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ANNEX II

GASIFIERS FOR IRRIGATION SUBPROJECT

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ANNEX II

GASIFIERS FOR IRRIGATION[1/]

I. BACKGROUND

The Farm Systems Development Corporation (FSDC) was created in 1975 as an autonomous, public corporation established to promote the organization and support of farmer irrigators associations and other farm-based associations. The corporation's purpose is to increase agricultural productivity, raise farmer incomes and promote rural development.

FSDC administers the Barangay Irrigation Service Association (BISA) program, a multifaceted rural development effort whose entry point is irrigation. The BISA program establishes irrigation organizations called Integrated Service Associations (ISAs), each composed of about 60 farmers. FSDC provides ISAs with technical and financial assistance to enable them to own and become capable of operating, maintaining and repairing pump and gravity irrigation systems, and to use other farm support packages.

FSDC's assistance program for ISAs entails the following principal elements: (1) organization and registration of ISAs; (2) initial training of ISA farmers and members of farm families; (3) financial and technical assistance in the construction of irrigation systems; (4) farm systems technology development (i.e., the efficient use of all on-farm resources in efforts to increase farm income); and (5) continuous follow-on training courses.

To date, the FSDC has organized, extended loans to, and helped develop approximately 1,800 farmer-owned ISAs representing some 94,000 farmers. FSDC also provides training assistance to enable the farmers to operate, maintain and manage their irrigation associations.

The irrigation program covers 140,000 hectares with the construction or rehabilitation of about 1,800 pump and gravity systems. Of the total number of systems, 272 are electrically driven where power is available, and 466 are diesel engine driven at sites where the local electric cooperatives have not extended powerlines. These ISAs have been the recipients of continuing education and training programs for adaptive farm technology packages including farm mechanization and collective management schemes for different farming activities.

1/ Gasification is the process of which converts solid carbonaceous fuel (wood, charcoal and some agricultural residues) to a gaseous fuel, usually known as "producer gas." A gasifier is the equipment performing the process.

The program's success has been threatened in recent years, however, because of ever spiraling diesel fuel costs which increased operation and production costs. These increases have two immediate negative effects: (1) reduced production because ISAs cannot afford to purchase the fuel necessary to operate at maximum levels; and/or (2) reduced profits to a level that makes loan repayment difficult. Through its evaluation and R&D programs, the FSDC implemented two efforts to respond to the energy problem. The first, beginning in 1979, was experimentation with alternative energy technologies and systems (windmills, photovoltaics and producer gas) for small pumps and the second effect, beginning in 1980, has been the shift from small pump systems to gravity irrigation systems, of which 1,062 systems were completed by December 1981.

This subproject of the AID-assisted Rural Energy Development Project will reduce diesel fuel use through the application of gasifier units to diesel engine driven pumps using woodchips, an indigenous renewable resource.

Gasifier technology in the Philippines was revived by the University of the Philippines (UP)/College of Engineering (it had been used extensively during World War II by the Japanese and Filipinos) in a project funded by the National Science Development Board and the AID-supported Energy Research and Development Center. FSDC began testing gasifier applicability in its irrigation projects based on the positive results of tests by the University of the Philippines. FSDC testing was done in cooperation with U.P. and funded under the AID assisted Small Farmer Systems I Project No. 492-0301. By mid-1979, five units were installed on FSDC's demonstration farm. This was followed by 12 pilot projects (one per region) designed to further test field applicability and to prepare a technology package for nationwide full-scale application. Twenty-five gasifier units were used in these pilots.

Having proven the viability of the technology, FSDC was mandated by Executive Order (EO 655 and 673) as the lead agency to implement a program applying gasifier equipment for irrigation and other farm-related purposes. FSDC then established a subsidiary, the Gasifiers and Equipment Manufacturing Corporation (GEMCOR) to produce the equipment required to help meet ISA needs. GEMCOR is also mandated to design models for use in rice mills, power generation and other farm equipment, and to demonstrate the applicability and acceptance of the technology, in order to encourage private groups to start manufacturing and marketing gasifiers on a commercial scale. (See Appendix B, GEMCOR.)

The gasifier conversion program will help accelerate GOP efforts to institutionalize gasifier technology use in rural economic activities. The Gasifiers for Irrigation subproject will provide funding for the application of gasifiers to diesel engines now operated by the ISAs plus new pumps being installed. The subproject's objectives are: (1) to promote gasifier use and ensure the continuous economic operation of pump irrigation systems and farming activities organized and operated

under the ISA program; (2) to generate new employment opportunities for farm families within the ISA locality by establishing woodlots to supply woodfuel needs to gasifier-run irrigation systems; (3) to promote maximum acquisition and application of the technology through a lending scheme; and (4) to increase the income of small farmers through higher net profits arising from reduced production costs.

AID participation in the FSDC gasifier conversion program will be through the Gasifiers for Irrigation Subproject of the Rural Energy Development Project. The subproject will facilitate funding for conversion equipment and development of woodlots at an estimated 495 sites. Further, technical assistance and training will be provided under a separately ESF funded Project Design Fund described in Section II, D. and Annex I, Appendix D.

II. SUBPROJECT DESCRIPTION AND SPECIFIC ANALYSIS

A. General

The overall goal of this subproject is the conversion of all FSDC-assisted diesel engine driven pump irrigation systems to combined producer gas/diesel fuel operations. This will involve 495 ISAs 1/ with a total membership of 26,000 farm families. It will cover a service area of 46,000 hectares, and require approximately 1,150 units of gasifier equipment. In order to ensure woodfuel availability for two pump sets and to avoid further deforestation, each ISA will develop and operate a small energy woodlot of approximately 6 hectares. To accomplish its goal, the program will be incorporated into present ISAs by making minor structural changes: (1) current engine pump operators will be trained to use and maintain the gasifier equipment, and (2) the addition of approximately 3 new members to form a Fuel Production Unit (FPU) in each ISA.

The gasifier conversion subproject offers packaged assistance to ISAs consisting of technical, financial and institutional support from FSDC through its field implementing units and GEMCOR and other suppliers. The subproject approach is patterned after the BISA program framework and will support FSDC's program of institutional development, financial assistance, and technical assistance.

(a) Institutional Development - This includes assistance in needs assessment, project planning and development of management systems for acquiring, operating, maintaining the gasifier equipment, fuel production and collection, as well as sharing in the financial obligation for repaying equipment and energy woodlot loans. Continuing education and training will be provided, as necessary, to effectively maintain the project.

1/ This includes the 466 currently operating on diesel, plus 29 new diesel systems scheduled on-line this year.

(b) Financial Assistance - The FSDC will extend loans to the ISAs to purchase gasifier equipment to convert current diesel driven pump systems and to establish small-scale energy woodlots. The gasifier loan will be made at the time of purchase. The woodlot loan will be spread over the three-year development of the woodlots for materials and labor for participating farmers-beneficiaries. This assistance will go to ISAs owning existing diesel systems which can be converted and new ISAs planning to install diesel operated systems within the year.

(c) Technical Assistance - FSDC, through GEMCOR, will supply gasifier equipment to requesting ISAs and train equipment operators and provide post sales service. In order to ensure a steady supply of fuel, FSDC will arrange training and technical assistance in planting, maintaining and harvesting various fast-growing tree species in marginal lands adjacent to the ISA area.

B. Gasifiers Technology - Operation and Feasibility

In order to address the ISAs' increasing energy problem, the FSDC turned to the gasifier as a technology using an available alternative energy source (biomass) readily adaptable to existing facilities. It concluded this choice would be the least expensive in terms of equipment costs and is an excellent substitute for diesel oil. Furthermore there is an abundance of biomass potential, and gasifier technology is known widely, having been used in Europe in the early 1900s and extensively used during World War II in the Philippines, Japan, Europe, Brazil, China and Australia. Commercial models with application for furnaces, boilers and stationary engines are currently being manufactured in the U.S., Germany, Sweden, France, Italy, Japan, U.K. and the Philippines. In addition, most of these countries have also developed prototypes for use in more complex systems, such as transport and farm vehicles.

FSDC has been testing the application of gasifiers to irrigation systems since 1979. At that time 5 units of diesel engines driving centrifugal pumps, and fitted with improved gasifiers, were installed at the FSDC testing site in Bulacan. All units, ranging in size from 10 to 60 horsepower were run continuously to generate performance data and ascertain fuel savings during dual fuel operation. At the same time, farmers who were recipients of similar diesel engine driven pump irrigation systems were invited to assess and receive training on the technology. Based on the farmers' recommendations, further improvements in design and operation were included, and pilot projects, designed to further test field applicability and prepare a technology package for nationwide full-scale application were started at twelve regional sites. These pilots have been using twenty-five gasifier units for 1 to 2 years, depending on the site, to test performance and to demonstrate the technology to local farmers. The units have all logged over 500 operating hours, with 10 units in the 800 to 2,500 hour range.

Results on the test and demonstration units, and initial runs for the pilot installations show that savings of diesel fuel oil can range

from 50 to 80% with a corresponding operating cost savings of 30 to 50%. However, as expected, a derating in the known output ranging from 5 to 15% was noted depending on rpm levels during operation.

Technically, gasification is the thermal decomposition of biomass or carbonaceous materials into a combustible gas typically known as "producer gas". The reactor used for producing the gas is called a gasifier. Producer gas, consists mostly of carbon monoxide (CO), hydrogen (H_2), and the incombustible components: carbon dioxide (CO_2) and nitrogen (N_2). The concentration of each one of these gases can vary depending upon the feedstock, equipment design and operating conditions.

The gas is extremely applicable to use in diesel or gasoline engines, because it has a relatively low heating value and may be cleaned and burned in a diesel engine in combination with a small amount of diesel fuel. Experiments in several countries for using this process on a commercial scale have used feedstocks ranging from woodchips to corn cobs and cotton gin trash. Gasifier system size is normally dictated by available engines rather than by gasifier capacity. Operating a manually fed, gasifier engine-pump system is a relatively easy operation. The gasifier itself has almost no moving parts and operates at near ambient pressure. Stack emissions are relatively low, and the inert ash by-product can be readily disposed of in the energy woodlots or rice fields.

With reasonable maintenance, it demonstrates no failure characteristics. If, for some reason, the gasifier unit is shut down, the diesel engine can continue to operate.

A complete gasification unit has three major components: the reactor; the gas cleaning train; and the piping and mixing box (Figure 1).

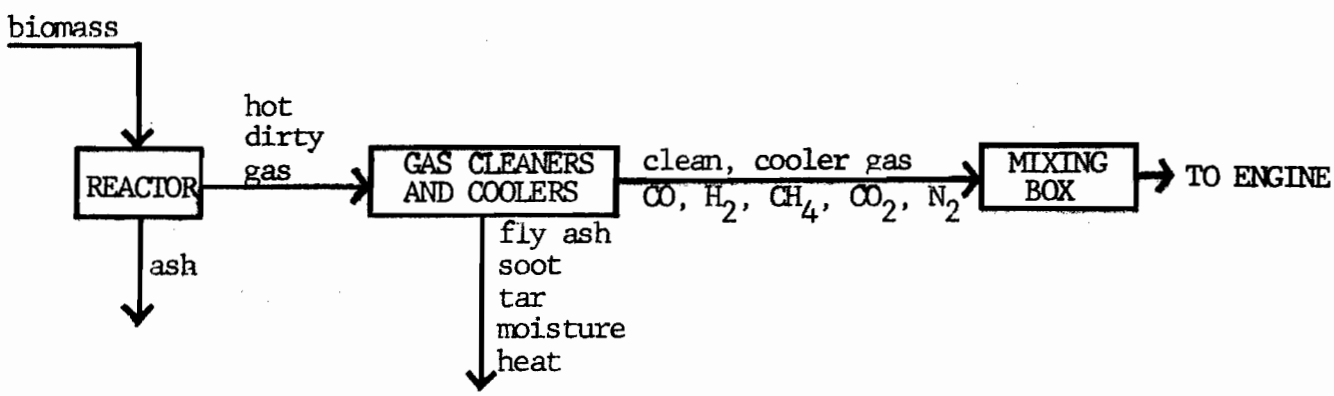


Figure 1. Block Representation of Gasifier System

A diagram of this system applied to an irrigation pump is shown in Figure 2. An explanation of the system follows below.

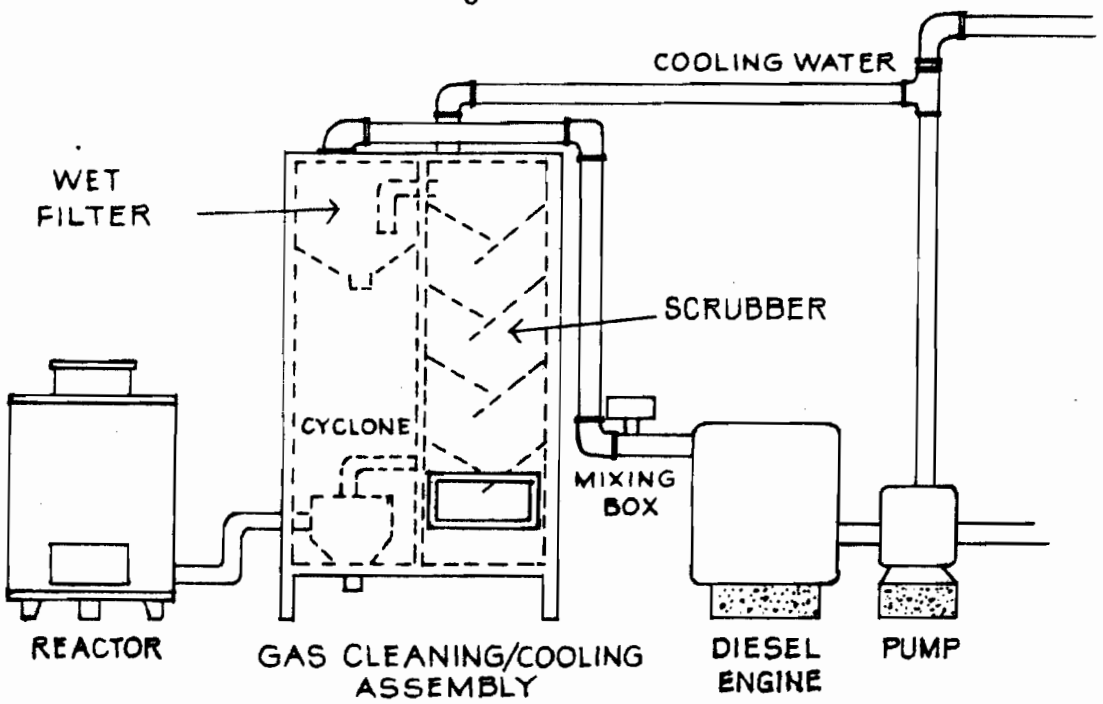


Figure 2. Gasifier for Irrigation Unit

In a typical producer gas unit for irrigation, woodchips are batch fed into a down-draft reactor where they are slowly burned. The down-raft reactor reduces the concentration of tars and oils in the gas to less than 10% of that in gas produced in updraft gasifiers. In addition, since the down-draft design results in relatively low gas velocities, the ash settles through the grate, and thus a very small percentage is carried over with the off-gases.

