. The disadvantages of wet electrostatic precipitators are high capital costs, poor performance when flow variations are encountered, and high maintenance requirements (Reed, 1981). Electrostatic precipitation is presently used to remove entrained coal tar and coal tar mist from coke oven gases (Nowacki, 1980).

Combinations of wet scrubbers can be used in series. After removal of the bulk of the oil pollutant droplets in the gas stream by a Venturi scrubber, a plate scrubber can then separate the entrained liquid from the gas stream. Wet scrubbers can be used in front of wet electrostatic precipitators to remove the bulk of pollutants and also to cool the gas stream from 400 degrees to approximately 150 degrees. The ESP unit is more efficient in operation at the 150-degree temperature. The ESP unit is used for the final gas clean-up (Reed, 1981).

The power requirement for electrostatic precipitators and mist eliminators is minimal. The major operating costs are for circulation of the scrubbing medium. Mist eliminators are generally heat expensive, due to high heat loss in the contact chambers. The capital cost of the electrostatic precipitators is the greatest. However, their removal efficiencies are also the highest (Reed, 1981).

We currently plan to use water as a scrubbing medium. The raw gas stream will be saturated with water vapor at the outlet temperature and pressure of the scrubbing system. Water is purged from the scrubbing system and the oil is removed. Soluble components of the raw gas stream will be in the purge scrub water. The purge scrub water is treated before it is released into the environment (Reed, 1981) (Evergreen, 1982).

This review of the scrubbing technologies available adds credibility to the no significant air quality degradation conclusion. The final design of the Biomass Energy Systems, Inc. plant might use any or several of the above methods in its cleanup section.

GAS CLEANUP[1]

	OIL SCRUBBING	WATER SCRUBBING
Disposal of purge liquid	Thermal oxidation with heat recovery of recycle after fractionation	Water Treatment before discharge
Oil droplet removal considerations	Entrainment and saturation of gas stream with oil	Oil entrainment from water
Makeup Quality	Oil might require fractionation to achieve proper boiling range material	Condensate quality water
Metallurgy	Carbon steel equipment is probably adequate if no water condensation occurs	Water will be acidic due to contaminants in the gas: Stainless steel scrubber required
Source of scrubbing medium	Available if oil produced by process can be used; otherwise must be imported	Readily available

[1]SOURCE: Biomass Gasification, T. B. Reed

7.5.1.6 Polycyclic Organic Matter (POM). Perhaps the greatest concern raised by the combustion of wood is particulates, which are a particularly worrisome emission from residential stoves and fireplaces. Industrial boilers and wood gasifiers, however, can employ the technology needed to control particulate emissions.

Condensable organics are a major component of incomplete wood combustion at low temperatures, and polycyclic organic matter (POM) makes up about 5-6 percent of the condensable organics. Since several species of POMs are known carcinogens, many experts consider this hazard to be the most dangerous component of incomplete combustion of wood (OTA, 1981).

Hydrocarbons are formed when fuels containing carbon and hydrogen are burned. The hydrocarbons are a result of incomplete cumbustion (Wilson, et al., 1980). Benzoalphapyrene is used as an indicator of ambient concentrations of potentially harmful hydrocarbons and is a potent carcinogen. Elevated concentrations of benzoalphapyrene have been observed near U.S. cities and are thought to be a result of the great rate of coal burning in these areas, specifically in Pennsylvania (Wilson, et al., 1980).

Benzoalphapyrene , for example, is a polycyclic aromatic hydrocarbon (PAH). Many of these chemicals are known to be carcinogens (Walbott, 1978; Wilson, et al., 1980). Particulate samples taken near coal-fired power generating facilities have demonstrated the presence of PAHs. PAHs are assumed to originate from the stack emissions since their concentrations vary with distances downwind. The condensation of PAH vapors on particulates would also result in this observed phenomenon (Wilson, et al., 1980).

The inefficient combustion characteristic of hand-stoked, open fires of coal, refuse, and wood are the worse producers of PAHs. The largest and most efficient units produce the least emissions of PAHs. Concentrations of PAHs have been falling over the last fifty years (Wilson, et al., 1980).

Again, we are convinced that POMs and PAHs will not be an emission hazard from the gasifier section of the plant, as designed by Evergreen Energy (1982). The wood fired boilers will be more subject to conventional wood boiler emissions and particulates will have to be scrubbed before leaving the stack. We expect the technology and operating efficiency of large size wood boilers to improve significantly in the interval before the Biomass Energy Systems, Inc. plant is constructed.

7.5.2 Water Discharge and Cleanup. Potential water quality discharges from the plant site include construction activities, leaching and runoff from wood and chip storage piles, and process wastes carried as water effluents.

