Center For Economic Research on Africa
School of Business
Montclair State University
Upper Montclair, New Jersey 07043

An Economic and Financial Analysis of Rural Water Supply Technologies in the Sudan:

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Phillip LeBel
Professor of Economics
Department of Economics and Finance
School of Business
Montclair State University
Lebelp@mail.montclair.edu

Abstract

Cost-effective water is a critical issue for rural populations in developing countries. We examine in this paper both traditional diesel and alternative renewable energy technologies for providing potable water to village communities as well as for small-scale irrigation in the Sudan. Based on a number of technical and economic assumptions, we find that the cost-effectivness of solar and wind technologies is sensitive not just to underlying discount and foreign exchange rate considerations, but also to the pricing of traditional diesel fuel in the Sudan. We find the current system of multiple pricing of diesel fuel to be inefficient and that renewable technologies can play a role in selected settings once one adopts economic pricing.

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Executive Summary

As elsewhere in Africa, diesel systems have been for some time a primary method for village and small-scale irrigation pumping. Now that the Sudan Renewable Energy Project (SREP) has been able to field test wind and solar renewable energy alternatives, a number of conclusions regarding the financial and economic viability of these systems can be drawn. In summary order, they are:

1. Water pumping consumers traditionally make technology purchasing decisions on the basis of capital rather than life cycle costs, which implies an implicitly high private discount rate.

2. When life cycle costs are taken into consideration, renewable energy resources can be a cost-effective alternative to diesel pumping systems. The costeffectiveness of renewable energy systems over conventional diesel systems can be demonstrated in terms of standardized life cycle unit costs, as measured per cubic meter of water produced.

3. The financial variables that affect the costeffectiveness of a water pumping system are: the discount rate, the foreign exchange rate, the price of conventional diesel fuel, credit terms for loans, tax rates, and inflation. Economic variables that afffect the cost-effectivness of water pumping systems are: the shadow unskilled labor rate, the shadow foreign exchange rate, and the financial variables cited net of taxes and loans.

4. The methodology used in this assessment is as follows:
   a. parametric variation of each variable alone and in combination with other variables
   b. ranking of the technologies in terms of cost-effectiveness and in terms of the parametric variations
   c. comparative regressions to illustrate the relative significance of variables to cost-effectiveness

5. The direction of causation of the financial and economic variables on cost effectiveness is as follows:
   a. higher discount rates work against renewables and in favor of diesel systems
   b. higher fuel prices work againwst diesel systems and in favor of renewables
   c. higher foreign exchange rates work in favor of diesel and against renewables because of the relatively higher capital unit cost of renewable technologies
   d. loans for equipment purchases raise the cost of all water pumping systems, but work relatively in favor of diesel over renewables because of the smaller relative capital cost of diesel systems

e. import duties on capital equipment, while raising the cost of all water pumping technologies, work in favor of diesel over eenewables because of the smaller capital cost of diesel systems
f. user fees presently charged for water in the Sudan tend to underestimate the life cost cost of water pumpting systems, contributing further to the bias in favor of conventional diesel systems.

7. For renewable water pumping technologies to succeed in the Sudan, policymakers will have to redress the above-cited sources of bias. Measures to do so include:
   a. set water tariffs at full life-cycle cost recovery rates
   b. set diesel fuel prices at unregulated levels and eliminate the existing system of fuel cross-subsidies that have favored diesel
   c. foster long-term credit programs for water pumping investment choices
   d. price all water pumping choices on the basis of unregulated foreign exchange rates, to reflect the social opportunity cost of all domestic and imported resources, even though this would reduce the nominal advantage of renewable energy technologies
   e. develop a viable institutional plan for commercialization of wind and solar systems through demonstration seminars not only to potential users but also to distributors and the public at large .
   f. reduce general inflationary pressures in the economy so as to foster long-term resource allocative efficiency

1. Introduction

For several years, the Government of the Sudan, in cooperation with various international development agencies, has explored the role of traditional and renewable trechnologies in meeting the demand for potable and irrigation water in rural communities. The institutional context of this initiative stems from the relative dependence on the Sudan on agriculture, and on the relatively low degree of urbanization in the country. In so doing, the government has examined these options in the context of known deposits of oil but for which the Sudan still imports the bulk of its supplies from abroad and seeks to balance the consequences of imports on the balance of payments against the need to balance the competing interests of urban and rural consumers of water, among other objectives. To do so, US AID and other development agencies, notably GTZ of Germany, have supported initiatives to test wind and solar technologies in the Sudan and to weigh the technical performance of these systems against traditional diesel water supply systems. The framework for this initiative is the Sudan Renewable Energy Project, or SREP. What this report seeks to address is whether the economics of these technologies justifies an expanded role for renewable technologies in comparison to traditional diesel systems.

In preparation for this evaluation, a number of background documents have been reviewed. A list of these documents is given in Appendix A. In addition, Associates in Rural Development (hereafter ARD) had commissioned three local consultancies concerning.the pricing of diesel fuel, the setting of financial and economic variables by the Ministry of Planning, as well as the setting of excise and import duty rates by the Sudanese government. Two of these reports were available at the time of this evaluation, while information on excise taxes and import duties was collected on the spot as part of this assessment.

Since its inception, SREP has focused on developing technical performance assessment capability of diesel, solar, and wind water pumping systems. In this process, SREP has also undertaken asurvey of diesel and fuel costs, as well as gathered information regarding cif costs of solar and windmill systems into the Sudan. The only market-based data are for diesel systems, as diesel water pumping units account for the overwhelming majority of water pumping in the Sudan. As a result, estimates for renewable systems have had to be gathered from both donor agencies and from technical specification literature. Given that the Sudan has been experiencing severe inflationary pressures during the past several years, this has meant that a financial and economic evaluation of both existing and alternative systems requires that sensitivity tests over a broad range of parameter intervals be done in order to cover the degree of uncertainty concerning both existing and prospective water pumping investment decisions.

The technical assessment approach taken by SREP has been to develop within a Lotus 1-2-3 spreadsheet format standardized measures of water pumping such as cubic meters or jerricans of water per unit of time for technically equivalent diesel, solar, and wind systems. This is an important step in enabling policymakers to gauge the relative importance of the various systems in terms of their cost-effectiveness. In turn, these technically equivalent systems have then been placed within a comparative financial and economic context using key variables such as the rate of discount, the foreign exchange rate, fuel costs, taxes, loan terms, shadow labor rates, and shadow foreign exchange rates. A system is considered competitive if in terms of the prevailing life cycle unit cost per cubic meter of water pumped it is the most cost-effective alternative. Cost-effectiveness is thus the method used to assess the competitiveness of solar and wind systems in comparison to conventional diesel pumping systems.

It would have been useful to also have information on the demand for water. With a measure of the benefits of water, it would then be possible to go beyond cost-effectiveness analysis to derive comparative net present values and the corresponding private and social rates of return to the alternative systems. The benefit in so doing is that it would also place water pumping investment decisions in a more complete economic environment than would be possible under cost-effectiveness analysis alone.

SREP team members have gathered some informal evidence regarding the demand for water in the Sudan. However, given the time and resource constraints under which SREP has had to operate, there has not been thus far a sufficiently reliable data base on which to estimate more formally the demand for water. Undertaking a water demand study would be a useful exercise for SREP in follow-up to the evaluations now under way or completed.

A SREP water demand study should encompass several levels ofanalysis. One is to provide a breakdown of end-users by typical water head and volume per consumint unit in order to better gauge the appropriateness of alternative systems among potential end users. The study should also encompass a spatial pattern of potential distribution in terms of the existing wind regime and in terms of present and projected central electrical generating capacity. In so doing, this would enable SREP to estimate with some precision the potential market for both conventional and renewable water pumping systems in the aggregate, and on a spatial basis, given undelrying assumptions regarding policy variable choices by the Sudanese government.

In terms of the present financial and economic analysis, given the degree of

uncertainty in the Sudanese economy, it was decided to use baseline technical performance data to parametrically test each financial and economic variable alone and in combination with each other to derive alternative life cycle unit costs per cubic meter of water pumped. In the absence of data on the demand for water, the superiority of one system over another thus stands on the relative cost-effectiveness of the respective systems.

Some 500 sensitivity tests were undertaken to assess the relative cost-effectiveness of the various systems. The results of these comparisons are presented in Appendix B, in Tables 1 through 10. From these results, a ranking of each of the three systems was then tabulated. In order to gain some generality from this procedure, two graphs were prepared, utilizing a series of variables to develop system ranking space over a parameter interval range.

Once the ranking of systems had been completed, a third procedure was used to gain some insight into the relative contribution of each variable on the cost-effectiveness of each system. In this procedure, the present-value data were compressed into a data base from which simple linear regressions were undertaken. The results of this exercise for the financial analysis are presented in Appendix C.

2. The Impact of Exchange Rates, Discount Rates, and Fuel Prices on the Relative Cost-Effectiveness of Water Pumping Technologies

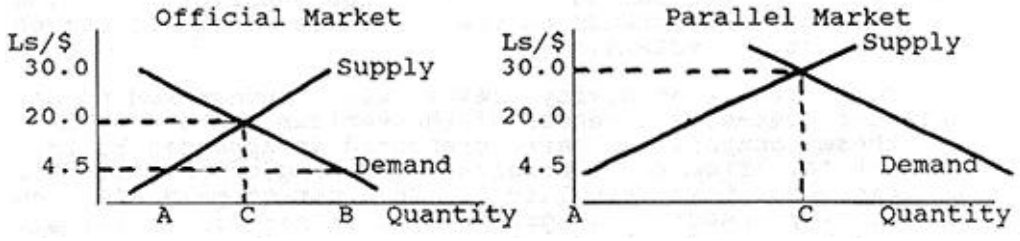
As noted in the previous section, the approach taken in this assessment has been to examine the significance of key financial and economic variables alone and in combination on the costeffectiveness of alternative systems. At present the Sudan has a multi-tiered exchange rate system. Official donor equipment assistance is priced at Ls 4.5 Sudanese pounds per $U.S. dollar, while donor salaries and related categories of international assistance are priced at Ls 12.2 pounds per $U.S. dollar. Given Sudan's recent inflation rates of between 50 and 100 percent per year, the pound has become severely overvalued.- As a result, the black market, or as it will be called here, the parallel market, exchange rate has operated with prices ranging between Ls 18 and Ls 30 per $U.S. dollar. Although Sudanese authorities have banned parallel market foreign exchange trading, and have even executed individuals for possession of undeclared foreign currency, were foreign exchange to be completely deregulated, the free market rate would most likely fall today to somewhere between Ls 15 and Ls 25 per $U.S. dollar, depending on the relative proportions of foreign exchange traded at official and parallel market rates.