The gas then passes through a series of cleansing and cooling devices. The gas cleaning train, consists of a cyclone filter, a wet scrubber and a wet filter (or impingement filter). The cyclone removes suspended particulate matter by centrifugal force. It is equipped, with a drain system in order to empty its contents periodically. In the wet scrubber, water is used to remove soluble matter from the gaseous streams. It is of the counterflow type, and is equipped with a sight glass and overflow channel. The wet filter uses diesel fuel to further remove residual contaminants. In addition to purification, the cleaning train also serves to cool the gas. Ideally the gas should be cooled to an ambient temperature in order to optimize the engine's output.

The gas passes to the "mixing box" located next to the diesel engine air intake. Two valves within the box are connected to the accelerator lever--one valve controls air flow while the other controls the gas flow. The gas is then mixed with diesel fuel and enters the engine.

Producer gas, when used in diesel engines, offers several advantages: minimal engine modification; displacement of up to 80% of diesel fuel; higher engine thermal efficiency than on pure diesel; and a cooler and cleaner engine exhaust.

Implementation of the gasification systems will involve the training of the existing two man pump operating team to feed, operate and maintain the gasifier.

C. Energy Woodlots - Operation and Feasibility

Development of the woodlot and chip production will be the responsibility of the ISA's new Fuel Production Unit (FPU). The woodlots will be developed on marginal lands adjacent to the paddy fields. In addition to fast-rotation tree species, the woodlots will be intercropped with grains, vegetables, camote or peanuts for use or sale by the farmers. Intercropping of some fruit trees may also take place. The woodlots will be planted with fast-growing species (preferably leguminous for soil improvement) best suited to individual sites. In most cases the trees will probably be Leucaena leucocephala. The lot will be divided into three sections and operated on a three-year cycle. Approximately 3 currently unemployed or underemployed farmers (who become new ISA members and comprise the FPU) will be employed in clearing, planting, maintaining, harvesting and chipping. Because of the woodlot's proximity to the rice fields, transportation of the wood to the gasifiers is quite simple. Trees will be cut and skidded from the lot directly to the gasifier unit which, in most cases, will be only a few hundred meters away. The chipping will be done by bolos and axes.

During periods when the rice fields are not being irrigated, the farmers will maintain the woodlots, harvest trees, and continue to produce woodchips in preparation for the approaching cropping season.

The cost of developing the woodlots, about ₱3,500 per hectare, will be covered by a loan from FSDC to the ISA. The ISAs will start planting the woodlots as a first step in the conversion program in order to develop their fuel supply while awaiting equipment delivery. Locally available wood, charcoal and some agricultural wastes will be used for fuel while the woodlots are maturing.

FSDC will provide technical, managerial and financial training to the ISAs and the new members as follows: equipment operation and maintenance to the newly assigned gasifier operators, tree production techniques for the new families responsible for the woodlots and the chipping; managerial training for woodlot operations and synchronizing fuel production with irrigation requirements; and a financial system for loan repayment.

There is extensive experience in the Philippines and elsewhere in developing and managing small woodlots on a continuous basis as proposed here. Sufficient data are available from other programs and research results to indicate that an assumed standard Leucaena growth rates of 25 MT per hectare per year is clearly reasonable. Yield data also indicates that second growth (coppicing) yields are greater than first growth. Leucaena is also initially preferred because it is not affected by pests or diseases of a serious nature which cannot be dealt

with by incorporating proven and accepted cultivation, maintenance and harvesting regimes.

FSDC recognizes the need for R & D. They are open to suggestions and are actively seeking technical support from every available source. Research will continue to investigate and adapt new technologies to further increase yields.

D. AID Participation

This nationwide subproject supports the AID/Philippines assistance strategy to develop indigenous energy resources, generate employment in the rural sector, particularly amongst depressed groups, increase their productivity and income, and improve environmental conditions. AID's participation in the Gasifiers for Irrigation Subproject will be to provide funding for gasifier conversion equipment and the development of energy woodlots at approximately 495 ISA sites: this includes 1,150 gasifier units and 2,970 hectares of woodlots. A subproject budget follows, and obligations and disbursements are detailed in Section IV, Financial Plan:

Total Subproject Costs
($000)

		Source		
		AID/ESF	GOP	Total
A.	AID Funding			
	1. Gasifier units	2,156		2,156
	2. Woodlots	1,221		1,221
B.	FSDC Contribution			
	1. Equipment packing, shipping, installation and engineering supervision		2,264	
	2. Woodlot program management		1,656	1,656
	Total	3,377	3,920	7,297

Additionally, but under a separately funded ESF project (Project Design Fund), FSDC is receiving assistance to further develop its technical capability to implement its gasification conversion program. This technical assistance project includes: analyses of gasifier applications in the Philippines to determine the most promising use of potentials; testing two small-capacity, simple gasifiers for use with rice mills and small electric generators; improvement, if needed, of current operation and maintenance systems; applied research to develop and modify energy woodlots which are appropriate to site-specific variables (including species selection and seed/seedling development, yield response, pest and diseases advisory services, fuelwood production cost

analyses, and cogeneration possibilities); and limited commodities, e.g., vehicles, tools and training aids. This project, to start by August 1982, will be carried out by Filipino and American professionals.

III. DETAILED SUBPROJECT ANALYSIS

A. Economic Feasibility: Analysis I

Gasification is a technology which converts solid carbonaceous fuel (wood, charcoal or other materials such as agricultural residues) to a gaseous fuel, generally referred to as producer gas. The resultant gas can then be utilized for purposes such as running internal combustion engines to produce shaft power which would not otherwise be technically possible with a solid fuel. The production of producer gas, of course, entails some losses in the conversion step and has other associated costs, most importantly the modification of end-use devices such as diesel or gasoline engines to use producer gas. In addition, in the case of wood as a feedstock, the cost of chipping and drying must also be included.

Similar to previous economic discussions in Annexes I and III, the cost in Analysis I is followed through the entire fuel cycle, starting with wood production and in this case, finishing with an examination of its relative attractiveness for use in agricultural pumping. The fuelwood raw energy production module for the gasification program is different from the larger scale schemes for the power plant and charcoal production subprojects. In this case, the production of wood will be on much smaller holdings adjacent to agricultural lands.

Under the gasifier program, there are two different paths for the fuel cycles from raw wood energy through to agricultural pumping. One path uses charcoal as the gasifier feedstock while the other eliminates the charcoaling step and uses woodchips directly. This discussion examines both of these options. The total cost for the complete fuel cycle for all three alternatives (charcoal, woodchips, diesel) is presented in Table 1, (all economic tables are in Appendix C) and detailed in the accompanying notes to the table. In all cases, the analysis is based on an equivalent agricultural pumping unit - output of 65 brake horsepower (Bhp) for one hour.

For purposes of discussion, we start the comparison with the diesel system. Based on empirical findings in the Philippines, approximately 0.238 kilograms (kg) of diesel fuel are needed for one Bhp hour. Using the unit costs of diesel based on $8.50/MBTU, the operating cost of the diesel system is $5.64 for one hour. There are no conversion costs for the diesel alternative.

In this program, 70% on a volume basis of the diesel oil is substituted by producer gas. (While higher degrees of substitution are possible, even up to 100% using a glow plug for starting, this would re-

quire engine modification.) The resulting fuel characteristic provides greater fuel security and generally fewer operating difficulties for farmers. The FSDC has developed empirical estimates of the fuel requirements, chips or charcoal, to produce the necessary Bhp output with varying fuel mixes. These estimates are used in calculating the operating costs in Table 1. The operating costs for the primary fuel refer to producer gas displacing 70% of diesel fuel requirements. The wood-based fuel cycles start with raw wood energy at $0.74/MBTU.

The woodchip cycle starts with cut raw wood, then the wood is transported, dried and chipped prior to gasification. As indicated in Table 1, this sequence of events results in a pump site fuel cost of $1.09/MBTU. Given the nature of the fuels and the conversion efficiency of the gasifier, more Btus of woodchips are required for substitution than is required with charcoal. The charcoal, of course, has already undergone a transformation and cost increases. For the 70% diesel substitution, the relative cost for charcoal is $1.41, and for woodchips is $0.82. Both costs are significantly lower than the $5.64 value of the diesel fuel that is replaced.1/

Both scenarios using charcoal and woodchips must also bear the cost of the gasifier. This unit is essentially the same for each fuel and has an associated annualized capital cost of $894.

Given a yearly operating time of 1200 hours, the hourly cost is $0.75/hr. This must be included in the fuel cycle cost for both charcoal and woodchip based producer gas substitution. Finally for both systems, the cost of the remaining 30% diesel is included. The resulting figures are formulated in Table 1. The data show that the woodchip system is the cheapest with an effective pumping cost of only 60% that of diesel, while the charcoal-based system is 70% that of diesel. However, if fuel supplies are farther away from end-use, charcoal systems become more attractive since the transport costs per unit of energy are much less than for wood.

Since the gasifier system utilizes only local materials, the effect of shadow pricing foreign exchange at ₱10 increases the cost of the diesel alternative by 25% to $7.05, making the wood-based system more attractive at a cost of only 52% that of diesel. If the opportunity cost of capital is higher, then gasification is slightly less attractive: a 25% discount rate implies about a 5% increase in the effective cost of the woodchip producer gas option, but it is still much more cost effective.

An attractive feature of the dual fuel system is its flexibility when there are gasifier operating difficulties. If, for example, the

1/ On a macro-economic level, it is estimated that energy savings resulting from this program will save approximately 47,128 barrels of imported oil per year. This is equal to $1.6 million, at $34 per barrel.

producer gas system only worked half the time it would still cost $5.40,[1] which is still lower than the 100% diesel system.

B. Economic Feasibility: Analysis II

An economic feasibility analysis of the use of gasifiers for irrigation was undertaken through the costing of the fuel cycle using woodchips to fuel a diesel pumpset modified with a gasifier and comparing the costs of that cycle with a pumpset running solely on diesel.

A standard economic feasibility analysis was conducted on the gasifier and woodlot subproject to determine its relative economic worth to the society at large in terms of diesel substitution. The estimated costs of the proposed activity, with nominal unskilled labor costs adjusted downward by 50% to reflect the high level of underemployment and the consequent low opportunity cost of labor in the Philippines, are compared with the value of the diesel fuel expected to be replaced by the wood-burning gasifier. The peso value of the diesel fuel savings was adjusted upward 25% to reflect the current undervaluation of foreign exchange.

The basic analysis indicates an extremely high economic benefit/cost (B/C) ratio of 4.1 at a 20% rate of discount (and 4.7 at 15%). (See Table 2.) The economic internal rate of return (IRR) cannot be calculated from the annual cost and benefit estimates prepared, since the economic benefits exceed costs every year beginning in Year 1. While a quarterly presentation of first year date might have been prepared to demonstrate this, it was not deemed necessary for the Project Paper.

A sensitivity analysis to allow for the possibility of higher costs and reduced benefits (such as lower diesel fuel prices and therefore lower cost savings) was conducted by simultaneously raising all costs by 20% and reducing benefit estimates by 25%. The latter simulates a drop in world market prices of oil from the present $34 to $25.50 per barrel, assuming the price of diesel fuel would fall by the same proportion (which it might not do if the demand for diesel fuel continues to increase relative to other oil derivatives). In this "worst case" scenario the B/C ratio drops from 4.1 to a still lofty 2.6 at 20% discount (and from 4.7 to 3.0 at 15%). Since the adjusted costs exceed benefits in year one an IRR can be calculated, and it turns out to be a whopping 165%. (Table 3.)

1/ If only 600 hours on producer gas, the most significant increase in cost is due to a doubling of the capital cost throughout the year. Then half of the time the effective cost would be $4.26 and half of the time $6.54 or an average of $5.40. This ignores the difference in farmer operating time, but this would not add a significant cost.

A second sensitivity analysis using the nominal benefit/cost estimates only, with no shadow prices, indicates a B/C ratio of 2.9 at 20% discount (3.2 at 15%) and an even higher IRR of 415%. (Table 4.)

The relative economic benefits of growing and substituting renewable woodfuel for imported diesel fuel seem to be indisputable, a conclusion not very sensitive to particular shadow pricing or cost estimation assumptions.

C. Financial Feasibility

The gasifier subproject includes the local currency costs for developing 495 six hectare woodlots at an estimated cost of $2,877,000, and the purchase and installation of 1,150 gasifiers at a cost of $4,420,000. The total project cost is equivalent to $7,297,000 of which ESF will cover $3,377,000 and the remaining $3,920,000 will be covered by the GOP. This section analyzes the costs and returns to (1) the farmers who will develop and maintain the woodlots, and (2) the ISA.

1. Woodlots

Under the gasifier program, the woodlots are developed on 6 hectares of land leased by the ISA which borrows and repays the money required to develop them. The ISA will establish a Fuel Production Unit (FPU) composed of three persons. The ISA will pay the FPU members an annual wage to develop and maintain the woodlot as well as harvest the trees and have an adequate supply of woodchips available.

The woodlot is developed over a three-year period, with one-third being planted each year, and harvested in three year cycles. New trunks grow from coppices which resprout from the stumps after each harvest, eliminating replanting costs. New trunks are again harvested every three years. Whereas the average annual growth rate is conservatively estimated in the financial tables at 25 MT of wood/ha/yr, or 75 MT/ha per three year harvest period, we believe actual growth will be something between 25 and 40 MT/ha/yr.