The major wastewater streams will result from condensation water, gas cooling, scrubber and boiler blowdowns, and the mist elimination section if there is such a section. The wastewater from these sources is first evaporated and then the combustible organics incinerated at 1800°F. The incinerator is a thermal oxidizer with a waste heat recovery unit. A packaged water tube steam generator can recover forty-five percent of the heat released from the oxidizing unit (Reed, 1981).

The probable effluents resulting from wood gasification and methanol synthesis have not been described in the literature available to us. They are expected to have a moderate BOD_5 loading (100-1000 mg/l) because of the volumn of organic compounds generated by the process (Mueller Assoc., 1981).

A pilot plant of the Evergreen Energy design (1982) will have to be constructed and operated before a really definitive treatment of this subject is possible. There will be a liquid waste stream requiring proper treatment, processing, and disposal. Techniques will be developed when the need is better defined. We cannot foresee a water quality treatment requirement that would be limiting to the methanol synthesis process or beyond the scope of existing water treatment technology.

DETOXIFICATION OF WASTES

CHEMICAL CLASS	MODEL COMPOUNDS	MICROBIAL SPECIES CAPABLE OF DEGRADING THE MODEL COMPOUND
Phenolics	Phenol	Pseudomonas Putila
Phenolics, Halogenated	Pentachlorophenol	Soil Bacteria
Aromatic Substrates, Monocyclic	Xylene	Pseudomonas Putila
Monocyclic, Halogenated	Fluorobenzoate	Pseudomonas spp.
Bicyclic	Biphenyl	Soil Bacteria
Bicyclic, Halogenated	PCB (Aroclors)	Psuedomonas spp.
Polycyclic	Benzo ( ) Pyrene	Pseudomonas spp.
Alkylated	Dibutyl Phthalate	Breuibacterium spp.
Chlorinated Aliphatics	Trichloroethane	Marine Bacteria
Ether Glycols	Ethylene Glycol	Aquatic Bacteria

SOURCE: "Microbial Degradation of Industrial Chemicals" Water Pol. Micro. VCL II.

7.5.3 Solid Waste. Solid wastes expected from the eucalyptus-to-methanol process are wood ash, unconverted carbon (perhaps), and the sludge from the wastewater treatment plant. The wood ash will vary with the feedstock and the environment in which it is grown; but, a generic composition was developed by the Oak Ridge National Laboratory (1980) and is provided below:

COMPOSITION OF WOOD ASH[3]

Element	Assumed Form	Typical Quantity (% of total ash)
Calcium	CaO	30-60
Potassium	K_2O	10-30
Sodium	Na_2O	2-15
Magnesium	MgO	5-10
Iron	Fe_2O_3	1-2
Silicon	SiO_2	2-7
Phosphorus	P_2O_5	5-15
Sulfur	SO_3	1-5

Note: These figures were determined under conditions that ensure complete combustion and the retention of all ash generated. The percentage composition was calculated by assuming that the elements are in the stated chemical form; the actual chemical forms may be different.

SOURCE: Alcohols From Biomass:, Mueller Associates, Inc., October, 1981

Nature has recycled wood ash over the years with every natural wildfire, and man has repeated the process with controlled burns. We see no reason why the wood ash should not be returned to the plantation at the start of each new rotation, every 7-8 years. Testing of the actual ash will indicate the presence and quantity of heavy metals and other possible toxic or hazardous substances. If they occur, another disposal strategy may become necessary.

Unconverted carbon, if any, may be rerouted back through the gasifier. Landfill disposal should be a viable disposal route for any of the solid wastes anticipated from the process.

We have the greatest uncertainty in predicting the composition of the biological sludge remaining after wastewater treatment. This could be relatively benign or high in a complex of organic species. We have no data available to better project the nature or quantity of this sludge at this time. Projections from the Evergreen Energy gasifier design (1982) indicate that it will not be a problem and can be disposed of in a manner consistent with existing wastewater treatment technology.

7.6 Environmental Impact of Accumulating Carbon Dioxide in the Atmosphere (Greenhouse Effect). Perhaps the major positive environmental impact of the wood-to-methanol energy system is it's recycling of carbon atoms, thereby not adding to the rate of increase of carbon dioxide in the atmosphere. Carbon dioxide is essential for photosynthesis, but high concentrations in the atmosphere could have disastrous environmental impacts. Carbon dioxide releases from man-made sources are becoming an important global pollution problem.