A simple diagram shown below illustrates the operation of the official and parallel

market rates and the corresponding distortion imposed on foreign exchange transactions.

Figure I

Foreign Exchange Operations in the Sudan



Other things equal, Sudan's exchange rate becomes progressively overvalued as domestic inflation rates exceed foreign inflation rates in the goods and currencies in which the Sudan has foreign trade. An overvalued exchange rate makes imports artificially cheap in terms of their true resource cost, i.e., in terms of the goods and services that the Sudan needs to export to fully cover the cost of these imports.

In terms of SREP activities, although renewable pumping systems are not yet available on a commercial basis, an overvalued exchange rate creates a nominal bias in favor of renewable energy systems if full commercialization were to be undertaken. The bias stems from the fact that while the capital equipment for diesel, solar, and wind systems would all have to be imported for the forseeable future, because solar and wind systems are more capital intensive than diesel units, an overvalued exchange rate works relatively in their favor. For the financial analysis, baseline installed capital costs of the various systems as estimated by SREP staff are:

SREP Estimates of Installed Capital Costs
(Fall 1989)

Diesel	Ls 323,950 pounds
Wind	Ls 374,100 pounds
Solar	Ls 391,815 pounds.

The actual degree of technology bias depends on the extent of foreign exchange rate overvaluation and on the extent to which particular types of water pumping units would be purchased at either official or at parallel exchange rates. For example, if all diesel units were bought solely through the official exchange rate of Ls 4.5 pounds per $U.S. dollar, while all renewable units were available only through a parallel rate of Ls 30

pounds per $U.S. dollar, then the bias would be in favor of diesel. In turn, if the Sudan were to allow all foreign transactions to be made on the basis of a freely fluctuating market rate of foreign exchange, then diesel units would still be favored because of the lower capital costs of diesel units relative to renewables, as long as domestic fuel subsidies in favor of diesel continued to remain in place.

In terms of the sensitivity tests, as noted in Table 1, as the exchange rate moves up from the official rate of Ls 4.5 pounds per $U.S. dollar, the cost-effectiveness ranking shifts from solar-wind-diesel to wind-solar-diesel and finally to diesel-wind-solar. Other things equal, for a freely fluctuating foreign exchange rate of Ls 20 pounds per $U.S. dollar, even with current subsidies for diesel fuel in place, for a technically equivalent level of capacity, wind systems would still be competitive over diesel units in the Sudan.

Discount rates reflect the evaluation of a project's future costs and benefits in comparison to present costs and benefits. Higher discount rates reduce the significance of future costs and benefits in favor of the present while lower discount rates provide the reverse. In terms of the SREP water pumping technologies, other things equal, higher discount rates work in favor of diesel systems because diesel units have lower installed capital costs than either wind or solar systems, and the operation and maintenance benefits of renewables over diesel which would be realized only over a period of time would be relatively insignificant.

The actual choice of a discount rate for development projects is a matter of some debate among economic policymakers. The World Bank generally uses a discount rate of 15 percent and this reflects comparable rates used by other development agencies and the government of the Sudan. Applying this rate to SREP water pumping technologies, as one moves from a foreign exchange rate of Ls 4.5 pounds per $U.S. dollar to a parallel rate of Ls 30 pounds per $U.S. dollar, the ranking of technologies shifts progressively from solar-wind-diesel to wind-solar-diesel, and finallv to diesel-wind-solar, much as was the case with variations in the exchange rate alone. However, it should be stressed, that while development agencies may use an official discount rate of 15 percent, given the degree of economic uncertainty in the Sudan, typical water pumping end users such as village communities and small-scale farmers tend to apply much higher rates, especially under conditions of severe inflation and exchange rate distortions.

Discussions with officials at the Agricultural Bank of the Sudan confirmed the implicitly high rates of discount by end users in terms of expressed end user sensitivity to relative capital costs among alternative water pumping systems. If end users consider capital costs most important, which appears to be the case in the Sudan, then they are

applying an implicitly high rate of discount to any investment decision. Since end users typically do not want to engage in any borrowing beyond a period of 2 to 3 years, this implies that their underlying private rate of discount is somewhere on the order of 50 percent or higher. Given that inflation rates in the Sudan have recently averaged between 60 and 100 percent per year, private discount rates of 50 percent or greater are not inconsistent. The result, however, is that regardless of the exchange rate applied to a particular investment purchase, there is a strong bias in favor of diesel units over renewables. As long as economic uncertainty is fueled by continuing high rates of inflation, diesel will continue to be favored over renewables for water pumping investment decisions.

Energy policy in the Sudan is biased in favor of continued dependence on fossil fuels for water pumping investments. A SREP local consulting report estimates that the official price of Ls 4.5pounds per imperial gallon is subsidized by as much as 150 percent. This bias stems not from the subsidy arising from an overvalued exchange rate, but from a complex system of cross-subsidies used by the Government Petroleum Corporation ex-refinery at Port Sudan. In terms of the sensitivity tests, fuel prices were varied up to Ls 100 pounds per imperial gallon to determine to what extent cost-effectiveness rankings would be altered. The general pattern is that the more overvalued the exchange rate, even for diesel fuel prices of up to Ls 100 pounds per imperial gallon and for discount rates of up to 20 percent, renewables were still cost-effective. However, once foreign exchange rates were allowed to reach more free market rates of between 20 and 30 pounds per dollar, then the rankings would shift progressively from solar-wind-diesel to wind-solar-diesel and finally to diesel-wind-solar.

It should also be noted that the Sudan has been the periodic beneficiary of crude oil donations by various neighboring oil producing countries, notably Saudia Arabia, Kuwait, and Libya. Although such donations have been nominally without cost, because they have not been predictable nor have they @ome without political stipulations, there is a positive economic cost which they embody, both in terms of the indirect costs as well as in terms of the replacement costs which the Sudan must incur as it peridically engages in spot or contract market purchases. As long as the Sudan can obtain such periodic donations, and as long as the political costs are not obvious, the Sudan can sustain the existing degree of technology bias in favor of diesel water pumping systems over wind and solar alternatives. Such donations also help to minimize the net deficit which the Government Petroleum Corporation incurs through its system of fuel crosssubsidies as well as the resulting net subsidies which it requires from the Sudanese treasury to sustain its existing level of operations.

In terms of the relative importance of foreign exchange, discount rates, and fuel prices, equations 4 through 6 of Appendix C show that in terms of the financial analysis, whether for diesel, solar, or for wind systems, a one unit increase in the discount rate adds more to the life cycle unit cost per cubic meter of water than a one unit increase in the foreign exchange rate or a one unit increase in the fuel price. As to the relative importance of these variables, for diesel systems, a one unit increase in the discount rate contributes approximately twenty times as much to the life cycle unit cost per cubic meter of water pumped as a one unit increase in the foreign exchange rate or a one unit increase in the price of fuel. For solar technology, a one unit increase in the discount rate increases more than twice as much as a one unit increase in the foreign exchange rate to the life cycle unit cost per cubic meter of water pumped, while for wind systems, the discount rate contributes three times as much as the foreign exchange rate to the life cycle unit cost per cubic meter of water pumped.

3. The Effects of Varying Capital Equipment Purchasing Options on the Cost-Effectiveness of Alternative Water Pumping Technologies: The Role of Financing Agencies and International Donor Institutions

Capital equipment purchases by village and small-scale farmer water users in the Sudan are undertaken by a variety of mechanisms. Although SREP staff did not have a complete profile of water pumping purchasing arrangements, several patterns have emerged. One is that whether by village or by farmer units, a significant percentage of purchases are made on a non-credit cash basis. Diesel engines and pumps in the Sudan currently available range in price from between Ls 9,000 to Ls 13,000 c.i.f. at locally available distributors in Khartoum, and the expected life cycle of these units ranges from between 3 and 7 years.

Although data on village and farmer incomes are sketchy, the fact that a significant proportion of end users are willing to make cash purchases suggests that water pumping investments do not represent a disproportionate of effective village and/or farmer income. At the same time, informal evidence from discussions with officials at the Agricultural Bank of the Sudan suggest that a large majority of diesel units which they sell are sold on short-term credit terms. Just what percentage of all diesel units bought by village and farmers in the Sudan are financed through credit, however, is not clearly known at this time.

Credit terms for diesel water pumping units by the Agricultural Bank of the Sudan are typically for 3 years, with an interest rate of 19 percent. This is clearly a subsidy to water pumping investments, given that inflation rates in the Sudan are currently estimated at well over 50 percent per year. To compensate for real loan losses engendered by

inflation, agricultural inputs such as fertilizer and equipment provided by the Agricultural Bank of the Sudan are typically priced on a cross-subsidy basis so that overall Bank operations are generally balanced on an accounting unit basis.

Sensitivity tests on the impact of water pumping credit terms show that while loans tend to raise the cost of all systems in terms of the present value per cubic meter of water pumped, the relative bias is in favor of diesel since the capital costs of diesel systems are less than for solar or for wind. However, credit is not as important a factor on the ranking of alternative systems as are foreign exchange and discount rates. Thus, even when credit terms for three year loans reach a level of 90 percent, to reflect a possible full inflationary cost recovery basis, the cost-effectiveness ranking of the various systems is still shaped primarily- by the prevailing discount and foreign exchange rates chosen. Equations 7 through 9 in Appendix C show that whether for diesef, solar, or wind systems, the discount rate is still the most important determinant of life cycle unit costs, followed by the foreign exchange rate, and finally by the loan rate. In relative terms, the discount rate contributes approximately four times as much to the variation in life cycle unit costs for all three systems as lending rate variations, with foreign exchange rates varying across systems.