Table 1 (all financial tables appear in Appendix D), summarizes the costs of developing the woodlots and projects an annual payment of $150 (₱1,200) to each of the three FPU members for their labor during the first three years. Beginning in Year 4 and annually thereafter, the FPU members will each be paid $587 (₱14,094 ÷ 3 = ₱4,698) for the harvest of trees and preparation of woodchips.

The costs of the woodlots are an integral part of the financial analysis of the gasifier discussed in the following section.

2. Gasifiers

This section presents the results of analyses of the financial feasibility of using gasifiers fed with woodchips to power diesel-driven pumping systems. The analyses were conducted for a typical irrigation

pump system managed by an Integrated Service Association (ISA), using two 65 HP pump units. The first analysis (Table 2) was to determine savings derived from a diesel driven pump irrigation system with a gasifier fed with woodchips. After determining costs and savings, a financial analysis (Table 3) was made to determine the effects that the installation of a gasifier would have on rice production costs in a typical ISA situation.

A comparative cost analysis was conducted in order to compute the cash savings that would accrue when a gasifier is used to power two 65 HP pump units. The analysis compares the operating costs of a diesel engine system without a gasifier against the same system with a gasifier using a 70:30 woodchip to diesel fuel ratio. Costs considered in the gasifier system include: amortization of the loans for the woodlot, the gasifier and irrigation unit, diesel fuel, lubricants, labor to produce the woodchips; and, repairs and maintenance of the gasification equipment. Based on a woodchip requirement of 43.3 kilograms per hour for one 65 HP pump and an operating time of 1,200 hours per year, the annual woodchip requirement for two 65 HP pump sets is estimated to be 103.92 metric tons.

A review of Table 2 reveals that with the gasifier unit producing 70% of the fuel requirements of the irrigation pumps, there is an annual net cash savings ranging from a minimum of $1,729 (₱13,835) to a maximum of $3,362 (₱26,892). Over 25 years the total cash savings would be $69,250 (₱553,999) or an average of $2,770 per year. The savings range from 12.0% of Year 8's net income to 21.9% of Year 1's net income. These projected savings are net of annual amortization costs for the gasifier unit and the woodlot as well as the cost of producing woodchips. Not reflected in the table are the very real savings of 47,128 barrels of oil equivalent a year; or $1.6 million of foreign exchange costs.

Whereas the financial data in Table 2 assumes a 70:30 ratio of woodchip fuel to diesel fuel, we estimate that if the gasifier unit produced only 52% of the energy to run the pumps, there would still be a net cash savings to the ISA. The net cash savings at 52% would be marginal in years 5-12 and range between $1,700 and $1,825 for the remaining years.

The Income Statement, Cash Flow Statement and Balance Sheet for the ISA during the first 8 years of the project are provided in Tables 3, 4 and 5 respectively.

D. Social Soundness Analysis

1. Beneficiaries

More than 26,000 families who are currently farming marginal lowlands by pump irrigation will directly benefit through fuel cost savings from the conversion of diesel-powered pumps to gasifiers. These

pump-irrigation farmers are the poorest of lowland paddy farmers. 1/ Compared to farmers in gravity-fed irrigation systems, the pump irrigation farmers: (a) have smaller holdings (1.8 ha. compared to roughly 2.5 ha.); (b) farm less fertile, more marginal lands; (c) operate within smaller, less efficient irrigation systems; and (d) experience higher production costs, particularly diesel fuel for their irrigation pumps.2/

Another group of direct beneficiaries are the nearly 1500 families who will be recruited by the irrigation associations to establish, operate, and maintain the woodlots and produce the woodchips to run the gasifiers. Most of these beneficiaries are landless agricultural laborers, one of the poorest socio-economic groups in rural Philippines. These people will receive wages that are significantly higher than their previous daily wages, plus they will have the benefit of permanent, year-round employment.

The project also has a relatively large number of indirect beneficiaries. It is assumed that savings in irrigation expenses because of modifying current diesel units to use gasifiers will result in the purchase of additional production inputs, the chief of which should be hired labor; additional labor inputs are also likely to result when some farmers who were planting only one crop a year begin to double-crop. The project can thus be expected to generate increased agricultural employment for unemployed and underemployed rural families.3/

2. Socio-Cultural Feasibility

The conversion of diesel-powered irrigation pumps to gasifier assisted pumps, the establishment and operation of woodlots and the production of woodchips to run the gasifiers are socially and culturally feasible within the rural Philippines. The farmers irrigation

1/ Definition and analysis of rural poverty is presented in CDSS Documents for years 1982, 1983, and 1984.

2/ Because they farm more marginal lands, their costs for fertilizer, plowing, transportation, and labor are also higher.

3/ Studies of Filipino paddy farmers have found that more than half of them are part-time farmers. Their holdings are generally too small to support their families and thus they are forced to seek additional, off-farm employment. They hire laborers to undertake most of the farming operations (plowing, planting, weeding, and harvesting), while they limit their own activities to supervising, caring for their carabao, and controlling the water. Further, it should be noted that the trend is for hired labor to replace family labor on the farm; this is accelerated for individual households experiencing increases in income.

service associations (ISA) have been in existence for several years. Their main function is to operate and maintain the irrigation pumping and distribution system. The modification of ISA pumps from diesel to gasifiers will not affect this function; in fact, once the modified pump sets begin providing water on a dependable basis, the management of the pumping and water distribution should become less time consuming and more efficient. At present, for example, much time is spent procuring and transporting diesel fuel for the pumps; further, periodic scarcities or other problems in obtaining sufficient diesel fuel result in irregular water distribution. With an assured and convenient supply of fuel, less time should be spent in procurement, and distribution can be scheduled in an orderly and reasonable fashion.

Overall supervision of the woodlot will be the responsibility of the ISA, though the actual day to day operations will be the responsibility of the three-person fuel production unit or FPU. FSDC personnel will provide technical assistance for establishing the woodlots, and modifying the pump units to use gasifiers. ISA supervision of the FPU should not be time-consuming nor should it conflict with the major tasks of irrigating and farming. It is probable that FPU members will be neighbors, friends, or relatives of the ISA members, and thus communication and role fulfillment should be facilitated.

The three FPU members are expected to establish and maintain the six hectare woodlot, and produce woodchips. Although this work will be different, they will receive adequate training and supervision to enable them to undertake these tasks successfully. The three members will be chosen by the ISA, and it can be expected that the ISA will choose three people who are hardworking, committed, and compatible (both with each other and with ISA members).

FPU members will not receive rights to the woodlot (the lease on the land is held by the ISA). Relationships between the ISA and FPU should be very similar to those between a landowner and his permanent, year-round agricultural laborers. Since the ISA members are all landowners or farm operators and the FPU members will likely be former agricultural laborers, no major sociological problems in this regard are envisioned.

During establishment of the woodlots, FPU members will receive a daily wage commensurate with the work performed. Once woodchip production begins, they will receive a regular daily wage for their labor. FSDC and ISA representatives are currently considering an added incentive in the form of a small percentage of the fuel savings realized by the ISA in converting to gasifiers. During the first year of each planting and after each harvest, FPU members will also be able to intercrop between the tree rows.[1/] All of this should provide strong economic

1/ FPU members, though full-time tree growers, can also be expected to seek supplementary income on the farms of ISA members during peak labor demand periods.

incentive for the FPU members.

The ISA has responsibility for the loan to establish the woodlot and convert the pumps from diesel to gasifiers. Repayment of the loan with moderate interest over eight years should not place the ISA under economic hardship. Savings in fuel costs over the loan period more than cover the amortization of loans for woodlot development and conversion to gasifiers.

Conversion from diesel fuel to gasifiers does not affect the ability of the diesel engine to run exclusively on diesel fuel. Thus, even if no producer gas is available to mix with diesel fuel, farmers can still irrigate, though they will have to use the more expensive diesel fuel. Since amortizations are payable from savings in fuel costs, there is naturally a point below which fuel savings do not cover amortization costs. In general, unless gas produced from woodchips is able to supply a minimum of 52% of fuel costs, farmers will be out-of-pocket in making their amortization payments. Given present economic conditions, these farmers would fall under severe financial strain, even in the short-term. It could be expected in such cases that some ISAs will default on their loans.

On the other hand, the break-even producer gas to diesel fuel ratio mentioned above is unlikely to be approached by any well-managed ISA woodlot. There is a strong incentive for both ISA and FPU members to ensure high production of woodchips/producer gas. Since the ISA is shouldering the financial responsibility of the loans, it is likely that they will make the strongest efforts to ensure that fuelwood production remains high.

3. Spread Effects

FSDC plans to assist 495 ISAs (26,000 farmers) to enter this program by 1984. Spontaneous replication of this subproject will be difficult for small farmer groups unless they have institutional support. Woodlot production costs in the initial years, capital costs of converting from diesel to gasifier, plus problems associated with obtaining leasehold land are major constraints. On the other hand, once the ISAs begin reducing their production costs, it can be expected that other government institutions and international donors will add their support to the programs's expansion. In fact, considerable private sector interest is being expressed in both buying and manufacturing gasifiers.

4. Equity

The subproject's benefits are channelled directly to the existing ISA, which is comprised almost exclusively of low-income smallholders doing pump irrigation on marginal lands. Water used by pump irrigation is usually drainage from upland areas or standing water, and thus even if water use for irrigation were increased it should not

threaten other irrigators.

Since all households farming a given area are already members of the ISA, conflicts between beneficiaries and others will be minimal. The distinction between beneficiaries and non-beneficiaries is already inherent in the more pervasive difference between those who own or have access to land and those who do not. Since this subproject does not entail any re-distribution of existing resources, this division between owner and non-owners will continue to exist. On the other hand, the problem is minimized given the small size of holdings and the general homogeneity of the communities.

Another key factor minimizing conflict between beneficiaries and others is that most farmers are "part-time farmers", because their holdings are generally too small to provide sufficient income for their families. Consequently, many farmers have off-farm jobs to supplement their incomes. They are primarily supervisors of hired labor on their own farms. The savings in irrigation costs resulting from conversion to gasifiers will likely encourage farmers to use additional production inputs, primary among which is labor. Thus, many of the beneficiaries' neighbors and fellow villagers will be able to find increased agricultural employment, reducing to some extent income disparities between those owning and having access to land and those who do not.

Another impact, in terms of equity, is its contribution toward improved water management. Most lands under pump irrigation are marginal. Fertility is lower, unevenness of the fields makes irrigation more difficult, and farms are less systematically laid out than those in gravity-fed systems. These factors exacerbate water management problems found in any irrigation system. By providing irrigation in a more timely fashion and at less cost, distribution and on-farm management problems are diminished.1/ The major beneficiaries of such improvements in irrigation efficiencies are likely to be tail-enders within the ISA. Finally, it should be noted that in a relative and sometimes actual sense, the pump irrigators are tail-enders compared to farmers in surrounding and nearby gravity flow systems. As a result of improved irrigation, relative income disparities between the pump irrigators and gravity-fed irrigators should be reduced.

5. Women in Development

Most ISA members are males, as are most farmers. Women engage directly in farming mainly as hired laborers, though during periods of peak labor demand female household members are frequently mobilized. As discussed earlier, savings in irrigation costs because of conversion

1/ FSDC already has an on-farm water management program in the areas where it has organized ISAs. Any improvement in irrigation efficiency because of conversions from diesel to gasifiers should facilitate and support these efforts in water management.

from diesel to gasifiers should result in increased labor inputs, and a large portion of those hired will probably be women.

It is important to note that among the poorer households, more than half of the women must engage in some productive activities in order to help their husbands provide for their families' needs; in addition, in rural areas it is not uncommon to find women as heads of household (most surveys report an average of 5-10% of households are headed by females). Generating additional employment opportunities will satisfy a real need of these women.

Women can also be expected to participate in the establishment, operation, and maintenance of the woodlots which will supply the woodchips for the gasifiers. The 3-person FPU responsible for each ISA's woodlot will undoubtedly involve the households of the FPU members. Women's labor input on the woodlot will complement the men's more physically exerting work. In addition, during the first year or so of each planting, FPU members will be intercropping vegetables, sweet potato, and other crops. This will probably be undertaken by women. Also, during the initial clearing operation, women will be able to gather and sell firewood from the woodlot.

E. Environmental Impact Analysis (EIA)

The degree to which the environment will be affected by the gasifiers is a function primarily of location and size of each project. In the development of this discussion, it is assumed that appropriate criteria will be used in siting the projects. The largest project will consist of two units generating gas for 2-65 hp engines. Thus, the total impact on the environment is expected to be small on an individual or on a cumulative basis.

The use of proper criteria for siting as well as the practice of sound engineering principles will ensure that the proposed gasifier systems will not be located in areas that can create public hazards. Such hazards can come about from floods, mud slides, or land slides.

Potential air quality impacts are substantially reduced through the use of gas cleaning equipment. The size of the gasifer systems as well as of the gas cooling unit will ensure that NO_x emissions will not be excessive. Similarly, water quality impacts resulting from the gas cleaning/cooling train will be minimal because of the relatively small size of the projects.

The implementation of appropriate siting criteria will ensure that a facility is not located in an area considered to be a critical habitat for rare or endangered aquatic, vegetative, or terrestrial biota, thus avoiding potential adverse impacts. Similarly, ensuring that emissions are properly treated prior to their release to the environment will also serve to prevent potential adverse impacts on biological resources.

The gas flow in gasifier systems is brought about through ordinary engine intake, i.e., suction. Thus, the system is basically silent and will add no perceptible increase in noise levels in the area. Some noise will occur during fuelwood stockpiling and during chipping. Both are considered minimal.

Potential adverse effects on social economies, land use, and resources can be mitigated through the use of applicable siting criteria, and through compliance with relevant zoning, and development plans in the area.

The development of the 6 hectare energy woodlots to be used as a fuel source for the gasifiers will have a positive environmental effect. Although some immediate negative influences will result from developing the woodlots, the introduction of nitrogen-fixing trees into the areas to be used will have a far more favorable environmental impact than current land uses.

The complete EIA for the gasifiers and the woodlots is contained in Appendix F.