While eucalypts from the Biomass Energy Systems, Inc. plantation (and all green plants) capture CO_2 from the atmosphere, burning of the methanol synthesized at our plant recycles the carbon dioxide once again. However, there will be no net increase in the carbon dioxide content of the atmosphere resulting from the biomass energy gasification system. No geologic sink of carbon, such as a coal mine, has been tapped in producing methanol from wood. Of course, any conventionally powered equipment used in harvesting and transporting wood and methanol would tap a carbon sink for their fuel, thereby adding carbon oxides to the atmospheric cycle.

8.0 ENVIRONMENTAL IMPACTS: METHANOL VS. GASOLINE

Methanol can be used as a gasoline blend (Johnson, et al., 1980). However, methanol apparently increases evaporative emissions through a physical-chemical interaction with gasoline (Kiteradge, pers. comm.). Another problem with methanol blends is phase separation in the presence of water. Methanol will dissolve in water, separating from the gasoline component. Corrosion of certain engine components made of materials susceptible to methanol corrosion also is a potential problem (Paul, 1978). On the positive side, methanol is more efficient than ethanol as an octane enhancer (Johnson, et al., 1980). Sun Oil Company is presently producing oxinol, a methanol and tertiary butyl alcohol additive. Some engine design changes, therefore, may be needed for methanol blends greater than 10-15 percent. The data are contradictory and large scale experimental trials are currently underway.

Methanol can be used in an undiluted form as a motor fuel. On a Btu basis, gasoline has about twice as many Btu's per gallon as methanol. A gallon of gasoline contains approximately 117,000 Btu's, while methanol contains approximately 57,000 Btu's per gallon. However, methanol has properties as a fuel which yields higher performance than the Btu data would indicate. Methanol has a higher octane value (Paul, 1978). This allows for a higher compression ratio. Compression ratios can be as high as 12:1, as opposed to the 18:1 in present unleaded fuel engines. Methanol will ignite and burn smoothly at a lean fuel to air ratio. This lean burn is characteristic of low emissions and high efficiency. The high flame propagation speed of methanol makes it ideal for stratified charge engines. Stratified charge engines give a leaner burn which contributes to efficiency and low emissions (Johnson, et al., 1980).

The Ford Motor Company is concentrating on methanol as the most likely candidate for an alternative fuel in the future. General Motors estimates that it can bring the methanol fuel vehicle on-line as fast as the methanol distribution system is developed (Johnson, et al., 1980).

Additional efficiency techniques are used in methanol engines. Exhaust gases are used to preheat the methanol; and, exhaust gases are used to dis-associate the methanol to hydrogen and carbon monoxide before injection into the combustion chamber. The waste heat, therefore, is used to increase the sensible and latent heat of the methanol fuel (Johnson, et al., 1980). Again, changes in engine design may be necessary to insure the safety of the driver from these recycling exhaust gases and waste heat.

Methanol used as an octane booster would eliminate lead emissions (Paul, 1978) that are the result of tetraethyl and tetramethyl lead additives in gasoline. The toxicity of lead in humans is discussed by (Waldbott, 1978 and Wilson, et al., 1980). No soot or particulates are produced when methanol is burned. Far more nitrogen oxide reduction is possible with methanol fuels than with gasoline. The environmental effects of nitrogen oxides are well documented (Committee on Medical and Biological Effects of Environmental Pollutants, 1977). Nitrogen oxides and sulfur oxides are responsible for "acid rain", which can be lethal to living systems. Carbon dioxide and hydrocarbon emissions also are reduced with the use of methanol instead of gasoline. Thus the "greenhouse" effect, discussed earlier, would be reduced, as would the "smog" cloud over urban areas. Aldehyde emissions increase somewhat, however. The extent to which atmospheric levels of formaldehyde would increase from large scale use of methanol is undetermined. If a significant problem from formaldehyde actually occurs, modifications in the exhaust system can control the aldehyde emissions. The basic toxicology of formaldehyde, a metabolite of methanol, is discussed in the health and safety document.

Petrochemicals release lead, mercury, fluoride, and cadmium into the environment. These are systemic atmospheric poisons that effect numerous organs. These pollutants are emitted from petrochemical users, such as power plants and automobiles. They constitute the greatest public health threat in the human environment at the present time because they accumulate in the human system and contribute to or cause illnesses that develop slowly and insidiously (Waldbott, 1978).

The overall reactivities of emissions from a methanol engine and a gasoline-methanol blend engine are less than that of a gasoline-powered engine (Paul, 1978). The environmental effects of the methanol engine compare quite favorably with the environmental effects of the gasoline-powered engine.