In terms of alternative water pumping commercialization scenarios, the existing bias in favor of diesel systems could be altered. As already noted, diesel water pumping systems are bought on both a cash and a credit basis by village and farmer end users. Given the overvaluation of exchange rates and the undervaluation of fuel prices, this clearly works in favor of continued reliance on diesel unit systems. Moreover, at present, all available wind and solar systems have been made available only on a test demonstration basis through official donor channels, including those made available to SREP for technical testing and evaluation.

Just as the Sudan has been the periodic beneficiary of periodic donations of crude oil, it is conceivable that wind and solar water pumping systems could also be made available on a donor basis. In the simplest scenario, were all wind and solar units made available to the Sudan on a donor basis, then these systems would be cost-effective against diesel systems, even with overvalued exchange rates, high discount rates, and high fuel prices. The problem would then be for Sudanese officials to decide how to allocate such systems in the geographic areas in which they would be most competitive, i.e., in the most favored wind regime locations as well as in those remote areas where diesel equipment and fuel would be least readily available and in which centrally supplied electricity would not be an option. However, foreign aid, whether in terms of crude oil donations or in terms of renewable energy technology donations, is not costless in economic terms.

Thus, energy technology choices by Sudanese officials should be guided more by the overall economic costs rather than by perceived nominal advantages of one system over another.

One additional factor affecting water pumping investment choices is the impact of taxes. All capital equipment in the Sudan is taxed at varying rates. The basic import duty rate is 18 percent, followed by an additional rate of 15 percent, and a 10 percent rate for national security. Thus, water pumping equipment can be taxed at rates ranging from 10 to 43 percent, depending on the configuration, and sensitivity tests over this range were conducted to determine the relative impact on the cost-effectiveness ranking of the various systems. In all cases, taxes obviously add to the life cycle unit cost per cubic meter of water pumped, and the relative b'las is in favor of diesel systems, since they have smaller capital costs than do wind and solar alternatives. However, taxes play only a marginal role in the ranking of the alternative systems, with discount and foreign exchange rates playing a much more dominant role. In general, as with previous comparisons, lower foreign exchange rates and lower discount rates work in favor of renewables over diesel, regardless of the given tax rate chosen. As to the rankings, they also follow the same pattern, with solar-wind-diesel favored at lower foreign exchange and discount rates, followed by windsolar-diesel at higher rates, and finally by diesel-wind-solar at higher foreign exchange and discount rates. In terms of the relative contribution of these variables, discount rates contribute far and away the most to life cycle unit cost variations in comparison to foreign exchange and tax rate variations, as can be seen in equations 10 through 12 in Appendix C.

All of the sensitivity tests in the present evaluation have assumed that any water pumping decision would be ultimately based on the positive financial and economic costs of all available alternatives. Indeed, even when all of the previously discussed tests have been conducted, the results have been confirmed on both a financial and economic cost comparison, as can be seen in terms of the sensitivity test results in Appendix B.

How do economic and financial sensitivity tests differ? All financial tests have been conducted with shadow labor costs at .5 and shadow foreign exchange at 1.5. While the choice of .5 for shadow labor rates may seem arbitrary, it is consistent with the high rates of open unemployment in the Sudan and the fact that so many Sudanese choose to work on a migratory basis in such neighboring countries as saudia Arabia and the Gulf states. As to the choice of 1.5 for the shadow foreign exchange rates this reflects an implicit overvaluation of the existing foreign exchange rate of 4.5 by at least 50 percent, which would imply a free market exchange rate of 6.75. Indeed, a foreign exchange rate of 6.75 is well below the 12.2 rate that the Sudanese government already allows for non-capital

equipment imports. Thus, given the underlying inflation rate and Sudan's deficit in its balance of payments, a shadow foreign exchange rate as high as 5 or 6 is not unreasonable to consider and tests over this range of values were used in the present assessment.

Sensitivity tests using alternative shadow foreign exchange and shadow labor rates with varying discount, foreign exchange, and fuel costs were undertaken as part of the present evaluation. Results reported in Appendix B show that in terms of the economic analysis, even when foreign exchange rates rise to Ls 25 per $U.S. dollar and when discount rates are as high as 30 percent., solar systems are competitive against diesel and wind, with wind ranking above diesel in the intermediate range of these variables. Similar results hold when the unskilled labor shadow price is allowed to vary from its base reference of .5 to as high as 1.5.

In sum, whether for financial or for economic evaluation, over a reasonable range of the variables of fuel prices, discount and foreign exchange rates, solar and wind pumping technologies can be cost-effective alternatives to diesel systems. Even when alternative credit and tax regimes are considered, the financial competitiveness of renewable systems is sustained.

What does the general finding of the competitive position of renewable water pumping systems suggest for Sudanese energy policy? First is that existing policies continue to be biased in favor of diesel over solar and wind energy alternatives. The bias stems from extensive fuel subsidies, from high effective rates of discount, from the relative impact of taxes and credit policies, even with the offsetting role of overvalued exchange rates.

One additional factor which should also be considered is that tariff rates for water charged to village and farmers now in place cover only a fraction of the underlying life cycle unit costs. A study now under way by the World Bank in the Sudan suggests that water tariffs now charged should be increased by a factor of between 5 and 10 to fully reflect the life cycle unit costs of water consumed. Were such water tariffs in place, the investment benefits of solar and wind energy alternatives would be more obvious to end users, which would in term help in establishing a viable basis for the commercialization of these technologies.

Finally, there does not appear to be at present an effective plan to translate the economics of solar and wind technology alternatives into an economic and financial reality. To do so would require not only continued testing of the technical, financial, and

economic performance of dtiesel, wind, and solar water pumping alternatives under various policy scenarios, but also a substantial commitment to commercialize renewable energy systems among wholesale and retail distributors as well as among potential end users. Given the economic pressures under which the Sudanese government is now operating, such a program does not now appear to be a priority. However, as evidence on the competitive role of renewable pumping systems accumulates, the economic value in making such a commitment expands.

4. Comments on the SREP Stove Development Program Report

As the water pumping assessment was undertaken, SREP staff were also involved in preparing a report on the role of fuelefficient cookstoves in the Sudan. A survey of Khartoum households shows mixed evidence on the potential for fuelefficient cookstoves. As the survey was not able to derive precise estimates of household income, it was difficult to assess the demand for cookstoves within a conventional economic theoretic framework. What did appear is that Khartoum cookstove users relied on a mix of technologies ranging from conventional charcoal stoves to butane gas and electric system alternatives. That conventional charcoal stoves appear to be used by a wide range of households appears to reflect dependability considerations by end users in particular the potential for interruption of gas and electric supplies for alternative systems. since charcoal prices continue to escalate in the Sudan, in reflection of both deforestation as well as by rising aggregate demand, it is clear that there is an economic role of fuel-efficient charcoal stoves.

Factors that affect the economics of fuel-efficient charcoal stoves in the Sudan include: the continued short-term tnderpricing of conventional charcoal as a common property resource, continued natural gas and kerosene subsidies arising from overvalued exchange rates, official price controls, and cross-subisdies of the Government Petroleum Corporation, as well as limited knowledge by potential consumers of fuel-efficient alternatives. The SREP stove study did not have available at the time of this assessment information regarding the relative cost of imported versus domestic components in conventional versus fuel-efficient alternatives. Discussions with SREP staff suggest that fuel-efficient alternatives do not contain a significantly higher percentage of imported components, in which case,, the sources of bias against fuel-efficient alternatives lie primarily in the already cited variables.

As in the case of solar and wind water pumping systems, the economics of fuel-efficient stoves in the Sudan will depend on continued testing and evaluation of existing and alternative systems, as well as on measuring the demand for energy by end users. As SREP should consider a study of water demand, so too should there be a study of fuelwood demand, building on the evidence already gathered by the SREP stove study

now being completed.

Appendix A
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Appendix B
Sensitivity Test Tables

Table 1
Sensitivity Tests for Discount Rates
Present Value per Cubic Meter, in Ls

	Financial Analysis			
Rates	**Diesel**	**Solar**	**Wind**	Assumptions used in Discount Rate Tests:
12%	20.65	18.22	17.36	1.0 Shadow price ofunskilled labor
15%	23.56	21.46	20.51	1.0 Shadow foreign exchange rate
20%	28.69	27.17	26.07	0% taxes on equipment
25%	34.04	33.13	31.86	12 = foreign exchange rate
30%	39.53	39.23	37.79	11.5 = Ls Fuel Cost/Imperial gallon
35%	45.08	45.43	43.79	$5.25 per peak watt solar energy value
40%	50.67	51.68	49.83	100 Depth of well, in meters
45%	56.29	57.96	55.90	2500 well cost per meter, in Ls
50%	61.93	64.26	61.97	Base Case Technical Assumption of no loans

	Economic analysis			
Rates	**Diesel**	**Solar**	**Wind**	Assumptions used in Discount Rate Tests:
12%	22.43	14.41	19.28	.5 Shadow price ofunskilled labor
15%	25.41	16.84	22.79	1.5 Shadow foreign exchange rate
20%	30.67	21.12	28.98	0% taxes on equipment
25%	36.16	25.61	35.43	12 = foreign exchange rate
30%	41.78	30.21	42.03	11.5 = Ls Fuel Cost/Imperial gallon
35%	47.48	34.88	48.72	$5.25 per peak wtt solar
40%	53.22	39.60	55.45	100 Depth of well, in meters
45%	58.99	44.35	62.21	2500 well cost per meter, in Ls
50%	64.78	49.12	68.98	Base Case Technical Assumption of no loans

Table 2
Sensitivity Tests for Foreign Exchange Rates
Present Value per Cubic Meter, in Ls