F. Administrative Feasibility

The FSDC will be the principal implementor of this subproject, and is eminently qualified to do so. Since its creation in 1975, it has organized 1,800 ISAs representing 94,000 farmers, including loan development and processing and training assistance to operate, maintain and manage the associations. FSDC currently has over 1,300 employees at its central, area and provincial offices. The administrative achievements and management procedures of the FSDC and the ISAs are fully described in the Project Paper: Small Farmer Systems II (492-0333). This project simply adds to the proven competence of that system by incorporating approximately 3 new members into each existing ISA, along with some additional training requirements for the new members and additonal loan processing and collections. It is recognized that this will add to the ISA's administrative workload. However, a close examination of numerous representative ISAs and detailed discussions with FSDC personnel confirm that the additional workload will not compromise the effectiveness of the ISAs. To assist in the early phases of this project, FSDC will call on the following GOP organizations: GEMCOR for training and equipment repair; Bureau of Forest Development (BFD) for land access and advisory services for woodlot development; Bureau of Soils for soil analysis and land preparation; and Ministry of Human Settlements (MHS) for enterprises development as needed.

Administratively, a typical successful equipment conversion request will flow as follows:

At the field level, the ISA will submit a proposal (in the form of a resolution) for converting its diesel equipment to the Area Office where the Technical Services Division (TSD) and Farm Support Services

Division (FSSD) will undertake an assessment of the ISA's economic and technical performance and conversion requirements, including the woodlot area. The proposal will then be endorsed as a loan application to the FSDC Board of Administrators for final approval.

At the central office, the engineering department evaluates the technical and financial analyses of the proposal. (The engineering department conducts training of area-based engineers and provides guidelines for effective project implementation.) The proposal is then forwarded to the Board of Administrators for approval. Upon approval, the engineering department orders the equipment from GEMCOR, and the Supply Management Department ships it to the area office.

The actual installation is supervised by GEMCOR and TSD personnel and performed by ISA members. After installation, the TSD and GEMCOR train the gasifier operator and conduct periodic visits to monitor project performance.

At the ISA level, the gasifier project is under the supervision of the ISA board of directors. (See Figure 3.)

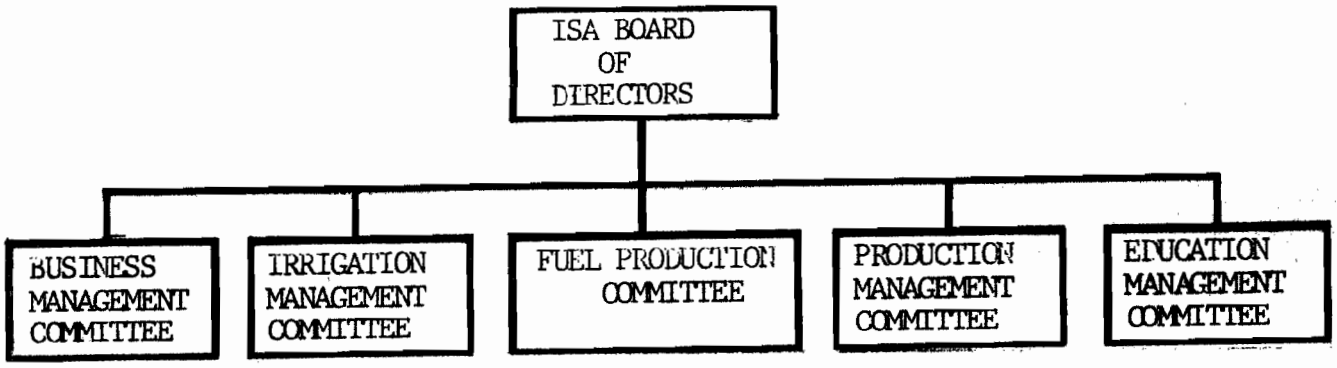


Figure 3
ISA Organizational Structure

The business management committee has general supervision of the conversion project, with assistance from the education, production and irrigation management committees. The education committee is responsible for arranging and conducting training of ISA members on basic technical and maintenance operations. The irrigation committee organizes a repair and maintenance crew and is responsible for the actual operation of the gasifier unit.

The fuel production committee will be responsible for supervising the development and operation of the woodlot and woodchip production. Its overall responsibility will be ensuring the ISA of a steady fuel supply for the gasifier-equipped irrigation system.

As stated earlier, close examination of this system has indicated that the additional workload for the ISA as a result of introducing this project is manageable. In fact, when measured against ensuring the continued effective and efficient operations of the ISA and its farm production goals, given ever increasing diesel fuel costs, the incentives are expected to motivate performance of moderately expanded tasks.

IV. FINANCIAL PLAN

This section describes the financial plan for obligating and disbursing funds for the Gasifiers for Irrigation Subproject. Overall economic and financial aspects of the subproject at the farmer, association and national levels are covered in Section III, A, B and C; Economic and Financial Feasibility.

A. Project Obligations

($000)

Source of Funds	FY 82	FY 83	FY 84	FY 85	FY 86	Total
AID GRANT	2,000	1,377	-	-	-	3,377

B. Disbursement Schedule

($000)

	Years 1	2	3	4	5	Total
a. AID Funds - Gasifier Units and Woodlot development	1,310	1,365	464	238	-	3,377
b. FSDC Funds Program Management installation and contingencies	1,384	1,800	400	236	100	3,920
Total	2,694	3,165	864	474	100	7,297

The AID grant funds will be equivalent to the costs of: (a) the purchase of up to 1,150 gasifier units to be installed at 495 irrigation sites; and (b) the costs of developing woodlots of approximately 6 ha. per site to provide a fuel source. Woodlot costs include clearing, planting, and maintenance. Funds for woodlot development will be paid by FSDC to the ISA in the form of a loan for agricultural inputs and salaries of the tree farmers.

FSDC contributions will finance the costs of: (a) packing and shipping the gasifier units to their sites; (b) civil works, installation and engineering supervision; and (c) program management costs, including training.

C. Disbursement Procedure

The disbursement procedure is discussed in the Summary Section of this Project Paper.

V. IMPLEMENTATION PLAN

This section covers implementation considerations for the gasifier subproject. Administrative feasibility questions are discussed in Section III.

A. Grant Implementing Schedule

	Project Month
Obligation	0
Conditions Precedent Met	3
First Disbursement of Dollars	4
Process Evaluation	18
Impact Evaluation	36

B. Subproject Implementation Schedule

During each of the first two subproject years, 575 gasifier units will be installed, for a total of 1,150. The following is the schedule of woodlot development:

Schedule for Woodlots Developed by Hectare

	Project Year 1	2	3	4
Developed for First 575 units	495	495	495	
Developed for Second 575 units		495	495	495
Total Per year	495	990	990	495
Cumulative	495	1,485	2,475	2,970

C. Project Management System

The GOP will be the grantee and the executing agency will be the MAC Secretariat at MHS. The FSDC will be the implementing agency.

More specifically, the Secretariat will deposit funds in favor of FSDC with the Philippine National Bank. FSDC will then be responsible for releasing funds to the ISAs in order to proceed with woodlot development. Funds for the gasifier will be released by FSDC directly to the gasifier supplier. Detailed loan procedures and conditions are discussed in Appendix E., Loan Plan.

The responsible person for this project at the MAC Secretariat will

be the Livelihood Support Fund Officer. AID will monitor the project, provide appropriate AID approvals, and participate in progress assessments as well as final project evaluation.

D. Procurement Procedures

FSDC will purchase approximately 1,150 gasifier units. Additionally, FSDC through the ISAs will purchase hand tools, fertilizers and seeds for woodlot development. FSDC has demonstrated capacity to conduct procurements under several previous AID loans. No off-shore procurement is planned for this segment of the project. AID will also make available to FSDC AID handclasp emblems for marking the gasifier units.

APPENDICES

TABLE OF ASSUMPTIONS

I. Gasifiers

a. Diesel engine: 65 HP
b. Diesel fuel consumption:

Operated on 100% diesel - 18.1 liters/hour
Operated on 70:30 substitution - 43.3 kilos/hour of woodchips and 5.43 liters/hour of diesel

c. Diesel fuel price: ₱3.20/liter

d. Woodchip labor: ₱135/MT

e. Hours of operation: 1,200 hours/year

Case . The engine is being operated on 100% diesel fuel.

Diesel fuel cost = Diesel fuel consumption/hour x no. of hours operated/year x diesel fuel price/liter

= 18.1 liters/hour x 1,200 hours/year x ₱3.20 liter
= ₱69,504/year

Case . The engine is being operated on a 70:30 fuel substitution using woodchips

Diesel fuel cost = Diesel fuel consumption/hour x no. of hours operated x diesel fuel price/liter

= 5.43 liters/hour x 1,200 hours/year x ₱3.20/liter

= ₱20,851

Woodchip costs = Woodchip consumption/hour x no. of hours operated x woodchip cost/kilo

= 43.3 kilos/hour x 1,200 hours/year x ₱.35/kilo

= ₱18,186

f. Area coverage: 80 hectares

g. Area irrigated and planted: Wet season - 80 hectares
Dry season - 56 hectares

h. Crop planted: Palay

i. Price of palay: ₱70/cavan

j. Two cropping seasons per year

k. Yield per hectare: Wet season - 70 cavans/hectare
Dry season - 80 cavans/hectare

l. Cost of production:

Labor - ₱500/hectare/cropping for land preparation and maintenance. This is to increase by 5% per annum. Ten percent of gross revenues for harvesting and other post harvest activities.

Seeds - ₱110/hectare/cropping to increase by 5% per annum

Pesticides - ₱250/hectare/cropping to increase by 5% per annum

Fertilizer - 3 bags of urea @ ₱130/bag - ₱390
4 bags of 14-14-14 @ ₱120/bag - 480
₱870/hectare/cropping to increase by 5% per annum1/

m. Administrative cost: 2.5 cavans/hectare planted/cropping. This represents contributions made by the members to the association to cover the salary of the pump operator, supplies, communication, transportation and other incidental expenses.

n. Diesel fuel cost is assumed to increase by 10%.

o. Lubricant is 10% of diesel fuel cost.

p. Costs of charcoal and woodchips are assumed to increase by 10% per year.

q. Repairs and maintenance: 3% for the first year, 4% for the second year, 5% for third year, 6% for the fourth to the sixth year of the original cost of:

Irrigation pump, machinery and accessories
Structures and civil works
Gasifier equipment

1/ Unsubsidized prices in the rural areas were used and these are expected to stabilize in the next few years.

II. Woodlots

a. Annual woodchip requirement for two 65 HP pump sets = 104 MT
43.3 kg/hour pump x 2 pumps x 1,200 hours/year x 1 MT/1,000 kg.
= 103.92 MT

b. Conversion efficiency to woodchips
Yield/hectare = 25 MT/ha/yr x .7 (efficiency) = 17.5 MT/ha/yr of woodchips

c. Total hectarage requirement = 104 MT/yr ÷ 17.5 MT (woodchips)
= 6 hectares

GEMCOR

The Gasifier and Equipment Manufacturing Corporation (GEMCOR) was established in March 1981, as a subsidiary to the Farm Systems Development Corporation (FSDC). Its purpose is to promote the use, manufacture and marketing, at reasonable cost, of equipment using indigenous materials that generate combustible gases to serve as a substitute for petroleum-based fuels.

GEMCOR started producing gasifiers in November 1981. The various models produced are used with irrigation pumps systems, power generation and other farm equipment. In addition to promotion and manufacturing, GEMCOR provides training in gasifier operations and maintenance to purchases, as well as an equipment servicing unit. To date, GEMCOR has produced 195 irrigation models. One hundred and fifty of these were ordered by FSDC and 10 were ordered by private farmers and local manufacturers for testing. It has orders for 170 of its boat model from local fishing organizations and government agencies for demonstration purposes, and has sold 150 units of its light utility vehicle model.

GEMCOR is located at Barrio Maduya, Carmona, Cavite, and its plant has an initial annual capacity of 1,500 units. Plans for expanding the plant's capacity to 4,000 units have been approved and construction has started . In addition, construction will start this Summer on a new plant in Tagum, Davao Norte to meet the first equipment requests in Mindanao. Initial plant capacity at this site will be 300 units annually.

ECONOMIC TABLES

Table 1
Comparison of Effective Cost
One Hour Agricultural Pumping (65 BHP)

		Charcoal	Wood Chips	Diesel
A.	Cost of Fuel (S/MBTU)			
A.1	Cost of Wood[a] (0.69/0.36) =	1.92	0.74	
A.2	Cost of Processing[b]	0.24	0.34	
A.3	Cost of Transport[c]	0.012	0.017	
	Total Cost of Fuel at Use Point ($/MBTU)	2.17	1.097	8.5
B.	Operating Cost ($/HR)			
B.1	MBTU/HR (For Main Fuel)[1/]	.651	.785	0.664
B.2	Operating Cost ($/HR = MBTU/HR x $/MBTU)	1.41	.86	5.64
C.	Cost of Equipment[e]			
	(Gasifier Installation) ($/HR x 1,200 HRS)	0.75	0.75	-
D.	Cost of Additional Fuel			
	MBTU/HR			
D.1	(MBTU/HR Diesel x 0.30)	0.20	0.20	-
D.2	Diesel Fuel Cost (MBTU/HR x 8.5)	1.70	1.70	-
	Total Cost ($/HR) (B.2 + C + D.2)	3.86	3.31	5.64

1/ Assuming 70% substitution, i.e. using 30% diesel.

Notes for Table 1

a) Assumes a .36 thermal conversion efficiency for wood to charcoal.

b) For charcoal, production costs ₱0.05/kg or ₱0.24/MBTU; for wood, chipping costs ₱0.34/MBTU which is largely (81%) labor.

c) Transport cost ₱0.25/km - ton; haul 10 km.

d) For a 65 BHP engine output assuming for charcoal and woodchips producer gas substitution of 70% of diesel by producer gas. At this level based on empirical tests, with 70% of the fuel substitution, the producer gas effectively contributes 37.8 BHP (58%) while the 30% diesel contributes the other 27.1 BHP (42%) for an equivalent 65 BHP hour. This requires .66 kg/hphr of charcoal and 1.14 kg/hp hr of woodchips with associated energy requirements of .866 MBTU/hr (charcoal) or 1.047 MBTU/hr (woodchips). These empirical estimates integrate numerically the theoretically known thermal efficiency losses in the gasification step and the derating of engine output with a producer gas mixture.

e) Gasifier cost of ₱30,000 including installation and site shed, capitalized at 20%, 10 yrs. all local costs.