Future Fuels of America, Inc., headquartered in Sacramento, California have an effective ongoing program in converting new cars to operate on 100% methanol. The methanol cars are called "Liberators"; and, they are entering the commercial fleet market as well as the private sector. Future Fuels is planning a network of franchised methanol stations throughout California. The State of California authorizes up to $1,000 per vehicle income tax credit for converting a car to the use of at least 85% fuel grade alcohol. These are the strongly positive incentives and mechanisms necessary to convert a part of the automotive fleet from gasoline to neat methanol. Biomass Energy Systems, Inc. anticipates within Florida commercial fleet use of most, if not all, of the methanol produced from eucalyptus in its plant.

9.0 WOOD GASIFICATION/METHANOL SYNTHESIS VS. COAL GASIFICATION AND LIQUEFACTION: A COMPARISON OF ENVIRONMENTAL EFFECTS

Within Florida, coal is the primary competitor of the eucalyptus energy system. Florida is moving strongly to increase coal usage, particularly for electrical generation and the replacement of industrial uses of natural gas. Many of Florida's environmentalists are concerned about the potential degradation of air and water quality which may accompany massive increases in coal combustion. Because of our concern for the Florida environment and wood fuel's competitive interface with coal, we have drawn on the current literature to compare the possible environmental impacts of the two energy systems.

In comparison to coal, biomass is an environmentally clean technology (Reed, 1981; Abelson, 1981). The biomass energy system also compares favorably in terms of environmental impacts with the development of oil shale. Once the environmental costs of coal and oil shale have been tallied, the economic balance could well tip in favor of the wood-to-methanol technology (Reed, 1981). The environmental costs of coal and oil shale development are many and include strip-mining.

Overall, the environmental controls required for coal and shale oil development are far more costly than the environmental controls required for the safe and clean development of biomass energy systems (Nowacki, 1980).

9.1 Impacts of Mining for Coal and Oil Shale. The adverse impact of strip-mining, especially in the West where the majority of the coal and oil shale deposits exist, is well known. The delicate water balances of the hydrologic cycles in the West are particularly susceptible to strip-mining. It is not known whether reclamation can replace the hydrologic cycles in such strip-mined areas. Reclamation of strip-mined areas in the American West with native vegetation has proven to be difficult. Permanent reclamation of strip-mined areas in fragile ecosystems has not been accomplished on other than a trial basis. Acid mine drainage, a leachate through coal/oil overburden in strip-mining and from deep mining, has impacted severely on surface water and vegetative restoration in many coal mining areas. Except for once every 25-50 years, no major land disturbance is required on eucalypt plantations because coppice stands will replace the original logged trees. After 6-7 years, the coppice-growth trees can be harvested again. At least three harvests should be possible before replanting. In fact, the ash from the methanol gasifier will be used to fertilize the coppice stands after each harvest. As mentioned earlier, trees have an environmental "cleansing" ability, and a eucalypt plantation may actually improve Central Florida's geologically new, poor soils, particularily by adding detritus and building humus.

9.2 Suitability for Gasification, Wood Vs. Coal. Because of its chemical makeup, woody biomass is particularly suited for gasification and the subsequent synthesis of methanol from synthesis gas. Not only does biomass gasification require less environmental control, but it is simpler, technically. Wood contains its own oxygen and water, and these two elements are important in forming the gaseous molecules from hydrocarbon feedstocks for the production of synthesis gas. The hydrogen to monoxide ratio for synthesis gas should be about 2 to 1. Wood has a relatively high hydrogen to monoxide value in its raw gas make up, and this reduces shift requirements downstream towards the methanol synthesis. The hydrogen to carbon content of biomass for syngas production is about 1.5. The hydrogen to carbon content of coal is more on the order of 1.0 (Reed, 1981).

A much greater change in composition is required for the conversion of coal to gas than the conversion of biomass. Low pyrolysis temperatures and high concentrations of volatiles in biomass make it easier to burn. While coal typically contains between 10 to 40 percent volatile matter, biomass contains between 70 to 100 percent volatile matter. Wood is more easily gasified than coal, and the temperature of gasification is about 700 degrees centigrade. Much higher temperatures are required for the gasification of coal (Reed, 1981).

9.3 Availability of Feedstocks for Conversion to Synfuels. In Biomass Energy Systems' proposed Florida setting, coal is not immediately available in large quantities and must be transported long distances. As much as one million acres of suitable land are available for eucalyptus cultivation in the study area. The close coordination proposed between the biomass energy plantations and the gasification-methanol synthesis plant(s) will insure a constant supply of immediately available wood feedstock in the vicinity of the plant. The area proposed for the biomass energy system is crisscrossed with railroads originally installed to service phosphate mining in the Central Florida district. The tens of thousands of acres of phosphate mined land in Central Florida are particularly suited for reclamation with biomass energy plantations. The plantations will provide a constant and renewable supply of energy. The primary plant site location is on mined land in southwestern Polk County.