Financial Analysis					Economic Analysis				
Discount Rate at 12%					EqFexch=18 Discount Rate at 12%				
ShFexch:	Fexch:	Diesel	Solar	Wind	ShFexch:	Fexch:	Diesel	Solar	Wind
1.50	4.50	20.26	15.05	15.28	4.00	4.50	37.41	17.29	22.87
1.50	12.00	20.65	18.22	17.36	1.50	12.00	22.43	14.41	19.28
1.50	20.00	21.08	21.61	19.58	0.90	20.00	18.84	13.71	18.42
1.50	30.00	21.60	25.84	22.36	0.60	30.00	17.04	13.37	17.99
Discount Rate at 20%					Discount Rate at 20%				
ShFexch:	Fexch:	Diesel	Solar	Wind		Fexch:	Diesel	Solar	Wind
1.50	4.50	28.09	22.54	22.91	4.00	4.50	48.70	25.07	33.97
1.50	12.00	28.69	27.17	26.07	1.50	12.00	30.67	21.12	28.98
1.50	20.00	29.34	32.10	29.43	0.90	20.00	26.34	20.18	27.78
1.50	30.00	30.15	38.27	33.64	0.60	30.00	24.18	19.71	27.18
Discount Rate at 25%					Discount Rate at 25%				
ShFexch:	Fexch:	Diesel	Solar	Wind		Fexch:	Diesel	Solar	Wind
1.50	4.50	33.30	27.53	27.99	4.00	4.50	56.23	30.25	41.23
1.50	12.00	34.04	33.13	31.86	1.50	12.00	36.16	25.61	35.43
1.50	20.00	34.84	39.10	35.99	0.90	20.00	31.34	24.49	34.01
1.50	30.00	35.84	46.56	41.14	0.60	30.00	28.93	23.93	33.30
Discount Rate at 30%					Discount Rate at 30%				
ShFexch:	Fexch:	Diesel	Solar	Wind		Fexch:	Diesel	Solar	Wind
1.50	4.50	38.63	32.64	33.19	4.00	4.50	63.94	35.58	48.90
1.50	12.00	39.53	39.23	37.79	1.50	12.00	41.78	30.21	42.03
1.50	20.00	40.58	46.27	42.69	0.90	20.00	36.46	28.92	40.38
1.50	30.00	41.67	55.07	48.82	0.60	30.00	33.80	28.27	39.56
Economic Analysis					**Economic Analysis**				
EqFexch=12 Discount Rate at 12%					EqFexch=25 Discount Rate at 12%				
ShFexch:	Fexch:	Diesel	Solar	Wind	ShFexch:	Fexch:	Diesel	Solar	Wind
2.67	4.50	29.44	13.22	19.35	5.56	4.50	46.75	22.06	27.01
1.00	12.00	19.43	11.29	16.94	2.08	12.00	25.90	18.02	21.99
0.60	20.00	17.04	10.83	16.37	1.25	20.00	20.93	17.08	20.81
0.40	30.00	15.84	10.60	16.08	0.83	30.00	18.42	16.56	20.18
Discount Rate at 20%					Discount Rate at 20%				
ShFexch:	Fexch:	Diesel	Solar	Wind	ShFexch:	Fexch:	Diesel	Solar	Wind
2.67	4.50	39.11	19.28	28.87	5.56	4.50	59.95	31.86	39.95
1.00	12.00	27.07	16.63	25.53	2.08	12.00	34.85	26.33	32.98
0.60	20.00	24.18	16.00	24.73	1.25	20.00	28.87	25.05	31.34
0.40	30.00	22.74	15.69	24.33	0.83	30.00	25.84	24.33	30.46
Discount Rate at 25%					Discount Rate at 25%				
ShFexch:	Fexch:	Diesel	Solar	Wind	ShFexch:	Fexch:	Diesel	Solar	Wind
2.67	4.50	45.55	23.31	35.20	5.56	4.50	68.75	38.39	48.56
1.00	12.00	31.15	20.20	31.24	2.08	12.00	40.81	31.88	40.29
0.60	20.00	28.93	19.45	30.29	1.25	20.00	34.15	30.37	38.34
0.40	30.00	27.33	19.08	29.81	0.83	30.00	30.78	29.51	37.30
Discount Rate at 30%					Discount Rate at 30%				
ShFexch:	Fexch:	Diesel	Solar	Wind	ShFexch:	Fexch:	Diesel	Solar	Wind
2.67	4.50	52.15	27.45	41.68	5.56	4.50	77.77	45.10	57.37
1.00	12.00	37.35	23.85	37.08	2.08	12.00	46.92	37.57	47.77
0.60	20.00	33.80	22.99	35.98	1.25	20.00	39.56	35.83	45.51
0.40	30.00	32.03	22.57	35.44	0.83	30.00	35.84	34.84	44.30

Table 3
Sensitivity Tests for Fuel Costs
Present Value in Cubic Meters, in Ls
Financial Analysis

Discount Rate at 12%												
	FExch=4.5			FExch=12			FExch=20			FExch=30		
Diesel Price	Diesel	Solar	Wind	Diesel	Solar	Wind	Diesel	Solar	Wind	Diesel	Solar	Wind
11.50	20.26	15.05	15.28	20.65	18.22	17.30	21.08	21.61	19.58	21.6	25.84	22.36
15.00	20.46	15.05	15.28	20.85	18.22	17.30	21.27	21.61	19.58	21.8	25.84	22.36
25.00	21.02	15.05	15.28	21.42	18.22	17.30	21.84	21.61	19.58	22.37	25.84	22.36
30.00	21.31	15.05	15.28	21.70	18.22	17.30	22.13	21.61	19.58	22.65	25.84	22.36
45.00	22.16	15.05	15.28	22.55	18.22	17.30	22.98	21.61	19.58	23.5	25.84	22.36
60.00	23.01	15.05	15.28	23.41	18.22	17.30	23.83	21.61	19.58	24.36	25.84	22.36
70.00	23.58	15.05	15.28	23.91	18.22	17.30	24.39	21.61	19.58	24.92	25.84	22.36
100.00	25.98	15.05	15.28	25.67	18.22	17.30	26.1	21.61	19.58	26.61	25.84	22.36
Discount Rate at 15%												
	FExch=4.5			FExch=12			FExch=20			FExch=30		
Diesel Price	Diesel	Solar	Wind	Diesel	Solar	Wind	Diesel	Solar	Wind	Diesel	Solar	Wind
11.50	23.09	17.76	18.04	23.56	21.46	20.51	24.07	25.41	23.15	24.70	30.34	26.45
15.00	23.29	17.76	18.04	23.76	21.46	20.51	24.27	25.41	23.15	24.90	30.34	26.45
25.00	23.86	17.76	18.04	24.33	21.46	20.51	24.83	25.41	23.15	25.46	30.34	26.45
30.00	24.14	17.76	18.04	24.61	21.46	20.51	25.12	25.41	23.15	25.75	30.34	26.45
45.00	24.99	17.76	18.04	25.47	21.46	20.51	25.97	25.41	23.15	26.60	30.34	26.45
60.00	25.84	17.76	18.04	26.32	21.46	20.51	26.84	25.41	23.15	27.45	30.34	26.45
70.00	26.41	17.76	18.04	26.88	21.46	20.51	27.39	25.41	23.15	28.02	30.34	26.45
100.00	28.11	17.76	18.04	28.59	21.46	20.51	29.09	25.41	23.15	29.72	30.34	26.45
Discount Rate at 20%												
	FExch=4.5			FExch=12			FExch=20			FExch=30		
Diesel Price	Diesel	Solar	Wind	Diesel	Solar	Wind	Diesel	Solar	Wind	Diesel	Solar	Wind
11.50	28.09	22.54	22.91	28.69	27.17	26.07	29.34	32.10	29.43	30.15	38.27	33.64
15.00	28.28	22.54	22.91	28.89	27.17	26.07	29.54	32.10	29.43	30.35	38.27	33.64
25.00	28.85	22.54	22.91	29.46	27.17	26.07	30.11	32.10	29.43	30.92	38.27	33.64
30.00	29.14	22.54	22.91	29.74	27.17	26.07	30.39	32.10	29.43	31.20	38.27	33.64
45.00	29.99	22.54	22.91	30.59	27.17	26.07	31.24	32.10	29.43	32.05	38.27	33.64
60.00	30.84	22.54	22.91	31.44	27.17	26.07	32.09	32.10	29.43	32.90	38.27	33.64
70.00	31.40	22.54	22.91	32.01	27.17	26.07	32.66	32.10	29.43	33.47	38.27	33.64
100.00	33.10	22.54	22.91	33.71	27.17	26.07	34.36	32.10	29.43	35.17	38.27	33.64

Assumptions used in the Financial Analysis
.5 = shadow price of unskilled labor
0% taxes on equipment
$5.25 per peak watt for solar
100 Depth of well (in meters)
2500 Well Cost per meter, in Ls
Base Case Technical Assumption of no loans

Table 4
Sensitivity Tests for Fuel Costs
Present Value per Cubic Meter, in Ls
Economic Analysis with Foreign Exchange Rate Equilibrium at 12