Table 2 Gasifier Production: Economic Benefit/Cost and Internal Rate of Return (IRR) Analysis (6 has. farm) (₱1000, 1981 Prices)

Year	Total Economic Cost 1/	Total Economic Benefit 2/	Present Value at 20% Rate of Discount Costs	Present Value at 20% Rate of Discount Benefits	Present Value at 15% Rate of Discount Costs	Present Value at 15% Rate of Discount Benefits	Net Economic Benefits
1	99.4	107.4	82.8	89.5*	86.4	93.4	8.0
2	52.4	161.0	36.4	662.4*	39.6	900.7*	108.6
3	52.4	161.0	30.3		34.5		108.6
4	23.0	.	11.1		13.2		138.0
5	7.1	.	2.9		3.5		153.9
6	7.1	.	2.4		3.1		153.9
7	7.1	.	2.0		2.7		.
8	7.1	.	1.7		2.3		.
9	37.1	.	7.2		10.5		123.9
10	7.1	.	5.0*		8.4*		153.9
.	.	.					.
.	.	.					.
17	37.1	.	1.7		3.4		123.9
18	7.1	.	1.2*		3.0*		153.9
.	.	.					.
.	.	.					.
25	7.1	161.0					153.9
TOTAL			184.7	751.9	210.6	994.1	

Benefit/Cost Ratio: at 20% Discount: 4.07
at 15% Discount: 4.72

Net Present Value: at 20% Discount: 576.2
at 15% Discount: 783.5

Internal Rate of Return (IRR): (Cannot be calculated from annual figures).

1/ See Table 5.

2/ It is estimated that 25.6 kg. of woodchips can be substituted for 12.67 liters of diesel fuel to run the irrigation pumps. Therefore, the economic value of the woodchips is equivalent to the economic cost of the diesel fuel saved. At the current wholesale cost (less taxes) of ₱2.48/liter of diesel, this translates into ₱1.227/kg. of woodchips. A 6-ha. farm is conservatively expected to produce 105 MT of woodchips annually, and this would be equivalent to ₱128,835 worth of diesel fuel, to which a foreign exchange shadow price of +25% is applied. The gasifier is expected to be in operation for 2/3 of year 1. Since diesel fuel is refined from crude oil in-country, the profits (revenues minus total costs) of the refineries should be deducted from the wholesale price as not representing Philippine economic costs avoided. These are a rather small percentage of the price, however, (no more than 2%, about half of which accrues to foreign owners) so ignoring them in these calculations does not result in a significant bias.

USAID/P, OD/PE, 3/30/82

Table 3 Gasifier Production: Economic B/C and IRR Sensitivity Analysis (for 6 ha. woodlots)--with Costs Increased 20% and Benefits Reduced 25% (₱1000, 1981 prices)1/

Year	Total Economic Cost +20%	Total Economic Benefits -25%	Present Value at 20% Rate of Discount Costs	Present Value at 20% Rate of Discount Benefits	Present Value at 15% Rate of Discount Costs	Present Value at 15% Rate of Discount Benefits	Net Economic Benefits	Net Present Value at 165.2% Rate of Discount
1	119.3	80.6	99.4	67.2	103.7	70.1	- 38.7	- 14.59
2	62.9	120.8	43.7	497.0*	47.6	675.8*	57.9	8.23
3	62.9	120.8	36.4		41.4		57.9	3.10
4	27.6	.	13.3		15.8		93.2	1.88
5	8.5	.	3.4		4.2		112.3	.86
6	8.5	.	2.8		3.7		112.3	.32
7	8.5	.	2.4		3.2		112.3	.12
8	8.5	.	2.0		2.8		112.3	.05
9	44.5	.	8.6		12.6		76.3	.01
10	8.5	.	5.9*		10.1*		112.3	.01
.	.	.					.	.00
.	.	.					.	
17	44.5	.	2.0		4.1		76.3	
18	8.5	.	1.5*		3.5*		112.3	
.	.	.					.	
.	.						.	
25	8.5	120.8					112.3	
TOTAL	523.2	2979.8	221.5	564.2	252.7	745.9		.00

Benefit/Cost Ratio: at 20% Discount: 2.55
at 15% Discount: 2.95

Net Present Value: at 20% Discount: 342.7
at 15% Discount: 493.2

Internal Rate of Return (IRR): 165.2%

* PV of constant stream of costs or benefits beginning and ending in years indicated.

1/ See Table 2 for basic economic cost and benefit estimates.

USAID/P, OD/PE, 4/6/82

Table 4 Gasifier Production: Economic B/C and IRR Sensitivity Analysis (for 6-ha. Woodlots) -- With No Shadow Pricing (₱1000, 1981 Prices)

Year	Total Nominal Cost 1/	Total Nominal Benefits 2/	Present Value at 20% Rate of Discount Costs	Present Value at 20% Rate of Discount Benefits	Present Value at 15% Rate of Discount Costs	Present Value at 15% Rate of Discount Benefits	Net Nominal Benefits	Net Present Value at 415.0% Rate of Discount
1	104.2	85.9	86.8	71.6	90.6	74.7	-18.3	-3.55
2	53.7	128.8	37.3	529.9*	40.6	720.6*	75.1	2.83
3	53.7	128.8	31.1		35.3		75.1	.55
4	31.8	128.8	15.3		18.2		97.0	.14
5	14.1	128.8	5.7		7.0		114.7	.03
6	14.1	128.8	4.7		6.1		114.7	.01
7	14.1	128.8	3.9		5.3		114.7	.00
8	14.1	128.8	3.3		4.6		114.7	
9	44.1	128.8	8.5		12.5		84.7	
10	14.1	128.8	9.9*		16.7*		114.7	
.	.	.					.	
.	.	.					.	
.	.	.					.	
17	44.1	128.8	2.0		4.1		84.7	
18	14.1	128.8	2.4*		5.9*		114.7	
.	.	.					.	
.	.	.					.	
.	.	.					.	
25	14.1	128.8					114.7	
TOTAL	599.5	3177.1	211.0	601.5	246.9	795.3	2577.6	.00

Benefit/Cost Ratio: at 20% Discount: 2.85
at 15% Discount: 3.22

Net Present Value: at 20% Discount: 390.5
at 15% Discount: 548.4

Internal Rate of Return (IRR): 415.0%

1/ See Table 5.
2/ See Table 2, fn. 2.

USAID/P, OD/PE, 4/6/82

Table 5. Economic Cost of Gasifier Production on 6-Ha. Woodlots (₱1000, 1981 Prices)

	Woodlot Development, Ops. & Maint.			Gasifier Construction[1/], Ops. & Maint.			Nominal Cost	Total Economic Cost[3/]		
Year	Unskilled Labor	Other	Total	Unskilled Labor	Other[2/]	Total	Total	Unskilled Labor	Other	Total
1	3.6	15.1	18.7	6.0	79.5	85.5	104.2	4.8	94.6	99.4
2	3.6	14.1	17.7		36.0	36.0	53.7	2.3	50.1	52.4
3	3.6	14.1	17.7		36.0	36.0	53.7	2.3	50.1	52.4
4	3.6	14.1	17.7	14.1		14.1	31.8	8.9	14.1	23.0
5	3.6	14.1	17.7	14.1		14.1	14.1	7.1		7.1
6	3.6	14.1	17.7	14.1		14.1	14.1	7.1		7.1
7	3.6	14.1	17.7	14.1		14.1	14.1	7.1		7.1
8	3.6	14.1	17.7	14.1		14.1	14.1	7.1		7.1
9	3.6	14.1	17.7	14.1	30.0	44.1	44.1	7.1	30.0	7.1
10	3.6	14.1	17.7	14.1		14.1	14.1	7.1		7.1
11	3.6	14.1	17.7	14.1		14.1	14.1	7.1		7.1
12	3.6	14.1	17.7	14.1		14.1	14.1	7.1		7.1
13	3.6	14.1	17.7	14.1		14.1	14.1	7.1		7.1
14	3.6	14.1	17.7	14.1		14.1	14.1	7.1		7.1
15	3.6	14.1	17.7	14.1		14.1	14.1	7.1		7.1
16	3.6	14.1	17.7	14.1		14.1	14.1	7.1		7.1
17	3.6	14.1	17.7	14.1	30.0	44.1	44.1	7.1	30.0	37.1
18	3.6	14.1	17.7	14.1		14.1	14.1	7.1		7.1
19	3.6	14.1	17.7	14.1		14.1	14.1	7.1		7.1
20	3.6	14.1	17.7	14.1		14.1	14.1	7.1		7.1
21	3.6	14.1	17.7	14.1		14.1	14.1	7.1		7.1
22	3.6	14.1	17.7	14.1		14.1	14.1	7.1		7.1
23	3.6	14.1	17.7	14.1		14.1	14.1	7.1		7.1
24	3.6	14.1	17.7	14.1		14.1	14.1	7.1		7.1
25	3.6	14.1	17.7	14.1		14.1	14.1	7.1		7.1

1/ Two units will utilize output from each 6-ha. woodlot.

2/ Initial construction in Year 1 and rehabilitation every 8 years thereafter, plus purchase of woodchips for first 3 years until woodlot begins production.

3/ Shadow prices applied to unskilled labor (-50%).

USAID/P, OD/PE, 4/6/82

Appendix D

FINANCIAL TABLES

Table 1
Gasifier Woodlot Development
Projected Resource Flow
Fuel Production Unit
(In Pesos)
(6 Hectares)

	Year 1	Year 2	Year 3	TOTAL
I. INFLOWS				
A. Loan Proceeds				
1. Cash	3,600	3,600	3,600	10,800
2. Tree Farm Supplies	11,321	11,610	12,771	35,702
Total Inflows	14,921	15,210	16,371	46,502
II. OUTFLOWS				
A. Program Management Cost	6,850	6,850	6,850	20,550
B. Tree Farm Start-up Costs				
1. Tools and Equipment	697	-	-	697
2. Silvicultural Inputs	2,100	2,100	2,100	6,300
3. Contingencies	645	645	645	1,935
Sub-Total	10,292	9,595	9,595	29,482
C. Cost Escalation	1,029	2,015	3,176	6,220
Total Outflows	11,321	11,610	12,771	35,702
III. NET CASH TO FUEL PRODUCTION UNIT	3,600	3,600	3,600	10,800
Net cash per member (3)	1,200	1,200	1,200	3,600

All costs in local currency.

Table 2

Gasifier Woodlot Development
Table - Cost Savings Analysis
Diesel Driven Pump Irrigation System
Without Gasifier Versus With Gasifier
(In Pesos)

Year	1	2	3	4	5	6-12	13-25
I. Costs Without Gasifier							
Amortization for Irrigation Loan	10,800	10,800	15,943	15,943	15,943	21,257	-
Diesel Fuel	69,504	69,504	69,504	69,504	69,504	69,504	69,504
Lubricant	6,950	6,950	6,950	6,950	6,950	6,950	6,950
Repairs and Maintenance	5,970	7,960	9,950	11,940	11,940	11,940	11,940
Total	93,224	95,214	102,347	104,337	104,337	109,651	88,394
II. Costs With Gasifier Using Woodchips							
Amortization for Irrigation Loan	10,800	10,800	15,943	15,943	15,943	21,257	-
Amortization for Gasifier Loan	6,745	6,745	6,745	6,745	6,745	6,745	6,745 1/
Amortization for Woodlot Loan	-	-	-	-	12,872	12,872	-
Diesel Fuel	20,851	20,851	20,851	20,851	20,851	20,851	20,851
Lubricant	6,950	6,950	6,950	6,950	6,950	6,950	6,950
Woodchip Labor	14,094	14,094	14,094	14,094	14,094	14,094	14,094
Repairs and Maintenance	6,892	9,190	11,487	13,785	13,785	13,785	13,785
Total	66,332	68,630	76,070	78,368	91,240	96,554	62,425
Savings (I vs. II)	26,892	26,584	26,277	25,969	13,097	13,097	25,969

1/ The gasifier unit would be replaced on average every 8 years and the amortization schedule is based on a six-year repayment. Thus between years 6 and 25 there could be six years (years 7 and 8, years 15 and 16, and years 23 and 24) when the annual amortization amount of ₱6,745 is not required.

Table 3

Gasifier Woodlot Development
Projected Income Statement
Diesel Driven Pump Irrigation System with Gasifier Using Woodchips
(In Pesos)

Year	1	2	3	4	5	6	7	8
Income								
Revenue from Rice Production (unmilled)	705,600	705,600	705,600	705,600	705,600	705,600	705,600	705,600
Expenses								
Development Cost				1,599	1,599	1,599	1,599	1,599
Production Cost	482,240	482,240	482,240	482,240	482,240	482,240	482,240	482,240
Administrative Cost	23,800	23,800	23,800	23,800	23,800	23,800	23,800	23,800
Diesel Fuel	20,851	20,851	20,851	20,851	20,851	20,851	20,851	20,851
Lubricant	6,950	6,950	6,950	6,950	6,950	6,950	6,950	6,950
Woodchip	14,094	14,094	14,094	14,094	14,094	14,094	14,094	14,094
Interest on Irrigation Loan	10,800	10,800	10,723	10,405	10,068	9,630	8,922	8,171
Interest on Gasifier Loan	3,328	2,918	2,458	1,944	1,368		723	
Interest on Woodlot Loan					7,673	7,053	6,351	5,568
Repairs and Maintenance	6,892	9,190	11,487	13,785	13,785	13,785	13,785	13,785
Depreciation: Structures & Civil Works	2,933	2,933	2,933	2,933	2,933	2,933	2,933	2,933
Depreciation: Pump, Machinery & Accessories	7,400	7,400	7,400	7,400	7,400	7,400	7,400	7,400
Depreciation: Gasifier	3,843	3,843	3,843	3,843	3,843	3,843	3,843	3,843
Total	583,131	585,019	586,779	589,844	596,604	594,901	592,768	591,234
NET INCOME	122,469	120,581	118,821	115,756	108,996	110,699	112,832	114,366

Table 4

Gasifier Woodlot Development
Projected Cash Flows Statement
Diesel Driven Pump Irrigation System with Gasifier
(In Pesos)