9.4 Sulfur Oxides and Metals. Relative to coal, biomass is very low in sulfur content. Wood rarely has more than a trace of sulfur in its composition. Therefore, sulfur oxides formed in combustion will be far less with biomass than with coal. Sulfur oxides from the combustion of biomass will be negligible. Sulfur oxides formed in the combustion of biomass can be easily and economically removed from the waste streams (Reed, 1981). Coal conversion mobilizes toxic trace metals, and coal tars have been shown to be highly carcinogenic (Hunter, 1969; Reed, 1981). Shale oil itself, the product oil, was observed to be carcinogenic as far back as 1910 (Hunter, 1969).

The sulfur content of biomass is on the order of less than one-tenth of one percent. The sulfur content in coals is on the order of two to four percent. Another advantage of the low sulfur content of biomass is that the potential for catalyst poisoning in the methanol process is much reduced due to the low content of sulfur in the gas stream.

RANGE IN AMOUNT OF TRACE ELEMENTS PRESENT IN COAL ASHES (ppm)

Element	........Anthracites.........			..Lignites and Subbituminous..		
	Maximum	Minimum	Average (5)*	Maximum	Minimum	Average (13)
Ag	1	1	**	50	1	**
B	130	63	90	1,900	320	1,020
Ba	1,340	540	866	13,900	550	5,027
Be	11	6	9	28	1	6
Co	165	10	81 (4)	310	11	45
Cr	395	210	304	140	11	54
Cu	540	96	405	3,020	58	655
Ga	71	30	42	30	10	23 (12)
Ge	20	20	**	100	20	**
La	220	115	142	90	34	62
Mn	365	58	270	1,030	310	688
Ni	320	125	220	420	20	129 (8)
Pb	120	41	81	165	20	60
Sc	82	50	61	58	2	18 (10)
Sn	4,250	19	962	660	10	156
Sr	340	80	177	8,000	230	4,660
V	310	210	248	250	20	125
Y	120	70	106	120	21	51
Yb	12	5	8	10	2	4
Zn	350	155	**	320	50	**
Zr	1,200	370	688	490	100	245

*Figures in parentheses indicate the number of samples used to compute average values.

**Insufficient figures to compute an average value.

SOURCE: DOE/HEW/EPA-01. Aproximate analysis of eucalyptus wood is provided in Working Document 7 (Davy McKee, 1981).

9.5 Gasification Impacts. Many biomass gasifiers currently in use produce raw gas streams consisting mainly of carbon monoxide and hydrogen. However, minor amounts of methane and higher molecular weight hydrocarbons, sulfur compounds, tars, and oils also are produced in the raw gas stream. The Texaco gasifier we intend to use eliminates the tar and oil problem. These improved designs (Reed, 1981) result in the nearly complete combustion of the biomass feed, which greatly reduces or eliminates the formation of undesirable hydrocarbons (Reed, 1981; Wilson, et al., 1980). The raw gas stream will be saturated with water vapor at the outlet temperature and pressure of a scrubbing system. Soluble components of the raw gas stream will be in the purge scrub water. The purge scrub water is treated before it is released into the environment (Reed, 1981). Sludge from the water treatment plant will be returned to the forest floor if of sufficient quality. Otherwise, it will be suitable for landfill disposal. The possibility exists for wastewater irrigation of the greenhouses; or, for upland disposal in the eucalyptus forest.

The costs of purifying the gas stream, in the case of wood, are far less than with coal. After gasification, wood leaves less than two percent ash by weight; whereas, the ash residue from coal combustion ranges between five and twenty percent. Furthermore, coal ash is large in volume per unit weight because of the high throughputs required in the industrial process. Coal ash also contains many toxic materials and is a disposal and reclamation problem in itself. Wood ash, in fact, will be used as a soil amendment on the plantation, whereas the vastly greater quantities of coal ash potentially are hazardous wastes. With a properly run gasifier, there should be few, if any carcinogenic tars or oil byproducts (Reed, 1981).

9.6 Water Consumption and Quality. Water must be prudently conserved in Central Florida. Excessive water usage has led to saltwater intrusion into freshwater aquifers along both coasts. Floridan aquifer levels remain severely depressed from recorded highs. The need for air scrubber water and scrubber water cooling largely are eliminated by the Texaco gasifier system. Economics in equipment and water usage are made in pump and compressor seal cooling, surface condensers, liquor treating, acid gas removal, and producer gas compression. A small scale cooling tower will have smaller water losses to evaporation.