	Discount Rate at 12%															
	FExch=4.5				FExch=12				FExch=20				FExch=30			
Diesel Price	SFExchFuel	Diesel	Solar	Wind	SFExchFuel	Diesel	Solar	Wind	SFExchFuel	Diesel	Solar	Wind	SFExchFuel	Diesel	Solar	Wind
11.50	2.67	29.44	13.22	19.35	1.00	19.43	11.29	16.94	0.60	17.04	10.83	16.37	0.40	15.84	10.60	16.08
15.00	2.67	29.97	13.22	19.35	1.00	19.63	11.29	16.94	0.60	17.16	10.83	16.37	0.40	15.94	10.60	16.08
25.00	2.67	31.48	13.22	19.35	1.00	20.20	11.29	16.94	0.60	17.50	10.83	16.37	0.40	16.15	10.60	16.08
30.00	2.67	32.24	13.22	19.35	1.00	20.48	11.29	16.94	0.60	17.67	10.83	16.37	0.40	16.26	10.60	16.08
45.00	2.67	34.51	13.22	19.35	1.00	21.34	11.29	16.94	0.60	18.18	10.83	16.37	0.40	16.60	10.60	16.08
60.00	2.67	36.79	13.22	19.35	1.00	22.19	11.29	16.94	0.60	18.69	10.83	16.37	0.40	16.94	10.60	16.08
70.00	2.67	38.30	13.22	19.35	1.00	22.75	11.29	16.94	0.60	19.03	10.83	16.37	0.40	17.17	10.60	16.08
100.00	2.67	42.85	13.22	19.35	1.00	24.46	11.29	16.94	0.60	20.05	10.83	16.37	0.40	17.85	10.60	16.08
	Discount Rate at 15%															
	FExch=4.5				FExch=12				FExch=20				FExch=30			
Diesel Price	SFExchFuel	Diesel	Solar	Wind	SFExchFuel	Diesel	Solar	Wind	SFExchFuel	Diesel	Solar	Wind	SFExchFuel	Diesel	Solar	Wind
11.50	2.67	32.94	15.41	22.79	1.00	22.20	13.22	20.05	0.60	19.62	12.70	19.39	0.40	18.34	12.44	19.07
15.00	2.67	33.47	15.41	22.79	1.00	22.40	13.22	20.05	0.60	19.74	12.70	19.39	0.40	18.42	12.44	19.07
25.00	2.67	34.99	15.41	22.79	1.00	22.96	13.22	20.05	0.60	20.08	12.70	19.39	0.40	18.64	12.44	19.07
30.00	2.67	35.74	15.41	22.79	1.00	23.25	13.22	20.05	0.60	20.25	12.70	19.39	0.40	18.76	12.44	19.07
45.00	2.67	38.02	15.41	22.79	1.00	24.10	13.22	20.05	0.60	20.77	12.70	19.39	0.40	19.10	12.44	19.07
60.00	2.67	40.29	15.41	22.79	1.00	24.95	13.22	20.05	0.60	21.28	12.70	19.39	0.40	19.44	12.44	19.07
70.00	2.67	41.80	15.41	22.79	1.00	25.52	13.22	20.05	0.60	21.62	12.70	19.39	0.40	19.67	12.44	19.07
100.00	2.67	46.35	15.41	22.79	1.00	27.22	13.22	20.05	0.60	22.64	12.70	19.39	0.40	20.35	12.44	19.07
	Discount Rate at 20%															
	FExch=4.5				FExch=12				FExch=20				FExch=30			
Diesel Price	SFExchFuel	Diesel	Solar	Wind	SFExchFuel	Diesel	Solar	Wind	SFExchFuel	Diesel	Solar	Wind	SFExchFuel	Diesel	Solar	Wind
11.50	2.67	39.11	19.28	28.87	1.00	27.07	16.63	25.53	0.60	24.18	16.00	24.73	0.40	22.74	15.69	24.33
15.00	2.67	39.64	19.28	28.87	1.00	27.26	16.63	25.53	0.60	24.30	16.00	24.73	0.40	22.82	15.69	24.33
25.00	2.67	41.15	19.28	28.87	1.00	27.83	16.63	25.53	0.60	24.64	16.00	24.73	0.40	23.04	15.69	24.33
30.00	2.67	41.91	19.28	28.87	1.00	28.12	16.63	25.53	0.60	24.81	16.00	24.73	0.40	23.16	15.69	24.33
45.00	2.67	44.18	19.28	28.87	1.00	28.97	16.63	25.53	0.60	25.32	16.00	24.73	0.40	23.50	15.69	24.33
60.00	2.67	46.46	19.28	28.87	1.00	29.82	16.63	25.53	0.60	25.83	16.00	24.73	0.40	23.84	15.69	24.33
70.00	2.67	47.97	19.28	28.87	1.00	30.38	16.63	25.53	0.60	26.17	16.00	24.73	0.40	24.07	15.69	24.33
100.00	2.67	52.52	19.28	28.87	1.00	32.09	16.63	25.53	0.60	27.19	16.00	24.73	0.40	24.75	15.69	24.33

Assumptions used in the Financial Analysis
.5 = shadow price of unskilled labor
0% taxes on equipment
$5.25 per peak watt for solar
100 Depth of well (in meters)
2500 Well Cost per meter, in Ls
Base Case Technical Assumption of no loans

Table 5
Sensitivity Tests for Fuel Costs
Present Value per Cubic meter, in Ls
Economic Analysis with Foreign Exchange Equilibrium at 18

Discount Rate at 12%																
		FExch=4.5				FExch=12				FExch=20				FExch=30		
SFExchFuel	Diesel Price	Diesel	Solar	Wind	SFExchFuel	Diesel	Solar	Wind	SFExchFuel	Diesel	Solar	Wind	SFExchFuel	Diesel	Solar	Wind
4.00	11.50	37.41	17.29	22.87	1.50	22.43	14.41	19.28	0.90	18.84	13.71	18.42	0.60	17.04	13.37	17.99
4.00	15.00	38.20	17.29	22.87	1.50	22.73	14.41	19.28	0.90	19.01	13.71	18.42	0.60	17.16	13.37	17.99
4.00	25.00	40.47	17.29	22.87	1.50	23.58	14.41	19.28	0.90	19.53	13.71	18.42	0.60	17.50	13.37	17.99
4.00	30.00	41.61	17.29	22.87	1.50	24.00	14.41	19.28	0.90	19.78	13.71	18.42	0.60	17.67	13.37	17.99
4.00	45.00	45.01	17.29	22.87	1.50	25.28	14.41	19.28	0.90	20.55	13.71	18.42	0.60	18.18	13.37	17.99
4.00	60.00	48.41	17.29	22.87	1.50	26.56	14.41	19.28	0.90	21.31	13.71	18.42	0.60	18.69	13.37	17.99
4.00	70.00	50.68	17.29	22.87	1.50	27.41	14.41	19.28	0.90	21.82	13.71	18.42	0.60	19.03	13.37	17.99
4.00	100.00	57.49	17.29	22.87	1.50	29.96	14.41	19.28	0.90	23.35	13.71	18.42	0.60	20.05	13.37	17.99
Discount Rate at 15%																
		FExch=4.5				FExch=12				FExch=20				FExch=30		
SFExchFuel	Diesel Price	Diesel	Solar	Wind	SFExchFuel	Diesel	Solar	Wind	SFExchFuel	Diesel	Solar	Wind	SFExchFuel	Diesel	Solar	Wind
4.00	11.50	41.50	20.11	26.89	1.50	25.41	16.84	22.79	0.90	21.55	16.05	21.81	0.60	19.62	15.66	21.32
4.00	15.00	42.29	20.11	26.89	1.50	25.71	16.84	22.79	0.90	21.73	16.05	21.81	0.60	19.74	15.66	21.32
4.00	25.00	44.56	20.11	26.89	1.50	26.56	16.84	22.79	0.90	22.24	16.05	21.81	0.60	20.00	15.66	21.32
4.00	30.00	45.69	20.11	26.89	1.50	26.99	16.84	22.79	0.90	22.50	16.05	21.81	0.60	20.25	15.66	21.32
4.00	45.00	49.10	20.11	26.89	1.50	28.27	16.84	22.79	0.90	23.27	16.05	21.81	0.60	20.77	15.66	21.32
4.00	60.00	52.50	20.11	26.89	1.50	29.54	16.84	22.79	0.90	24.03	16.05	21.81	0.60	21.28	15.66	21.32
4.00	70.00	54.77	20.11	26.89	1.50	30.39	16.84	22.79	0.90	24.54	16.05	21.81	0.60	21.62	15.66	21.32
4.00	100.00	61.58	20.11	26.99	1.50	32.95	16.84	22.79	0.90	26.07	16.05	21.81	0.60	22.64	15.66	21.32
Discount Rate at 20%																
		FExch=4.5				FExch=12				FExch=20				FExch=30		
SFExchFuel	Diesel Price	Diesel	Solar	Wind	SFExchFuel	Diesel	Solar	Wind	SFExchFuel	Diesel	Solar	Wind	SFExchFuel	Diesel	Solar	Wind
4.00	11.50	48.70	25.07	33.97	1.50	30.67	21.12	28.98	0.90	26.34	20.18	27.78	0.60	24.18	19.70	27.18
4.00	15.00	49.49	25.07	33.97	1.50	30.97	21.12	28.98	0.90	26.52	20.18	27.76	0.60	24.30	19.71	27.18
4.00	25.00	51.76	25.07	33.97	1.50	31.82	21.12	28.98	0.90	27.03	20.18	27.76	0.60	24.64	19.71	27.18
4.00	30.00	52.90	25.07	33.97	1.50	32.25	21.12	28.98	0.90	27.29	20.18	27.76	0.60	24.81	19.71	27.18
4.00	45.00	56.30	25.07	33.97	1.50	33.52	21.12	28.98	0.90	28.05	20.18	27.76	0.60	25.32	19.71	27.18
4.00	60.00	59.71	25.07	33.97	1.50	34.80	21.12	28.98	0.90	28.82	20.18	27.76	0.60	25.83	19.71	27.18
4.00	70.00	61.98	25.07	33.97	1.50	35.65	21.12	28.98	0.90	29.33	20.18	27.76	0.60	26.17	19.71	27.18
4.00	100.00	68.79	25.07	33.97	1.50	38.20	21.12	28.98	0.90	30.86	20.18	27.76	0.60	27.19	19.71	27.18

Assumptions used in the Economic Analysis
.5 = shadow price of unskilled labor
0% taxes on equipment
$5.25 per peak watt for solar
100 Depth of well (in meters)
2500 Well Cost per meter, in Ls
Base Case Technical Assumption of no loans

Table 6
Sensitivity Tests for Fuel Costs
Present Value per Cubic Meter, in Ls
Economic Analysis with Foreign Exchange Equilibrium at 25