Year	0	1	2	3	4	5	6	7	8
Receipts									
Revenue from rice production (unmilled)		705,600	705,600	705,600	705,600	705,600	705,600	705,600	705,600
Proceeds from:									
Woodlot		18,735	17,675	17,675					
Irrigation Loan	180,000								
Gasifier Loan	27,730								
ISA Equity	22,018								
Total	229,748	724,335	723,275	723,275	705,600	705,600	705,600	705,600	705,600
Disbursements									
Woodlot Development		18,735	17,675	17,675					
Structures/Civil Works	88,000								
Pump, Machinery and Accessories	111,000								
Gasifier Installation	30,748								
Amortization of:									
Irrigation Loan		10,800	10,800	15,943	15,943	15,943	21,257	21,257	21,257
Gasifier Loan		6,745	6,745	6,745	6,745	6,745	6,745	-	-
Woodlot Loan						12,872	12,872	12,872	12,872
Production Cost		482,240	482,240	482,240	482,240	482,240	482,240	482,240	482,240
Administrative Cost		23,800	23,800	23,800	23,800	23,800	23,800	23,800	23,800
Diesel Fuel		20,851	20,851	20,851	20,851	20,851	20,851	20,851	20,851
Lubricant		6,950	6,950	6,950	6,950	6,950	6,950	6,950	6,950
Woodchips		14,094	14,094	14,094	14,094	14,094	14,094	14,094	14,094
Repair and Maintenance		6,892	9,190	11,487	13,785	13,785	13,785	13,785	13,785
Total	229,748	591,107	592,345	599,785	584,408	597,280	602,594	595,849	595,849
Net Cash Inflow		133,228	130,930	123,490	121,192	108,320	103,006	109,751	109,751
Beginning Balance			133,228	264,158	387,648	508,840	617,160	720,166	829,917
Ending Balance		133,228	264,158	387,648	508,840	617,160	720,166	829,917	939,668

Table 5

Gasifier Woodlot Development
Projected Balance Sheet
Diesel Driven Pump Irrigation System
With Gasifier Using Woodchips
(In Pesos)

Year	0	1	2	3	4	5	6	7	8
Assets									
Current Assets									
Cash	-	133,228	264,158	387,648	508,840	617,160	720,166	829,917	939,668
Pump, Machinery & Accessories	111,000	103,600	96,200	88,800	81,400	74,000	66,600	59,200	51,800
Gasifier Equipment	30,748	26,905	23,062	19,219	15,376	11,533	7,690	3,847	-
Structures & Civil Works	88,000	85,067	82,134	79,201	76,268	73,335	70,402	67,469	64,536
Development Cost	-	18,735	36,410	54,085	62,347	60,748	59,149	57,550	55,951
Total	229,748	367,535	501,964	628,953	744,231	836,776	924,007	1,017,983	1,111,955
Liabilities and Equity									
Irrigation Loan	180,000	180,000	180,000	174,780	169,242	163,366	151,741	139,406	126,320
Gasifier Loan	27,730	24,313	20,486	16,199	11,398	6,022	-	-	-
Woodlot Loan	-	18,735	36,410	54,085	63,946	58,747	52,926	46,405	39,097
ISA Equity									
Retained Earnings	22,018	22,018	144,487	265,068	383,889	499,645	608,641	719,340	832,172
Net Income Per Year	-	122,469	120,581	118,821	115,756	108,996	110,699	112,832	114,366
Total	229,748	367,535	501,964	628,953	744,231	836,776	924,007	1,017,983	1,111,955

Table 6
Gasifier Sub-Project
Summarized Total Costs
(000)

	GOP	ESF	TOTAL
Woodlot development costs			
Program management and cost escalation (₱26,770 x 495)	13,251	-	13,251
Labor and other costs (₱19,732 x 495)	-	9,767	9,767
Total peso costs - 495 woodlots	13,251	9,767	23,018
Dollar equivalent	1,656	1,221	2,877
Gasifier Costs			
Gasifier (₱15,000 x 1,150)	-	17,250	17,250
Shipping and installation costs (₱15,748 x 1,150)	18,110	-	18,110
Total peso costs - 1,150 gasifiers	18,110	17,250	35,360
Dollar equivalent	2,264	2,156	4,420
Total peso project costs	31,361	27,017	58,378
Total dollar equivalent project costs	3,920	3,377	7,297

LOAN PLAN

Under the Gasifiers for Irrigation subproject the Farm Systems Development Corporation (FSDC) provides loans to the ISAs for: the acquisition of gasifiers to supplement the use of diesel in diesel engine driven pump irrigation systems; and the development of woodlots on denuded or marginal lands adjacent to an irrigation project to produce a steady fuel supply of the gasifiers.

1. GASIFIERS

A. General

The loan finances the purchase of gasifier equipment including shipping and installation. The loan amount is based on actual equipment costs, with the ISA providing 10% of actual project costs, i.e., labor during installation, as its equity in the project.

The loan's interest rate is 12% annually, and starts to accrue after equipment installation and turn-over to the ISA. Repayment starts at the end of the first cropping season after turnover and is due at the end of each succeeding cropping season until paid in full.

B. Loan Releases

Releases are in commodity form (the gasifier unit) not exceeding the amount approved for financing by the FSDC Board of Administrators and are made upon submission of the following requirements:

1. Loan Contract duly signed by the ISA President;
2. Registration documents;
3. ISA Board Resolution stating intention to secure a loan from FSDC and authority of the ISA President or duly authorized ISA Officer to act as signing officer for all loan disbursements and execution of loan proceedings; and a statement of the ISA's equity contribution.

FSDC purchases the gasifier equipment from the Gasifier and Equipment Manufacturing Corporation (GEMCOR) on behalf of the ISA, and charges the amount to the ISA loan including freight and installation costs.

The ISA acknowledges receipt by signing a Memorandum of Receipt.

C. Collection

Repayment size is determined by an amortization schedule, and the ISA collects gasifier loan payments from the members as part of the members' irrigation fee. Collection takes place at the peak of the harvest season when ISA members have ready cash from crop sales. Processing loan repayments is the responsibility of the association's secretary-treasurer.

Built-in measures to safeguard funds are established, such as, official receipts are issued for any cash receipts and transportations are entered into account books. Periodic audits are made on these accounts to check and control loan activities.

2. WOODLOTS

A. General

The energy woodlot loan covers the three year costs of developing the woodfuel supply, including: first year land preparation, cultivation and maintenance activities; and second and third year cultivation and maintenance activities.

The loan's interest rate is 12% annually and starts to accrue upon release. The loan has a 12-year maturation, with a 4-year grace period and repayment starts in the fifth year. Loan disbursements are staggered during the three years of woodlot development.

B. Loan Release

Loans granted to the ISA are released in the form of cash not to exceed the amount approved for financing by the FSDC Board of Administrators and loan releases are made only upon submission of the following:

1. Loan Contract duly signed by the ISA President;
2. Registration documents;
3. ISA Board Resolution stating the intention to secure a loan from FSDC: and authority of the ISA President or duly authorized ISA officer to act as signing officer for all loan disbursements and execution of loan proceedings.

Loan releases are staggered on the basis of the funding requirements prepared by the Project Manager. The ISA acknowledges receipt of the funds with an Official Receipt or submission of an acknowledgement receipt.

With the assistance of the Area FSDC Technician, the association determines its financial needs for major activities based on a production calendar. This calendar plots the duration and schedule of each activity, including manpower and materials requirements, for the development of the energy woodlot.

Supported by a work program and statement of financial requirements, a request for funds is presented to the ISA general assembly for approval. Upon approval, withdrawal of the specified amount of funds is made by the authorized ISA representatives.

C. Collection

The association members repay the loan based on an amortization schedule; the first payment due on the last calendar day of the fourth year. The ISA secretary-treasurer is responsible for collections, and account book entries must be made. As in all ISA transactions, the account books are subject to outside audit and scrutiny by ISA members.

3. PROGRAM MANAGEMENT

The loan finances FSDC costs for program management, including supervision and technical assistance.

The loan's interest rate is 2%, and starts to accrue with the start of the project at the ISA. Payment is due in the fifth year.

Environmental Assessment of Gasification

INTRODUCTION

This component of the program involves the utilization of gasifiers to fuel pump irrigation systems. An overall diagram of the system is presented in Figure 1. It is projected that approximately 1190 units having a total capacity of about 5500 hp will be installed.

Fuel Source

The source of fuel to the gasifiers will be wood. The wood will be obtained from tree farms. Estimates indicate that a 6-ha. woodlot will produce sufficient wood to satisfy the requirements of 65-hp system. Loans will be made available to the farmers to enable them to operate their tree farms. Woodchips will be purchased by the farmers while the woodlots are being developed.

Fuel Specifications

The feedstock to the gasifier must be chipped (either manually or mechanically) to a particle size smaller than 13.3 cm.

Fuel Consumption

The fuel consumption is expected to be approximately 25 kilograms per charge. At 50 percent diesel substitution, a typical 65 hp engine can consume about 80 kilograms of fuel in an 8-hour period.

System Description

The gasification system consists of three major components: (1) the gasifier, (2) the gas cleaning train, and (3) the piping and mixing box.

Gasifier

The reactor to be used in this program will be of the downdraft design. This particular type of gasifier reduces the concentration of tars and oils in the gas to less than 10 percent of that in gas produced in updraft gasifiers. In addition, since the downdraft design results in relatively low gas velocities, the ash settles through the grate, and thus a very small percentage is carried over with the off-gases.

A schematic diagram of a downdraft gasifier is given in Figure 2.

Gas Cleaning Train

This part of the gasification system is designed to remove impurities from the gas. In this particular case, the gas cleaning equipment consists of a cyclone, a wet scrubber, and a wet filter.

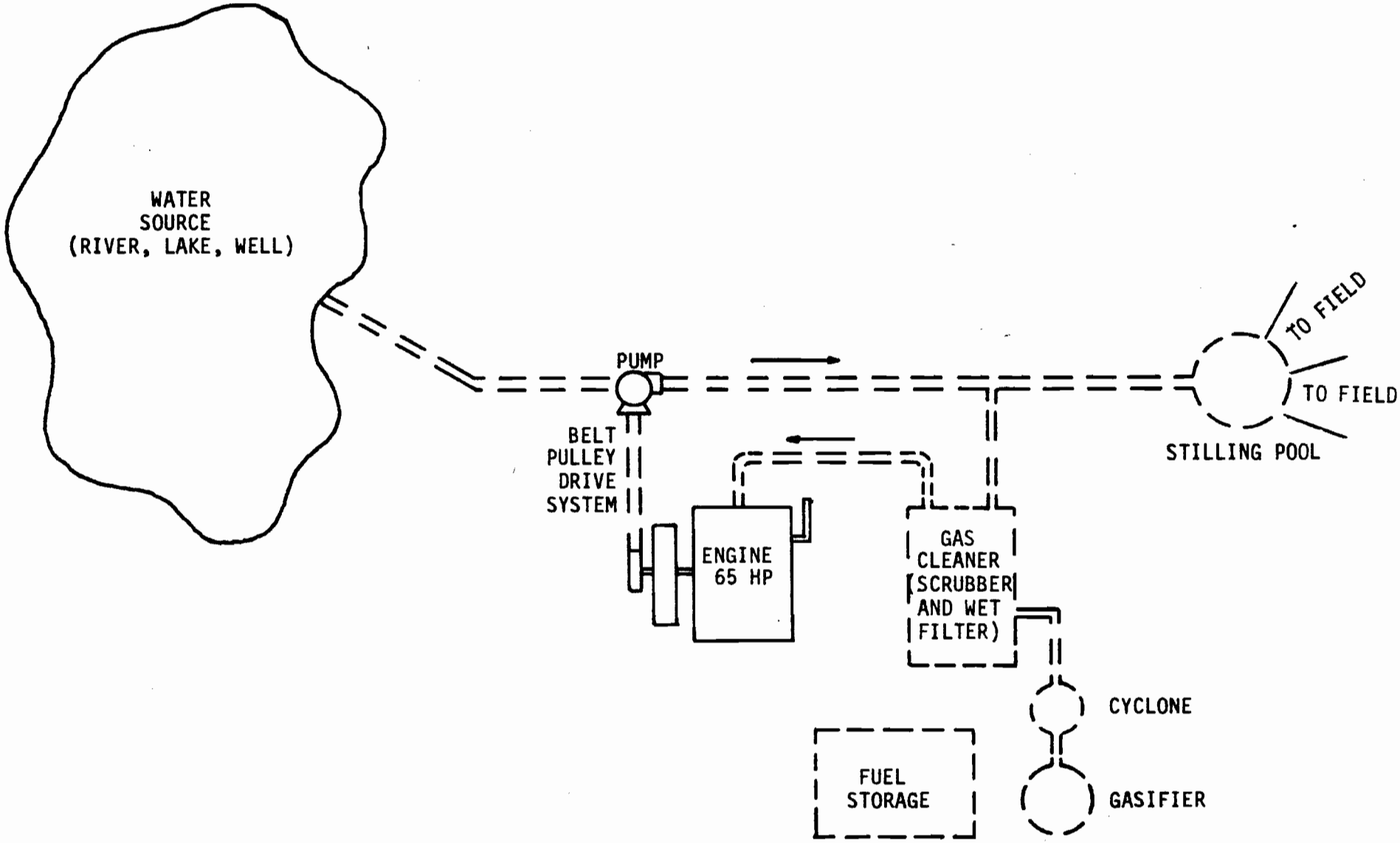


Figure 1. Lay Out of a Pump Irrigation System
Adapted to Gasifier Operation

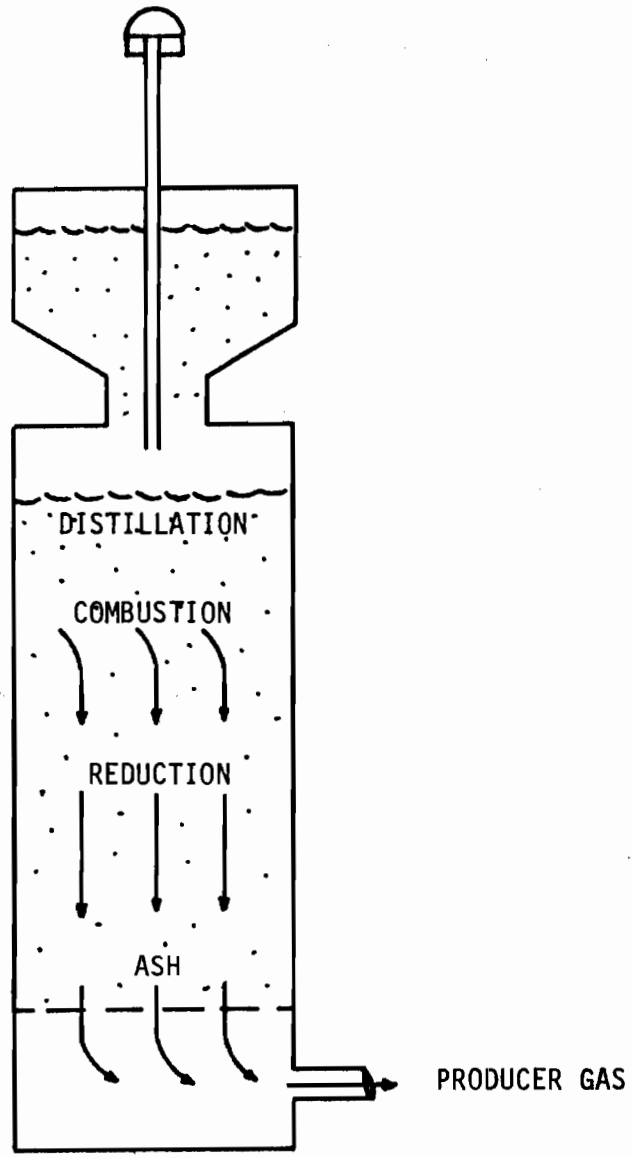


Figure 2. Downdraft Reactor.