The major wastewater streams in the wood gasification/methanol synthesis plant will result from condensation water, gas cooling, and the mist elimination section. The wastewater from these sources is first evaporated and then the combustible organics incinerated at 1800°F. The incinerator is a thermal oxidizer with a waste heat recovery unit. A packaged water tube steam generator can recover forty-five percent of the heat released from the oxidizing unit (Reed, 1981).

With coal, on the other hand, process waters originate from the following: moisture in the coal; water of constitution or decomposition; water added for stoichiometric balances; by-product recovery; and gas scrubbing. The principal source of pollution is the process waters. The process waters are expected to be similar in chemical make up to ammonia liquor from coking industries (Nowacki, 1980).

The process water which is not discharged is biologically treated. However, some chemicals present in ammonia liquor are refractory, and some may be detrimental to bacterial survival. These include heavy metals, cyanide, halogenated compounds, phenols, mercaptans, and thiourea (Nowacki, 1980).

The gas liquor liquid waste stream from coal conversion contains tars, oils, phenols, ammonia, particulates, carbon dioxide, hydrogen sulfide, chloride, sulfate, cyanide, and pherrol cyanide. Also observed were the following elements: antimony, arsenic, boron, bromine, cadmium, chlorine, lead, mercury, and nickel. Fugitive tars also will occur in the wastewater stream, along with: (1) phenols, alcohols, and their methylated derivitives; (2) pyridines, quinolines, indolines; (3) polycyclic, aromatic hydrocarbons which may be absorbed by particulates; and (4) hydrogen fluoride, fatty acids, trace organics, and trace elements. Since it is not economically or technically feasible to recycle all wastewaters for process consumption, severely polluted aqueous discharges are probable (Nowacki, 1980). The costs of clean-up prior to discharge could be sufficiently high to render the methanol-from-coal processes noncompetitive.

9.7 <u>Impacts from Feedstock Storage and Preperation</u>. Raw material handling and pretreatment involves the storage, handling, chipping, and milling of the wood feedstock. The dust and fines generated in the chipping and milling operations do not carry the burden of carcinogenic materials in the form of polycyclic, aromatic hydrocarbons as do the equivalent operations in the coal conversion plants (Reed, 1981). Much of the chipping will occur at the harvest site.

There are minimal adverse environmental impacts associated with the storage and milling of eucalyptus feedstock. The hogging operation chips and mills the wood into small pieces to make a more uniform feed to the gasifier. Efficient operation of the biomass gasifier requires that the green wood be dried before use as fuel for the gasifier. Drying continues once the tree is cut through the transportation and storage interval. Correct moisture content of the biomass feedstock to the gasifier enables the gasifier to be run at higher efficiencies, since the higher heating value to the biomass feed has been adjusted to optimum conditions (Reed, 1981). Wood particles will be dried to 15 percent moisture before being fed into the gasifier.

As mentioned, fugitive dust and noise are expected from the ongoing processes at the facility. A significant drying will occur in the wood yard, aided by stockpiling systems and the tendency of stems to split into many deep fissures. We will have a 4-6 month supply of logs in the plant yard and forest. We also expect to employ a flasher dryer, using exhaust gas as a drying agent. Counter-current flow of the hot gases over the chips would be an efficient use of energy in this type of system (Karchesy and Koch, 1979). The production of hot gases for use in the dryer will consume about six percent of all the wood dried (Karchesy and Koch, 1979).

In contrast to wood feedstock storage, the stockpiling of coal creates serious environmental pollution problems. Coal dust and fines can be blown off the stockpiles with their toxic leachates, settling out in the surrounding environment (Wilson, et al., 1980). A biomass energy plantation intrinsically is an effective air pollution scrubber, particularly useful in the removal of particulate matter from the air (Smith, 1981). In fact, eucalypt plantations could be used as buffer zones around coal stockpiling areas as an effective mitigative treatment.

The leachate from unburned coal contains many toxic substances. Among these toxic substances are: arsenic, barium, beryllium, cadmium, chromium, lead, mercury, and selenium. The leachate has an extremely low pH, and therefore will solubilize and mobilize toxic and hazardous heavy metals. Additional environmental havoc would be caused by aluminum, copper, iron, nagnesium, titanium, and zinc, all of which are present in the leachate (Nowacki, 1980).

Coal storage leachate poses a serious pollution potential for adjacent surface waters. The runoff water from coal storage areas requires collection, neutralization, demineralization, ion-exchange filtration, and a settling basin (Nowacki, 1980). The technology of ion-exchange filtration, a necessary part of the detoxification program for this waste stream, is not well developed on an industrial scale.