Discount Rate at 12%																
		FExch=4.5				FExch=12				FExch=20				FExch=30		
SFExchFuel	Diesel Price	Diesel	Solar	Wind	SFExchFuel	Diesel	Solar	Wind	SFExchFuel	Diesel	Solar	Wind	SFExchFuel	Diesel	Solar	Wind
4.00	11.50	46.75	22.06	27.01	2.08	25.90	18.02	21.99	1.25	20.93	17.08	20.81	0.83	18.42	16.56	20.18
4.00	15.00	47.86	22.06	27.01	2.08	26.32	18.02	21.99	1.25	21.18	17.08	20.81	0.83	18.58	16.56	20.18
4.00	25.00	51.01	22.06	27.01	2.08	27.50	18.02	21.99	1.25	21.89	17.08	20.81	0.83	19.05	16.56	20.18
4.00	30.00	52.59	22.06	27.01	2.08	28.09	18.02	21.99	1.25	22.24	17.08	20.81	0.83	19.29	16.56	20.18
4.00	45.00	57.32	22.06	27.01	2.08	29.86	18.02	21.99	1.25	23.31	17.08	20.81	0.83	19.99	16.56	20.18
4.00	60.00	62.05	22.06	27.01	2.08	31.63	18.02	21.99	1.25	24.31	17.08	20.81	0.83	20.70	16.56	20.18
4.00	70.00	65.21	22.06	27.01	2.08	32.81	18.02	21.99	1.25	25.08	17.08	20.81	0.83	21.17	16.56	20.18
4.00	100.00	74.67	22.06	27.01	2.08	36.35	18.02	21.99	1.25	27.21	17.08	20.81	0.83	22.58	16.56	20.18
Discount Rate at 15%																
		FExch=4.5				FExch=12				FExch=20				FExch=30		
SFExchFuel	Diesel Price	Diesel	Solar	Wind	SFExchFuel	Diesel	Solar	Wind	SFExchFuel	Diesel	Solar	Wind	SFExchFuel	Diesel	Solar	Wind
4.00	11.50	51.53	25.61	31.69	2.08	29.15	21.03	25.97	1.25	23.81	19.97	24.62	0.83	21.10	19.37	23.90
4.00	15.00	52.64	25.61	31.69	2.08	29.56	21.03	25.97	1.25	24.05	19.97	24.62	0.83	21.27	19.37	23.90
4.00	25.00	55.79	25.61	31.69	2.08	30.74	21.03	25.97	1.25	24.76	19.97	24.62	0.83	21.74	19.37	23.90
4.00	30.00	57.37	25.61	31.69	2.08	31.33	21.03	25.97	1.25	25.12	19.97	24.62	0.83	21.98	19.37	23.90
4.00	45.00	62.10	25.61	31.69	2.08	33.10	21.03	25.97	1.25	26.18	19.97	24.62	0.83	22.68	19.37	23.90
4.00	60.00	66.83	25.61	31.69	2.08	34.87	21.03	25.97	1.25	27.25	19.97	24.62	0.83	23.39	19.37	23.90
4.00	70.00	69.99	25.61	31.69	2.08	36.05	21.03	25.97	1.25	27.95	19.97	24.62	0.83	23.86	19.37	23.90
4.00	100.00	79.45	25.61	31.69	2.08	39.59	21.03	25.97	1.25	30.08	19.97	24.62	0.83	25.27	19.37	23.90
Discount Rate at 20%																
		FExch=4.5				FExch=12				FExch=20				FExch=30		
SFExchFuel	Diesel Price	Diesel	Solar	Wind	SFExchFuel	Diesel	Solar	Wind	SFExchFuel	Diesel	Solar	Wind	SFExchFuel	Diesel	Solar	Wind
4.00	11.50	59.95	31.86	39.95	2.08	34.85	26.33	32.98	1.25	28.87	25.05	31.34	0.83	25.84	24.33	30.46
4.00	15.00	61.05	31.86	39.95	2.08	35.27	26.33	32.98	1.25	29.12	25.05	31.34	0.83	26.00	24.33	30.46
4.00	25.00	64.21	31.86	39.95	2.08	36.45	26.33	32.98	1.25	29.83	25.05	31.34	0.83	26.48	24.33	30.46
4.00	30.00	65.79	31.86	39.95	2.08	37.04	26.33	32.98	1.25	29.82	25.05	31.34	0.83	26.71	24.33	30.46
4.00	45.00	70.52	31.86	39.95	2.08	38.81	26.33	32.98	1.25	31.24	25.05	31.34	0.83	27.42	24.33	30.46
4.00	60.00	75.25	31.86	39.95	2.08	40.58	26.33	32.98	1.25	32.31	25.05	31.34	0.83	28.12	24.33	30.46
4.00	70.00	78.41	31.86	39.95	2.08	41.76	26.33	32.98	1.25	33.02	25.05	31.34	0.83	28.59	24.33	30.46
4.00	100.00	87.87	31.86	39.95	2.08	45.30	26.33	32.98	1.25	35.14	25.05	31.34	0.83	30.01	24.33	30.46

Assumptions used in the Economic Analysis
.5 = shadow price of unskilled labor
0% taxes on equipment
$5.25 per peak watt for solar
100 Depth of well (in meters)
2500 Well Cost per meter, in Ls
Base Case Technical Assumption of no loans

Table 7
Sensitivity Tests for Loans
Present Value in Cubic Meters, in Ls
Financial Analysis

	Discount Rate at 12%											
	FExch=4.5			FExch=12			FExch=20			FExch=30		
Diesel Price	Diesel	Solar	Wind	Diesel	Solar	Wind	Diesel	Solar	Wind	Diesel	Solar	Wind
11.50	15.05	15.05	15.28	20.65	18.22	17.36	21.08	21.61	19.58	21.60	25.84	22.36
15.00	19.72	19.72	20.02	25.67	23.85	22.77	26.23	28.24	25.71	26.94	33.74	29.38
25.00	22.03	22.03	22.35	28.14	26.62	25.44	28.78	31.51	28.72	29.56	37.63	32.83
30.00	24.00	24.00	24.36	30.26	28.99	27.72	30.95	34.32	31.31	31.82	40.97	35.80
45.00	26.02	26.02	26.40	32.43	31.42	30.06	33.18	37.18	33.95	34.12	44.38	38.83
60.00	28.08	28.08	28.49	34.64	33.90	32.43	35.45	40.10	36.65	36.47	47.85	41.91
70.00	30.17	30.17	30.60	36.88	36.40	34.85	37.75	43.06	39.38	38.85	51.38	45.05
Discount Rate at 15%												
	FExch=4.5			FExch=12			FExch=20			FExch=30		
Diesel Price	Diesel	Solar	Wind	Diesel	Solar	Wind	Diesel	Solar	Wind	Diesel	Solar	Wind
11.50	23.09	17.76	18.04	23.56	21.46	20.51	24.07	25.41	23.15	24.70	30.34	26.45
15.00	28.03	22.48	22.83	28.63	27.14	25.98	29.28	32.11	29.33	30.08	38.32	33.53
25.00	30.76	25.10	25.48	31.44	30.28	29.00	32.16	35.82	32.76	33.06	42.73	37.45
30.00	33.10	27.34	27.75	33.84	32.98	31.59	34.63	39.00	35.69	35.62	46.52	40.82
45.00	35.50	29.63	30.07	36.30	35.74	34.24	37.16	42.25	38.69	38.23	50.38	44.25
60.00	37.93	31.97	32.43	38.80	38.54	36.94	39.73	45.56	41.74	40.89	54.32	47.75
70.00	40.41	34.34	34.84	41.35	41.39	39.68	42.35	48.92	44.85	43.63	58.33	51.31
Discount Rate at 20%												
	FExch=4.5			FExch=12			FExch=20			FExch=30		
Diesel Price	Diesel	Solar	Wind	Diesel	Solar	Wind	Diesel	Solar	Wind	Diesel	Solar	Wind
11.50	28.08	22.54	22.91	28.69	27.17	26.07	29.34	32.10	29.43	30.15	38.27	33.64
15.00	32.71	26.97	27.40	33.44	32.49	31.19	34.22	38.38	35.23	35.20	45.75	40.28
25.00	35.95	30.07	30.54	36.77	36.22	34.77	37.64	42.78	39.29	38.73	50.98	44.93
30.00	38.73	32.73	33.23	39.62	39.42	37.85	40.57	46.55	42.77	41.77	55.47	48.92
45.00	41.57	35.45	35.99	42.54	42.68	40.99	43.57	50.41	46.33	44.86	60.06	53.00
60.00	44.46	38.21	38.79	45.51	46.01	44.19	46.62	54.95	49.95	48.02	64.73	57.15
70.00	47.40	41.02	41.64	48.52	49.39	47.44	49.72	58.32	53.63	51.22	69.48	61.36
Discount Rate at 25%												
	FExch=4.5			FExch=12			FExch=20			FExch=30		
Diesel Price	Diesel	Solar	Wind	Diesel	Solar	Wind	Diesel	Solar	Wind	Diesel	Solar	Wind
11.50	33.30	27.53	27.99	34.04	33.13	31.86	34.84	39.10	35.99	35.84	46.56	41.14
15.00	37.15	31.21	31.72	38.00	37.56	36.12	38.91	44.32	40.81	40.04	52.78	46.67
25.00	40.84	34.75	35.31	41.79	41.81	40.21	42.81	49.34	45.44	44.07	58.76	51.98
30.00	44.01	37.79	38.38	45.05	45.46	43.72	46.15	53.65	49.41	47.53	63.88	56.53
45.00	47.25	40.89	41.52	48.38	49.19	47.31	49.57	58.04	53.47	51.07	69.11	61.18
60.00	50.55	44.05	44.72	51.76	52.99	50.96	53.06	62.52	57.61	54.67	74.44	65.92
70.00	53.91	47.26	47.97	55.21	56.85	54.67	56.59	67.07	61.81	58.33	79.86	70.73

Assumptions used in the Financial Analysis
.5 = shadow price of unskilled labor
0% taxes on equipment
$5.25 per peak watt for solar
100 Depth of well (in meters)
2500 Well Cost per meter, in Ls
Base Case Technical Assumption for loans:
3 years
30 percent of loan as down payment

Table 8
Sensitivity Tests for Equipment Taxes
Present Value in Cubic Meters, in Ls
Financial Analysis