The cyclone removes suspended particulate matter by centrifugal force. It is equipped with a drain system so that its contents can be emptied periodically.

In the wet scrubber, water is used to remove soluble matter from the gaseous streams. It is of the counterflow type, and is equipped with a sight glass and overflow channel.

The wet filter uses diesel fuel to further remove residual contaminants.

In addition to purification, the cleaning train also serves to cool the gas. Ideally the gas should be cooled to ambient temperature in order to optimize the engine's output.

Mass Balance

Inputs to a typical gasification system include: fuel, combustion air, and water. Outputs from the system include: producer gas, char, waste water, soot, fly ash and tar.

A mass balance is presented in Figure 3 for a generalized gasification system in which is utilized a unit input of one ton of biomass. System outputs are expressed in quantities per unit of input of biomass feedstock.

Emissions

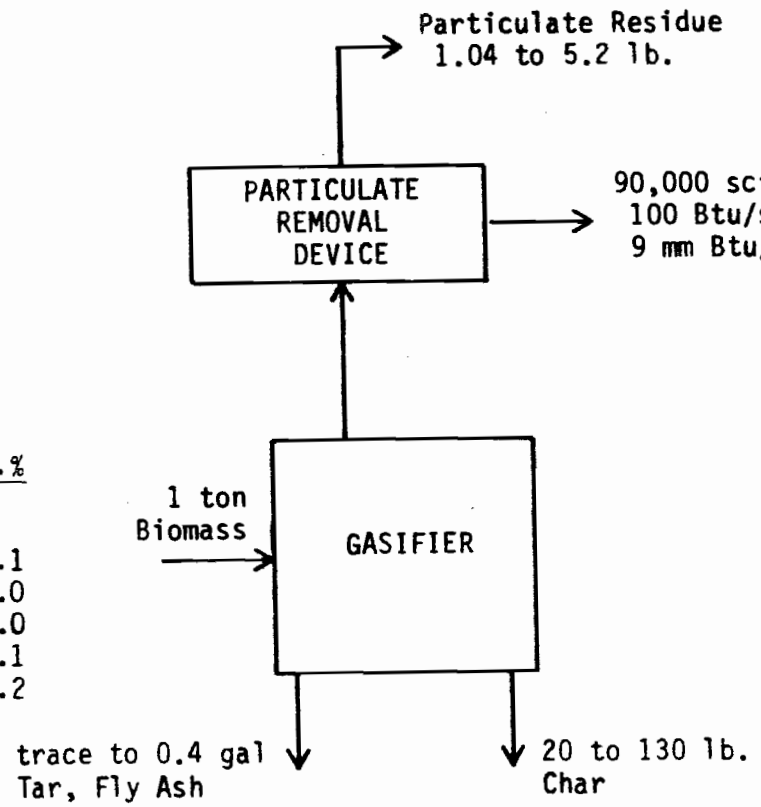
As previously indicated, emissions from gasification systems include gases, water, solid wastes, and noise. Since the maximum number of units at a particular site will be two, rated at an average of 65 hp each, the emissions are expected to be relatively small.

Air

The air emissions of concern are particulates and NO_x. Since wood typically has a very low sulfur content, SO_x emissions resulting from the use of producer gas should be extremely low.

Particulate emissions are generally a function of gasifier design, fuel feed rate, and efficiency of the gas cleaning system. Downdraft gasifiers should not produce substantial levels of particulates. For instance, a gasifier built by the University of California was tested when coupled to a boiler. The results of the tests showed that the particulate emissions averaged 0.7 lb/hr at an output of 8 to 10 million Btu/hr. Loading in the flue gas averaged 0.08 grains/SCF of flue gas.

Research has shown that particulate emissions are a function of feed rate. A correlation between feed rate and emissions is presented in Figure 4. It should be noted that the data in the figure were obtained when a wet fuel was used. The figure shows that relatively low emissions can be had even at high gasification rates. Emissions from boilers utilizing producer gas have NO_x levels on the order of 130 ppm. Other data have shown NO_x to vary between 0.01 to 0.1 lb/10^6 Btu. In general, when



BIOMASS COMPOSITION

Specie	Max.%	Min.%
C	56	38
H	6.5	5.1
N	2.4	0.0
S	39.9	0.0
O	45.4	0.1
Ash	19.2	0.2

PRODUCER GAS COMPOSITION

Specie	Max.%	Min.%
CO_2	13	4
O_2	5	trace
CO	27	12
H_2	19	5
CH_4	1	trace
N_2	69	54
Particulate (grains/scf)	0.1	0.02

CHAR COMPOSITION

Specie	Max.%	Min.%
C	79	35
H	4.0	2.1
N	1.9	0.1
S	0.9	0.1
O	24.5	7.9
Ash	2.3	49.2

Figure 3. Gasifier Mass Balance.

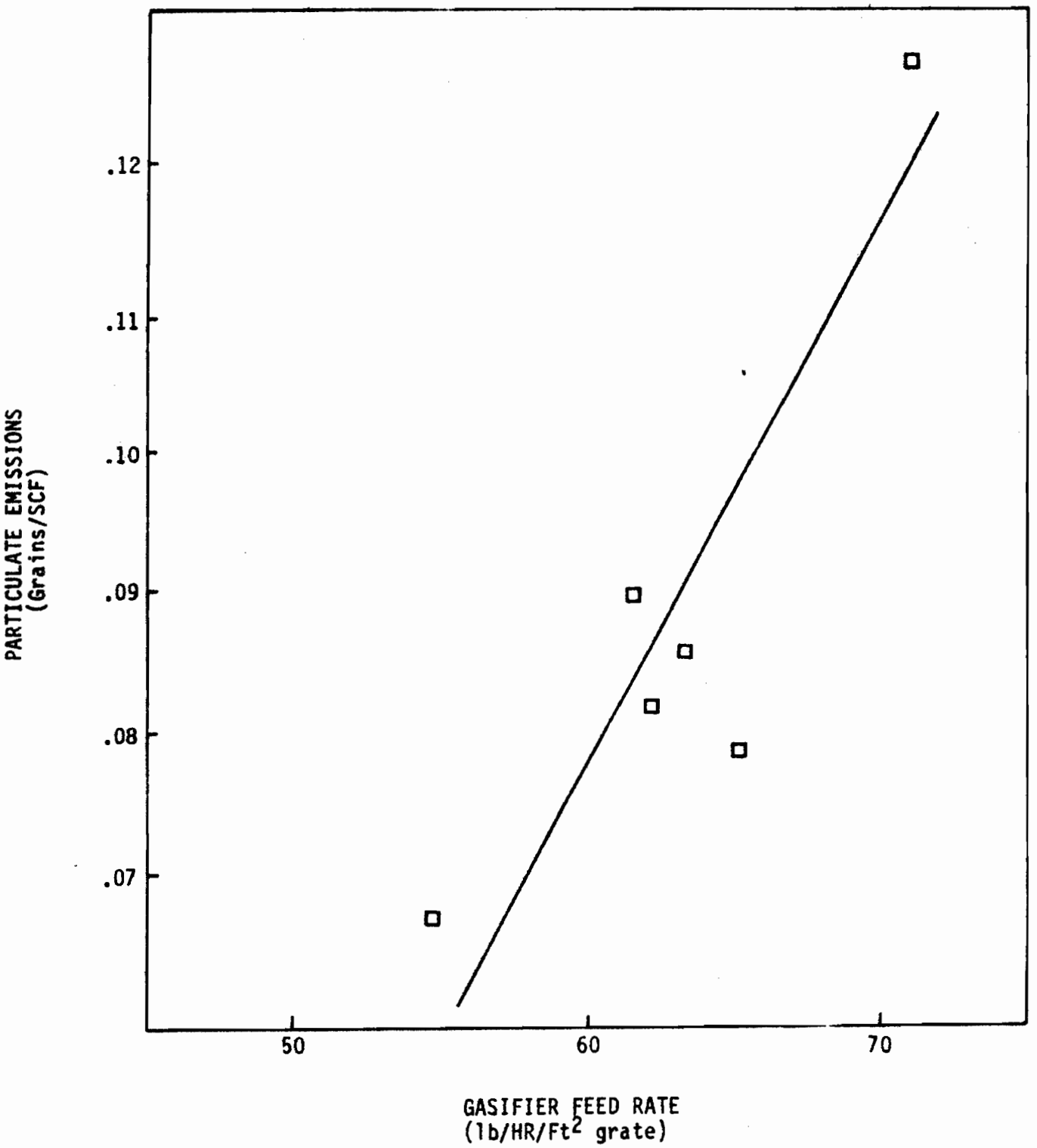


Figure 4. Particulate Emissions as a Function of Fuel Feed Rate

producer gas is used to supplement fossil fuel combustion, the combustion temperature of the reaction is reduced due to the lower heating value of the producer gas, and the concentration of NO_x is correspondingly reduced.

When producer gas is used in diesel engine applications, the gas must be cooled to nearly ambient conditions before being injected into the engine. This is done in order to maintain the volumetric efficiency when the engine is switched from diesel fuel only to a mixture of diesel fuel/producer gas. When high percentages of producer gas (on the order of 70 to 80 percent) are used, the exhaust temperature is reduced approximately 250°F. This reduction in exhaust temperature causes a decrease in NO_x concentrations in the exhaust gas.

Liquid

Liquid emissions result from gas cleaning/cooling.

A large percentage of the tars are removed in the cyclone while the remainder is removed in the scrubber. Analyses of the water used in a gas cleaning/cooling train are presented in Table 1.

Solid Waste

The gasification process generates two types of solid waste: fly ash and char.

The fly ash collected in the cyclone amounts to about 0.1 to 0.2 percent of the feed. The composition of this material indicates that it contains about 73 percent fixed carbon, 7 percent volatile matter, and 20 percent ash.

The char, a product of incomplete combustion, is generated at about 1 to 7 percent of the feed. Ultimate analysis of various types of char are presented in Table 2. The data in the table show that the char need not be treated as a waste but rather as a solid fuel.

Noise

Noise will be generated during construction and during the operation of the system.

The noise due to construction activities will, of course, be temporary and would not be excessive. Noise generated by the purification systems will be negligible in comparison to that of the diesel engine.

POTENTIAL ENVIRONMENTAL IMPACTS

The degree to which the environment will be affected is a function primarily of location and size of the project. In the development of this document it is assumed that appropriate criteria will be used in siting the projects. The largest project will consist of two units generating gas for 2-65 hp engines. Thus, the total impact on the environment seems to be small on an individual or on a cumulative basis.

Table 1

COMPOSITIONS OF WASTEWATER FROM GAS PURIFICATION SYSTEMS

Constituent	Feedstock: Dry Wood	Feedstock: Sawdust (Wet)
Cl (mg/l)	57.00	5.24
Na (mg/l)	9.05	25.90
K (mg/l)	19.60	44.30
Ca (mg/l)	176.00	2.42
Mg (mg/l)	6.60	56.00
TKN (mg/l)	240.00	506.00
pH	3.95	1.80
Conductivity (umhos/cm)	2,600.00	13,400.00
Alkalinity (p^H3.7, mg/l) as $CaCO_3$		
Organic Acids (mg/l)	8,720.00	8,400.00
TOC (mg/l)	17,200.00	20,800.00
COD (mg/l)	53,500.00	65,890.00
Total Solids (mg/l) at 104°C	18,800.00	
Total Volatile Solids (mg/l) at 550°C	16,677.00	
Suspended Solids (mg/l) at 104°C	1,680.00	
Volatile Suspended Solids (mg/l) at 550°C	1,650.00	

Table 2

Ultimate Analysis of Pyrolysis Chars
(weight percent, dry basis)

Material	C	H	N	S	O	Ash	Higher Heating Value Btu/lb
Fir bark char	49.9	4.0	0.1	0.1	24.5	21.4	8,260
Rice hull char	36.0	2.6	0.4	0.1	11.7	49.2	6,100
Grass straw char	51.0	3.7	0.5	0.8	19.7	24.3	8,300
Animal waste char[a]	34.5	2.2	1.9	0.9	7.9	48.8	5,450
Redwood charcoal (790° to 1020°F)	75.6	3.3	0.2	0.2	18.4	2.3	12,400
Redwood charcoal (860° to 1725°F)	78.8	3.5	0.2	0.2	13.2	4.1	13,100
Oak charcoal (820° to 1185°F)	67.7	2.4	0.4	0.2	14.4	14.9	10,660
Oak charcoal (1060°F)	64.6	2.1	0.4	0.1	15.5	17.3	9,910

[a] Contains 3.7 percent Cl lumped with oxygen

A detailed discussion of the environmental impacts resulting from the proposed gasification program follows.

Earth Resources

Impacts dealing with earth resources will be minimal with the installation of the gasifiers, as they require no excavation, soil displacement and, because of their size, no major construction creating hazardous conditions.

The required land area for the gasifiers is approximately twice that currently occupied by the stand-alone diesel engines: a relatively small area.

Each woodlot will require approximately 6 hectares. As the trees will be grown on marginal and denuded lands, they will have a beneficial effect on each site. Approximately 12,870 hectares of land will be reforested on the 495 sites in this program.