Groundwater supplies will be polluted by coal stockpile leachates wherever there are opportunities for seepage of contaminated water on-site. A more serious threat to groundwater supplies, however, would be the leachate from fugitive dust and fines which escape the coal plant boundries. As dust and fines settle, they will leach toxic substances. Should groundwater supplies become polluted, the surrounding community will be burdened with the additional expense of having to treat their water supply for the new pollution load. Depending on the nature of the toxic pollutants, technology for their removal from potable water supplies may or may not exist. Even if the technology did exist, it could prove prohibitively expensive. The result would be the loss of the groundwater resource. Groundwater resources in Florida are at a premium. Competition by various users is fierce. Loss of aquifer services due to toxic pollution could not be tolerated.

Finally, stockpiled coal must be processed before use in the synthetic fuel power plant. Coal washing results in an aqueous waste that must be collected, neutralized, demineralized, put through an ion-exchange filter, and settled. The settled sludge is a hazardous waste and will threaten groundwater supplies. Coal crushing and conveyance releases dust and fine particles. Cyclone separators, fabric filters, negative pressure grinders, wet scrubbers, and electrostatic precipitators are among the technologies required to control coal dusts and fines (Nowacki, 1980).

In summary, there is good evidence that wood gasification/methanol synthesis processes pose fewer and less serious environmental problems than the fossil fuel feedstock alternatives. Much of the waste in the wood-to-methanol processes are recycled. Proper design, maintenance and safety procedures can result in minimal environmental impact from the wood-to-methanol system.

9.8 Solid Wastes from Coal Processing. Solid wastes generated by coal technology are enormous in magnitude in comparison with biomass solid wastes (Wilson, et al., 1980; Nowacki, 1980; Reed, 1981). The concentrations and variety of toxic metals in coal ash far surpass those found in wood ash (Comar, 1975; Walbott, 1978; Joensuu, 1971; Reed, 1981). Arsenic has been found in coal ash leachate (Turner, 1981).

Pond effluents from twelve coal ash disposal systems were observed to contain quantities of total dissolved arsenic from less than 0.5 to as much as 150 micrograms per liter. In fact, the more toxic trivalent oxidation state accounted for from less than three percent to as much as forty percent of the dissolved arsenic in the pore water. In one instance, the pore water from the saturated zone in the ash pile contained about 1,000 micrograms per liter of arsenic, with most of this arsenic in the most toxic trivalent form (Turner, 1981).

Refuse from coal cleaning consists of rack mineral matter and coal particles. Other major solid waste streams consist of ashes, slags, and chars from the conversion process. Ash and slag are made up of metallic oxides and trace element compounds. The coal and char particles contain organic and mineral materials, and the waste treatment sludges resulting from raw-gas scrubbing and other environmental controls will contain mixtures of coal-tar residues, sand, coal fines, treatment by-products, and untreated quantities of organic molecules, some of which are toxic materials (Nowacki, 1980). R. R. Colwell and G. S. Sayler (1978), in their article, Microbial Degradation of Industrial Chemicals, warn of the following:

> Increased use of coal and coal conversion products threaten to contribute yet another class of contaminants to the aquatic environment. The significant of which are the polysiclic aromatic hydrocarbons. Although commonly encountered in nature, polysiclic aromatic hydrocarbons (PAH) arrising from increased applications of coal technology, will concentrate in the environment to levels significantly above naturally occurring concentrations. Unfortunately, PAH's are compounds that are potentially mutagenic and their ecological impact is relatively unknown.

Coal ash contains mercury, cadmium, arsenic, selenium, and flourine. Although these elements and their compounds are volatile, they are more likely to be associated with the fly ash in airborne particulates cleaned from the raw gas stream. These fly ash and airborne particulates are solid waste streams which eventually must be disposed of (Wilson, et al., 1980). Coal ash leachate from a Lurgi process gasifier has had measured pH's over a range of 3 to 10 (Nowacki, 1980). In all leachate samples tested, the following elements exceeded recommended levels: boron, calcium, cadmium, potassium, manganese, ammonia, lead, and sulfate (Dallaire, 1981).

In the coal liquefaction process, ash and slag are produced under pressure in the reducing environment. The mineralogy and chemical form of the waste stream chemical species may effect the solubility of some elements in the ash. Solubilization will increase their mobility consequently making them more hazardous (Nowacki, 1980).

Other solid effluents include spent catalyst, spent sulfur guard reactor absorbants (such as zinc sulfide and elemental sulfur), sludges from flu gas desulfurization (such as calcium sulfite and calcium sulfate), and sludge from evaporated aqueous process condensates (Nowacki, 1980).