Discount Rate at 12%												
Tax Rate:	FExch=4.5			FExch=12			FExch=20			FExch=30		
	Diesel	Solar	Wind	Diesel	Solar	Wind	Diesel	Solar	Wind	Diesel	Solar	Wind
0.00	20.26	15.05	15.28	20.65	18.22	17.36	21.08	21.61	19.58	21.60	25.84	22.36
10.00	20.41	15.22	15.40	20.84	18.68	17.69	21.31	22.37	20.12	21.89	26.99	23.17
28.00	20.68	15.53	15.62	21.19	19.50	18.27	21.73	23.74	21.09	22.40	29.04	24.63
33.00	20.75	15.61	15.68	21.28	19.73	18.43	21.84	24.12	21.36	22.54	29.61	25.03
43.00	20.90	15.78	15.80	21.47	20.19	18.75	22.07	24.88	21.90	22.83	30.76	25.84
Discount Rate at 15%												
Tax Rate:	FExch=4.5			FExch=12			FExch=20			FExch=30		
	Diesel	Solar	Wind	Diesel	Solar	Wind	Diesel	Solar	Wind	Diesel	Solar	Wind
0.00	23.09	17.76	18.04	23.56	21.46	20.51	24.07	25.41	23.15	24.70	30.34	26.45
10.00	23.27	17.96	18.19	23.79	22.01	20.90	24.35	26.32	23.79	25.04	31.71	27.41
28.00	23.59	18.33	18.45	24.20	22.99	21.59	24.84	27.95	24.95	25.65	34.16	29.15
33.00	23.68	18.43	18.52	24.31	23.26	21.79	24.98	28.41	25.27	25.82	34.84	29.63
43.00	23.86	18.64	18.66	24.54	23.81	22.17	25.26	29.32	25.92	26.16	36.21	30.59
Discount Rate at 20%												
Tax Rate:	FExch=4.5			FExch=12			FExch=20			FExch=30		
	Diesel	Solar	Wind	Diesel	Solar	Wind	Diesel	Solar	Wind	Diesel	Solar	Wind
0.00	28.09	22.54	22.91	28.69	27.17	26.07	29.34	32.10	29.43	30.15	38.27	33.64
10.00	28.32	22.80	23.10	28.98	27.87	26.56	29.70	33.27	30.26	30.59	40.03	34.88
28.00	28.73	23.28	23.43	29.51	29.13	27.46	30.34	35.37	31.75	31.37	43.18	37.11
33.00	28.85	23.41	23.52	29.65	29.48	27.70	30.52	35.96	32.16	31.59	44.06	37.73
43.00	29.08	23.67	23.71	29.95	30.18	28.20	30.87	37.13	32.99	32.03	45.81	38.97
Discount Rate at 25%												
Tax Rate:	FExch=4.5			FExch=12			FExch=20			FExch=30		
	Diesel	Solar	Wind	Diesel	Solar	Wind	Diesel	Solar	Wind	Diesel	Solar	Wind
0.00	33.30	27.53	27.99	34.04	33.13	31.86	34.84	39.10	35.99	35.84	46.56	41.14
10.00	33.58	27.85	28.22	34.40	33.99	32.47	35.28	40.54	37.00	36.38	48.72	42.67
28.00	34.09	28.43	28.63	35.05	35.54	33.57	36.07	43.13	38.84	37.35	52.61	45.42
33.00	34.23	28.60	28.75	35.23	35.98	33.87	36.29	43.85	39.34	37.62	53.68	46.18
43.00	34.52	28.92	28.97	35.59	36.84	34.48	36.73	45.29	40.36	38.15	55.84	47.71

Assumptions used in the Financial Analysis
.5 = shadow price of unskilled labor
11.5 = Ls fuel cost/Imp gallon
0% taxes on equipment
$5.25 per peak watt for solar
100 Depth of well (in meters)
2500 Well Cost per meter, in Ls
Base Case Technical Assumptions: no loans

Table 9
Sensitivity Tests for Unskilled Labor
Present Value in Cubic Meters, in Ls
Economic Analysis with an Equilibrium Foreign Exchange Rate at 18

Discount Rate at 12%															
Shadow	Shadow	FExch=4.5			Shadow	FExch=12			Shadow	FExch=20			Shadow	FExch=30		
Labor Rate	FExch Rate	Diesel	Solar	Wind	FExch Rate	Diesel	Solar	Wind	FExch Rate	Diesel	Solar	Wind	FExch Rate	Diesel	Solar	Wind
0.50	4.00	37.41	17.29	22.87	1.50	22.43	14.41	19.28	0.90	18.84	13.71	18.42	0.60	17.04	13.37	17.99
0.70	4.00	37.64	17.42	23.00	1.50	22.66	14.53	19.41	0.90	19.07	13.84	18.55	0.60	17.27	13.50	18.12
1.00	4.00	37.99	17.61	23.20	1.50	23.02	14.73	19.61	0.90	19.42	14.03	18.74	0.60	17.62	13.69	18.31
1.50	4.00	38.58	17.93	23.52	1.50	23.60	15.05	19.93	0.90	20.01	14.35	19.07	0.60	18.21	14.02	18.64
Discount Rate at 15%																
Shadow	Shadow	FExch=4.5			Shadow	FExch=12			Shadow	FExch=20			Shadow	FExch=30		
Labor Rate	FExch Rate	Diesel	Solar	Wind	FExch Rate	Diesel	Solar	Wind	FExch Rate	Diesel	Solar	Wind	FExch Rate	Diesel	Solar	Wind
0.50	4.00	41.50	20.11	26.89	1.50	25.41	16.84	22.79	0.90	21.55	16.05	21.81	0.60	19.62	15.66	21.32
0.70	4.00	41.74	20.24	27.03	1.50	25.66	16.98	22.98	0.90	21.80	16.19	21.95	0.60	19.87	15.80	21.46
1.00	4.00	52.11	20.45	27.24	1.50	26.02	17.18	23.14	0.90	22.17	16.40	22.16	0.60	20.24	16.01	21.67
1.50	4.00	42.72	20.80	27.59	1.50	26.64	17.53	23.49	0.90	22.78	16.75	22.51	0.60	20.85	16.35	22.02
Discount Rate at 20%																
Shadow	Shadow	FExch=4.5			Shadow	FExch=12			Shadow	FExch=20			Shadow	FExch=30		
Labor Rate	FExch Rate	Diesel	Solar	Wind	FExch Rate	Diesel	Solar	Wind	FExch Rate	Diesel	Solar	Wind	FExch Rate	Diesel	Solar	Wind
0.50	4.00	48.70	25.07	33.97	1.50	30.67	21.12	28.98	0.90	26.34	20.18	27.78	0.60	24.18	19.71	27.18
0.70	4.00	48.96	25.22	34.12	1.50	30.93	21.28	29.14	0.90	26.61	20.33	27.97	0.60	24.44	19.86	27.34
1.00	4.00	49.36	25.46	34.36	1.50	31.33	21.52	29.37	0.90	27.00	20.57	28.18	0.60	24.84	20.10	27.58
1.50	4.00	50.01	25.85	34.76	1.50	31.98	21.91	29.77	0.90	27.66	20.96	28.57	0.60	25.49	20.49	27.97
Discount Rate at 25%																
Shadow	Shadow	FExch=4.5			Shadow	FExch=12			Shadow	FExch=20			Shadow	FExch=30		
Labor Rate	FExch Rate	Diesel	Solar	Wind	FExch Rate	Diesel	Solar	Wind	FExch Rate	Diesel	Solar	Wind	FExch Rate	Diesel	Solar	Wind
0.50	4.00	56.23	30.25	41.35	1.50	36.16	25.61	35.43	0.90	31.34	24.49	34.01	0.60	28.93	23.93	33.30
0.70	4.00	56.51	30.43	41.52	1.50	36.44	25.78	35.61	0.90	31.62	24.66	34.18	0.60	29.22	24.11	33.47
1.00	4.00	56.93	30.69	41.79	1.50	36.86	26.04	35.87	0.90	32.05	24.93	34.45	0.60	29.64	24.37	33.74
1.50	4.00	57.63	31.13	42.23	1.50	37.56	26.48	36.31	0.90	32.75	25.36	34.89	0.60	30.30	24.81	34.18

Assumptions used in the Economic Analysis
0% taxes on equipment
$5.25 per peak watt for solar
100 Depth of well (in meters)
2500 Well Cost per meter, in Ls
Base Case Technical Assumption of no loans

Table 10
Sensitivity Tests for Unskilled Labor
Present Value in Cubic Meters, in Ls
Economic Analysis with an Equilibrium Foreign Exchange Rate at 25

Discount Rate at 12%																
Shadow	Shadow	FExch=4.5			Shadow	FExch=12			Shadow	FExch=20			Shadow	FExch=30		
Labor Rate	FExch Rate	Diesel	Solar	Wind	FExch Rate	Diesel	Solar	Wind	FExch Rate	Diesel	Solar	Wind	FExch Rate	Diesel	Solar	Wind
0.50	5.56	46.75	22.06	27.01	2.08	25.90	18.02	21.99	1.25	20.93	17.10	20.81	0.83	18.42	16.56	20.18
0.70	5.56	46.99	22.19	27.14	2.08	26.14	18.15	22.12	1.25	21.17	17.21	20.94	0.83	18.65	16.68	20.31
1.00	5.56	47.34	22.38	27.34	2.08	26.49	18.34	22.32	1.25	21.52	17.40	21.14	0.83	19.00	16.88	20.51
1.50	5.56	47.92	22.70	27.66	2.08	27.08	18.66	22.64	1.25	22.10	17.72	21.46	0.83	19.59	17.20	20.81
Discount Rate at 15%																
Shadow	Shadow	FExch=4.5			Shadow	FExch=12			Shadow	FExch=20			Shadow	FExch=30		
Labor Rate	FExch Rate	Diesel	Solar	Wind	FExch Rate	Diesel	Solar	Wind	FExch Rate	Diesel	Solar	Wind	FExch Rate	Diesel	Solar	Wind
0.50	5.56	51.53	25.61	31.69	2.08	29.15	21.03	25.97	1.25	23.81	19.97	24.62	0.60	21.20	19.37	23.90
0.70	5.56	51.78	25.75	31.84	2.08	29.39	21.17	26.11	1.25	24.05	20.11	24.76	0.60	21.35	19.51	24.04
1.00	5.56	52.14	25.96	32.05	2.08	29.76	21.38	26.32	1.25	24.42	20.31	24.97	0.60	21.72	19.71	24.25
1.50	5.56	52.75	26.30	32.40	2.08	30.37	21.72	26.67	1.25	25.03	20.66	25.33	0.60	22.33	20.06	24.61
Discount Rate at 20%																
Shadow	Shadow	FExch=4.5			Shadow	FExch=12			Shadow	FExch=20			Shadow	FExch=30		
Labor Rate	FExch Rate	Diesel	Solar	Wind	FExch Rate	Diesel	Solar	Wind	FExch Rate	Diesel	Solar	Wind	FExch Rate	Diesel	Solar	Wind
0.50	5.56	59.95	31.86	39.95	2.08	34.85	26.33	32.98	1.25	28.87	25.05	31.34	0.60	25.84	24.33	30.46
0.70	5.56	60.21	32.02	40.11	2.08	35.12	26.49	33.14	1.25	29.13	25.21	31.50	0.60	26.10	24.48	30.62
1.00	5.56	60.61	32.25	40.34	2.08	35.51	26.72	33.38	1.25	29.52	25.44	31.74	0.60	26.50	24.72	30.86
1.50	5.56	61.25	32.64	40.74	2.08	36.17	27.11	33.77	1.25	30.18	25.83	32.13	0.60	27.15	25.11	31.25
Discount Rate at 25%																
Shadow	Shadow	FExch=4.5			Shadow	FExch=12			Shadow	FExch=20			Shadow	FExch=30		
Labor Rate	FExch Rate	Diesel	Solar	Wind	FExch Rate	Diesel	Solar	Wind	FExch Rate	Diesel	Solar	Wind	FExch Rate	Diesel	Solar	Wind
0.50	5.56	68.75	38.39	48.56	2.08	40.81	31.88	40.29	1.25	34.15	30.37	38.34	0.60	30.78	29.51	37.30
0.70	5.56	69.03	38.57	48.73	2.08	41.10	32.05	40.47	1.25	34.43	30.54	38.52	0.60	31.06	29.68	37.48
1.00	5.56	69.45	38.83	49.00	2.08	41.52	32.32	40.73	1.25	34.85	30.80	38.79	0.60	31.48	29.95	37.74
1.50	5.56	70.15	39.27	49.44	2.08	42.22	32.75	41.17	1.25	35.56	31.24	39.23	0.60	32.19	30.38	38.18