Air Quality

Air emissions resulting from gasification systems can originate in fuel preparation and combustion of the gas, and can come from leaks in the system prior to combustion, as well as from ash collection and disposal operations. Emissions from fuel transportation activities can also increase concentrations of pollutants. Because of the relatively small number of units and sizes of the gasification facilities to be developed in the Philippines, no major air quality impacts are expected on an individual or on a cumulative project basis.

Fugitive emissions of producer gas (i.e., gas leaks directly vented to the atmosphere) are estimated to be in the range of 0 to 0.1 percent of the total producer gas. Consequently, the air quality in the vicinity of the gasifier can be affected by the CO and HC present in the gas. However, with appropriate ventillation, the concentrations of CO and HC would not be great enough to have a significant impact. A large release of gas may occur in the event of a mechanical failure or an accident. In such a case the entire gaseous stream may be vented to the atmosphere. Application of sound engineering and safety practices in gasification projects will be the main safeguards for avoiding these types of emissions. Emissions associated with transportation of the feedstock to a gasification system can be minimized through conventional maintenance practices, and by properly covering delivery trucks to reduce dust emissions. Emissions from fuel storage, and fuel handling and preparation are also expected to be minimal.

When biomass fuels are derived from crop residues, consideration must be given to the presence of pesticides and herbicides in the gases, and to solids discharged from the system. In general, residual levels of pesticides and herbicides are quite low in crop residues and hence are not anticipated to present environmental problems. Forestry wastes are virtually devoid of such residues.

The thermodynamics of gasification indicate that residual pesticides and herbicides would be destroyed in the process. However, during

the drying process, some volatile compounds may be distilled from both pesticides and herbicides. The ultimate fate of such distillates are a function of the gasifier configuration. For example, in the updraft mode, these distilled compounds may be carried as a gaseous species, and ultimately enter the atmosphere as products of combustion if the producer gas is used in either boiler or engine applications. On the other hand, in a downdraft operation, the distillates may be more fully destroyed.

Since the source of fuel for the gasifiers will be from energy plantations, herbicides and pesticides are not expected to create any environmental impacts.

Water Quality

In general, water requirements for gasification systems are relatively small. The quantity and quality of the wastewater, of course, depend upon the feedstock, design, and size of gasifier, as well as on the type and degree of gas cleaning. Specific data on the quantity of water required for gas cleaning are not available. However, the amounts of water generated by the proposed gasification are expected to be small.

Proper engineering and safety procedures should be followed in order to minimize environmental impacts.

Solid Waste

The fly ash and char generated by the gasifications system do not present a serious disposal problem.

Based on preliminary estimates, it is expected that each 65 hp unit could generate from 0.1 - 0.7 kg of char and about 0.01 to 0.02 kg of fly ash each hour of operation.

Biological Resources

The implementation of a gasification system may have certain impacts on the biological resources in the vicinity of the installation.

Air, noise, and wastewater emissions may cause damage to native vegetation or adversely affect wildlife and aquatic biota. Similarly a certain amount of vegetation may have to be removed during construction, and thereby wildlife habitat may be destroyed.

Since the irrigation systems will involve the use of relatively small land areas, the utilization of appropriate siting criteria will result in no significant impact on biological resources.

Noise

Noise emissions have been identified as being generated during construction, and during the receiving, handling, and processing of the fuel. Construction noise may be temporarily adverse. Operational levels, although continuous, are not considered to be significant. The reactors will increase noise levels only if equipment components are improperly installed. However, fans and other pieces of equipment

associated with gasifiers may cause an increase in ambient noise conditions. Mitigative measures would include special noise reduction enclosures, placement of noisiest equipment in structures, or an enlargement of site boundaries in order to reach the desired low noise level.

Land Use/Socioeconomics

The gasification systems are not expected to affect zoning regulations or land use patterns, since the systems will be located in agricultural areas.

The construction and operation of gasification systems will generate a small number of jobs in the area, since the units will be produced in a factory. Furthermore, the operation of the system will not be labor-intensive. However, 7-8 farm families will be employed in the growing and harvesting of wood.

These systems will have a positive impact on the economic development of the area, due to the fact that farmers will be able to irrigate their lands at a lower cost than is possible with the sole use of diesel fuel.

Natural Resources

The proposed gasification projects can have a very beneficial impact on the natural resources of the country. This would be accomplished through the substitution of renewable for non-renewable resources for energy generation.

It has been estimated that one ton of biomass can substitute for about two barrels of oil. The estimate is based on a gasifier conversion efficiency of 75 percent. Therefore, the proposed units could displace up to 109,996 barrels of oil each year.

Although the construction and operation of gasification facilities will require the use of gasoline, oil, electricity, and other materials, each project will be a net energy producer, and will use renewable fuels.

Health and Safety

Health and safety hazards are related to the occupational areas of gasification projects, and can result from the following events:

- toxic gas leaks (e.g., carbon monoxide); and
- fuel pile fires

Fires in fuel storage areas can result from spontaneous combustion, from carelessness, or from equipment sparks. Adequate safety procedures can mitigate these potential impacts.

Health and safety aspects of gasification projects are very important. By providing proper engineering of control systems and appropriate design of safety systems, the likelihood of accidents is minimized, and would not be considered significant.

MITIGATION MEASURES

The use of proper criteria for siting as well as the practice of sound engineering principles will ensure that the proposed gasification systems will not be located in areas that can create public hazards. Such hazards can come about from floods, mud slides, or land slides.

Potential air quality impacts can be substantially reduced through the use of gas cleaning equipment. The size of the gasification systems as well as of the gas cooling unit will ensure that NO_x emissions will not be excessive.

Water quality impacts resulting from the gas cleaning/cooling train will be minimal due to the relatively small size of the projects.

The implementation of appropriate siting criteria will insure that a facility is not located in an area considered to be critical habitat for rare or endangered aquatic, vegetative, or terrestrial biota, thus avoiding potential adverse impacts. Similarly, ensuring that emissions are properly treated prior to their release to the environment, will also serve to prevent potential adverse impacts on biological resources.

Excessive noise levels can be prevented through the use of enclosures, establishment of adequate site boundaries (for noise attenuation), proper establishment of fuel transport routes and delivery times, and ensuring of compliance with all appropriate regulations.

Potential adverse effects on social economies, land use, and resources can be mitigated through the use of applicable siting criteria, and through compliance with relevant zoning, and development plans in the area.

2. Woodlots

The 6ha. woodlots required to support the Gasifier for Irrigation Program are much smaller than the tree farms needed for the power plant and charcoal production programs. Their development and management, however, are basically the same and so are their environmental effects, although different in scale. For example the woodlots will not have a great an effect on recharging aquifers or watershed improvements as the much larger tree farms will.

The environmental impact assessment below, and the accompanying table, describe the effects of developing energy woodlots at the 495 gasifier sites.

Table 3 shows the influence on the environmental resulting from woodlot development activities in this program. The time frame of these influences, their onset and duration, are also shown. These influences are individually assessed as favorable or adverse in varying degrees of importance as perceived by the team. Finally, measures which can mitigate or correct adverse influences are suggested.

On the whole, the change from the present vegetation and land use to woodlot development using ipil-ipil will have a predominantly positive impact on the environment. Whatever negative influences result from this change are outweighed by the significant positive influences and can be easily corrected.

The highly adverse impacts indicated in Table 1 are expected to be of short-term duration. One, which is the increase in soil erosion because of soil disturbance during site preparation, cultivation, and road construction, is common to woodlot development projects. This adverse impact takes effect during the immediately following rainy season, but only for the first season as vegetation development and soil stabilization quickly follow. Another, the influx of pests like rats because of concentration of available food provided by the new plants, is also common among reforestation species. This is critical mainly during the early stages of the first growing season, and can be mitigated by proper cultural practices.

It is also believed by some that the heavy rainfall, the allellopathic effect of ipil-ipil on the underbrush, and the rapid decomposition of ipil-ipil litter would tend to induce sheet erosion in the long term. However, this is counteracted by effective rainfall interception by the canopy and increased infiltration resulting from the interweaving root system of the plants. The negative and positive effects would therefore tend to balance each other and the total effect would be of minor consequence compared to soil erosion in degraded grasslands.

Another consideration is continual biomass harvest. The harvesting process in itself would have only minor influence, especially if one during the dry season, since the nature of the product would require only the use of manual methods. Moreover, the duration of its impact is quite short as ipil-ipil stumps coppice well and quickly. The rotation of four years should not cause much drain in soil nutrients since the plant produces organic matter and fixes nitrogen.

Other adverse impacts are of relatively less significance. Many of these, such as loss of genetic diversity, increased susceptibility to diseases, and short-term increase in siltation of creeks, are again common to woodlot development activities.

The highly favorable impacts of woodlot development on the bio-physical environment, on the other hand, are of long-term duration. One is improved microclimatic conditions such as stabilized soil temperature and moisture because of the higher and close ipil-ipil canopy structure. Another is the increase in primary biomass especially wood resulting from the reforestation of degraded areas with fast-growing trees.

Other highly favorable impacts include the vegetational change from Imperata-Themeda or Chromolaena-dominated grasslands to woodlots with consequent change of vegetational structure to that of close-canopy, open understory type; increased soil fertility; stabilization of water flow with improved infiltration, drainage, and aquifer recharge; and decreased run-off because of the more effective rainfall interception provided by the canopy.

The net result in the interplay of the long-term favorable impacts and the predominantly short-term adverse impacts would be the considerable improvement of the bio-physical environment from a grassland or savannah type to a forest type. These conclusions are common to program sites nationwide and in fact in other similar sites in the country, as well, which can support ipil-ipil or other forest species. Whether the resulting forest plantation is used for wood chip production, wood-fired power generation, charcoal production, or simply fuelwood production, its very beneficial effects are the same.

Table 3
Environmental Impacts of Woodlots for Woodchip Production

Environmental and Resource Items	Predicted Impacts: Description	Causative Factors	Time Frame: Onset	Time Frame: Duration	Relative Weight	Mitigating Measures and Remarks
A. Physical Environment						
1. Run-off	a) Net decrease of run-off due to rainfall interception, surface flow impedance, increased infiltration	Presence of ipil-ipil canopy cover, organic matter and deeper root system	M*	L*	HF*	Positive impact
2. Erosion	a) Increased soil erosion due to soil disturbance in planting and consequent flow concentration on trails	Plowing, dibling, and site clearing	I	S	HA	Conduct activities that may cause soil disturbance during the dry season or before onset of rains
	b) Overall decrease of soil erosion from less run-off and raindrop impact	Presence of ipil-ipil canopy cover, organic litter, and interweaving root system	M	L	F	Positive impact. All activities that may potentially cause soil disturbances should be conducted during the dry season
3. Soil Fertility	a) Increased soil fertility	N-fixing capability of ipil-ipil and increased organic matter	M	L	HF	Positive impact
4. Water Quality	a) Increased siltation of creeks and rivers at some sites	Soil disturbance in clearing and planting	I	L	A	Conduct activities which may cause soil disturbance during the dry season

*Symbols

Onset
I = Immediate
M = Medium term (about 4-5 years)
L = Long term (5 and above)

Duration
S = Short term
M = Medium term
L = Long term

Relative Weight
HF = Highly favorable impact
F = Favorable impact
A = Adverse impact
HA = Highly adverse

Table 1
Environmental Impacts of Woodlots for Woodchip Production

Environmental and Resource Items	Predicted Impacts: Description	Causative Factors	Time Frame: Onset	Time Frame: Duration	Relative Weight	Mitigating Measures and Remarks
	b) Stabilization of flow with improved infiltration, drainage and aquifer recharge	Improved canopy cover, organic litter/matter on soil and deeper inter-weaving root system	M	L	HF	Positive impact
	c) Generation of wood wastes	Harvesting and chipping will generate wastes which may reach water systems.	L	L	A	Develop program for use of wood waste in gasifier or composting
5. Microclimate	Improved and stabilized soil temperature and moisture, humidity and wind movement	Higher and close canopy structure of ipil-ipil and the wind-break effect of its rigid stems	M	L	HF	Positive impact
6. Air Quality	Overall improvement of air quality in the area due to increased oxygen, reduced dust in air	Concentrated tree growth	I	L	HF	Positive impact
B. Biological Environment						
1. Primary Productivity	a) Loss of some savannah and secondary forest trees within the woodlot	Site preparation, clearing for trails	I	L	HA	Extension campaigns to emphasize importance of remaining trees
	b) Increased primary biomass especially wood	Reforestation of formerly denuded areas with fast growing trees	M	L	HF	Positive impact

Table 1
Environmental Impacts of Woodlots for Woodchip Production

Environmental and Resource Items	Predicted Impacts: Description	Causative Factors	Time Frame: Onset	Time Frame: Duration	Relative Weight	Mitigating Measures and Remarks
2. Succession	a) Vegetational change from *Imperata* - *Themeda* or *Chromolaena* dominated grasslands to pure plantations of ipil-ipil with consequent change of vegetation structure to close canopy, open understory type	Dominance by faster and taller growing ipil-ipil through shading, general improvement of soil structure and fertility and protection from fire.	M	L	HF	Positive impact
	b) Change in animal population from predominantly grassland/savannah types to forest type	Transformation of their habitat	L	L	F	Positive impact
3. Genetic Resources	Loss of genetic diversity and also probably the flexibility to adapt to environmental changes	Simplification of vegetative cover to a dominant species which is ipil-ipil	M	L	A	Intercrop other species with ipil-ipil and plant belts of mixed species
4. Pest Occurrence	a) Increase of insect pests especially that of *Araecerus fasciculatus* which usually attacks giant ipil-ipil pods	Monoculture/concentration of the insect pest's food source	M	L	A	Monitor pest occurrence and perform necessary pest management strategy

Table 1
Environmental Impacts of Woodlots for Woodchip Production

Environmental and Resource Items	Predicted Impacts: Description	Causative Factors	Time Frame: Onset	Time Frame: Duration	Relative Weight	Mitigating Measures and Remarks
	b) Potential influx of vertebrate pests like rats (i.e. Rattus mindanensis, Rattus exulans querati)	Young shoots of ipil-ipil are food for these rats	I	M	A	Clear area where young ipil-ipil are planted and growing
5. Aquatic Resources	Possible degradation of aquatic resources (i.e. fishes) due to siltation at some sites	Planting, wood harvesting and chipping	I,M	L	A	Strict implementation of erosion control measures