9.9 Fly Ash from Coal. The fly ashes of coal approach being considered hazardous. Utility industry fly ash samples have been shown to contain in their leachates heavy metal concentrations which are 10 to 50 times drinking water standards (Dallaire, 1981). This means that some coal fly ashes could be considered hazardous wastes. In any case, the fly ashes are found with the other concentrated toxic metals and refractory organics in the settling ponds (Nowacki, 1980). These settling ponds constitute a huge concentration of toxics perched over the water table.

9.10 Control of Air Emissions from Coal Conversion Technology. The control of air emissions is most difficult when dealing with coal conversion technologies. The emissions have not yet been definitely characterized, acceptable emission levels have not been determined, and the adequacy of available control technology is not known. The air emissions originate from a variety of sources: (1) raw material handling and pretreatment, (2) vent gases from start-up, (3) shut-down, (4) lock-hopper operation, (5) byproduct recovery, (6) storage and upgrading, (7) waste treatment, (8) acid gas removal, (9) sulfur recovery, (10) catalyst regeneration, and (11) power generation. Fugitive air emissions also will escape from valve stems, flanges, loading racks, equipment leaks, pump seals, sumps, etc. Operation under great pressure increases the potential for fugitive emissions (Nowacki, 1980).

Sulfur dioxides result from sulfur recovery, plant tail gas, and stack gases of auxiliary combustion systems. Carbonyl sulfide and carbon disulfide can pass through the sulfur recovery traps.

If an amine process is used in acid gas removal, ambient concentrations of aminos may react with nitrogen oxides to form nitrosomines (Nowacki, 1980). Nitrosomines are carcinogens (Walbott, 1978). The inefficiencies of the sulfur recovery traps will be much more significant in the case of coal with its greater initial sulfur content than in the case of biomass.

Overall coal liquefaction effluents will differ from coal combustion effluents. Liquefaction effluents are in the reduced rather than the oxidized state. The fate of trace elements through coal conversion may be different from that evidenced by coal combustion. Arsenic, beryllium, mercury, selenium, cadmium, fluorine, and lead are toxic and volatile elements which are expected to volatilize during coal conversion, resulting in possible fugitive emissions (Wilson, et al., 1980; Walbott, 1978; Nowacki, 1980). The majority of the heavy metals are expected to end up in the solid waste stream in byproducts, such as ash, chars, and filter cakes (Nowacki, 1980).

9.11 Pollutants in the Product Oils of Coal Conversion and Shale Oil. The product oil resulting from coal conversion can contain titanium, beryllium, copper, cobalt, and lead. The heavy metals may be in the form of organic complexes. Also contained in the product oil of coal conversion can be significant amounts of particulate material including arsenic, antimony, boron, fluorine, and tellurium (Nowacki, 1980). Mercury, selenium, cadmium, lead, arsenic, and beryllium are all volatile, toxic (Walbott, 1978), and are in the list of trace metals found in Synthoyl (Nowacki, 1980). Other trace metals found in synthetic oil from coal liquefaction are silica, iron, aluminum, potassium, sodium, calcium, magnesium, molybdenum, and cobalt.

Polycyclic aromatic hydrocarbons (PAH) are present in the product oils of coal and shale oil liquefaction (Colwell and Sayler, 1978). The following PAHs were found in coal liquefaction synthetic product oil: phenanthrene, 413 parts per million; benzo (alpha) anthracene, 18 parts per million; and benzo (alpha) pyrene, 41 parts per million (Nowacki, 1980). These are carcinogenic organic molecules (Walbott, 1978; Wilson, et al., 1980; Colwell and Sayler, 1978). Concentrations of PAHs in the heavier fractions of the product oil are expected to exceed that of petroleum products. The distillate fuel oils which boil between 200 and 450 degrees centigrade, produced by coal hydrogenation and coal pyrolysis, will contain high concentrations of PAHs. These product oils no doubt will be more carcinogenic then the equivalent petroleum fractions in the same boiling range (Nowacki, 1980). Ten to one hundred times the levels of polynuclear aromatic compounds occur in product oil than in smoke. While condensed tobacco smoke only contains one part per million of benzo (alpha) pyrene, a carcinogen, concentrations in coal derived products range from forty to fifty parts per million (Nowacki, 1980).

9.12 Conclusion. Clearly, the environmental clean-up costs of coal conversion to liquid fuels is much higher than those for the wood-to-methanol system. The use of wood as a fuel to replace coal well may prove to be highly beneficial for the Florida environment as well as cost effective. The public and those controlling state and federal energy policy need to recognize that the eucalyptus energy system offers a viable alternative in Central and South Florida to coal, an alternative likely to carry a lower environmental price tag.

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