Assumptions used in the Economic Analysis
0% taxes on equipment
$5.25 per peak watt for solar
100 Depth of well (in meters)
2500 Well Cost per meter, in Ls
Base Case Technical Assumption of no loans

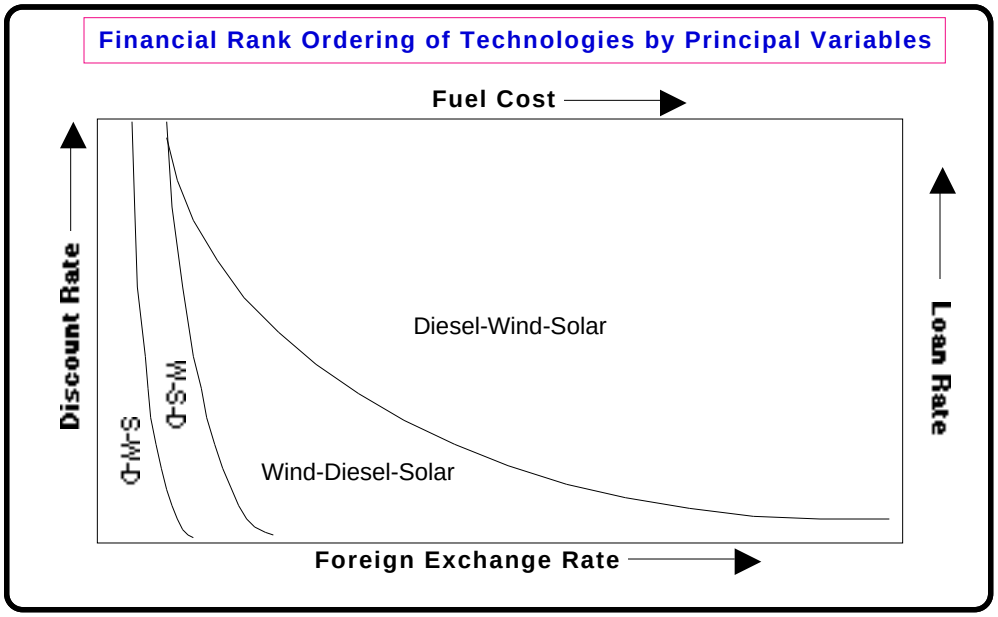
Table 11
Sensitivity Test Summary Rankings
Financial Analysis

Variable:	Parameter Range	System Ranking	Variable:	Parameter Range	System Ranking	Variable:	Parameter Range	System Ranking
Discount Rate	12-30%	W-S-D						
	35-45%	W-D-S						
	50%	D-W-S						
Foreign Exchange Rate		Discount Rates: 12% 15% 20% 25% 30%						
	4.50	S-W-D S-W-D S-W-D S-W-D S-W-D						
	12.00	W-S-D W-S-D W-S-D W-S-D W-S-D						
	20.00	W-D-S W-D-S W-D-S D-W-S D-W-S						
	30.00	D-W-S D-W-S D-W-S D-W-S D-W-S						
Fuel Costs		Discount Rates: 12% 15% 20%	Loans	3 years Down Payment of:	Discount Rates: 12% 15% 20% 25%	Equipment Taxes	Tax Rate:	Discount Rates: 12% 15% 20% 25%
		Foreign Exchange Rate at 4.5			Foreign Exchange Rate at 4.5			Foreign Exchange Rate at 4.5
	11.50	S-W-D S-W-D S-W-D		0%	S-W-D S-W-D S-W-D S-W-D		0%	S-W-D S-W-D S-W-D S-W-D
	15.00	S-W-D S-W-D S-W-D		38%	S-W-D S-W-D S-W-D S-W-D		10%	S-W-D S-W-D S-W-D S-W-D
	25.00	S-W-D S-W-D S-W-D		50%	S-W-D S-W-D S-W-D S-W-D		28%	S-W-D S-W-D S-W-D S-W-D
	30.00	S-W-D S-W-D S-W-D		60%	S-W-D S-W-D S-W-D S-W-D		33%	S-W-D S-W-D S-W-D S-W-D
	45.00	S-W-D S-W-D S-W-D		70%	S-W-D S-W-D S-W-D S-W-D		43%	S-W-D S-W-D S-W-D S-W-D
	60.00	S-W-D S-W-D S-W-D		80%	S-W-D S-W-D S-W-D S-W-D			
	70.00	S-W-D S-W-D S-W-D		90%	S-W-D S-W-D S-W-D S-W-D			
	100.00	S-W-D S-W-D S-W-D						
Fuel Costs		Discount Rates: 12% 15% 20%	Loans	3 years Down Payment of:	Discount Rates: 12% 15% 20% 25%	Equipment Taxes	Tax Rate:	Discount Rates: 12% 15% 20% 25%
		Foreign Exchange Rate at 12			Foreign Exchange Rate at 12			Foreign Exchange Rate at 12
	11.50	W-S-D W-S-D W-S-D		0%	W-S-D W-S-D W-S-D W-S-D		0%	W-S-D W-S-D W-S-D W-S-D
	15.00	W-S-D W-S-D W-S-D		38%	W-S-D W-S-D W-S-D W-S-D		10%	W-S-D W-S-D W-S-D W-S-D
	25.00	W-S-D W-S-D W-S-D		50%	W-S-D W-S-D W-S-D W-D-S		28%	W-S-D W-S-D W-S-D W-S-D
	30.00	W-S-D W-S-D W-S-D		60%	W-S-D W-S-D W-S-D W-D-S		33%	W-S-D W-S-D W-S-D W-S-D
	45.00	W-S-D W-S-D W-S-D		70%	W-S-D W-S-D W-D-S W-D-S		43%	W-S-D W-S-D W-S-D W-S-D
	60.00	W-S-D W-S-D W-S-D		80%	W-S-D W-S-D W-D-S W-D-S			
	70.00	W-S-D W-S-D W-S-D		90%	W-S-D W-S-D W-D-S W-D-S			
	100.00	W-S-D W-S-D W-S-D						
Fuel Costs		Discount Rates: 12% 15% 20%	Loans	3 years Down Payment of:	Discount Rates: 12% 15% 20% 25%	Equipment Taxes	Tax Rate:	Discount Rates: 12% 15% 20% 25%
		Foreign Exchange Rate at 20			Foreign Exchange Rate at 20			Foreign Exchange Rate at 20
	11.50	W-D-S W-D-S W-D-S		0%	W-D-S W-D-S D-W-S D-W-S		0%	W-D-S W-D-S D-W-S D-W-S
	15.00	W-D-S W-D-S W-D-S		38%	W-D-S D-W-S D-W-S D-W-S		10%	W-D-S W-D-S D-W-S D-W-S
	25.00	W-D-S W-D-S W-D-S		50%	W-D-S D-W-S D-W-S D-W-S		28%	W-D-S D-W-S D-W-S D-W-S
	30.00	W-S-D W-S-D W-D-S		60%	W-D-S D-W-S D-W-S D-W-S		33%	W-D-S D-W-S D-W-S D-W-S
	45.00	W-S-D W-S-D W-D-S		70%	W-D-S D-W-S D-W-S D-W-S		43%	W-D-S D-W-S D-W-S D-W-S
	60.00	W-S-D W-S-D W-D-S		80%	W-D-S D-W-S D-W-S D-W-S			
	70.00	W-S-D W-S-D W-S-D		90%	W-D-S D-W-S D-W-S D-W-S			
	100.00	W-S-D W-S-D W-S-D						
Fuel Costs		Discount Rates: 12% 15% 20%	Loans	3 years Down Payment of:	Discount Rates: 12% 15% 20% 25%	Equipment Taxes	Tax Rate:	Discount Rates: 12% 15% 20% 25%
		Foreign Exchange Rate at 30			Foreign Exchange Rate at 30			Foreign Exchange Rate at 30
	11.50	D-W-S D-W-S D-W-S		0%	D-W-S D-W-S D-W-S D-W-S		0%	D-W-S D-W-S D-W-S D-W-S
	15.00	D-W-S D-W-S D-W-S		38%	D-W-S D-W-S D-W-S D-W-S		10%	D-W-S D-W-S D-W-S D-W-S
	25.00	W-D-S D-W-S D-W-S		50%	D-W-S D-W-S D-W-S D-W-S		28%	D-W-S D-W-S D-W-S D-W-S
	30.00	W-D-S D-W-S D-W-S		60%	D-W-S D-W-S D-W-S D-W-S		33%	D-W-S D-W-S D-W-S D-W-S
	45.00	W-D-S W-D-S D-W-S		70%	D-W-S D-W-S D-W-S D-W-S		43%	D-W-S D-W-S D-W-S D-W-S
	60.00	W-D-S W-D-S D-W-S		80%	D-W-S D-W-S D-W-S D-W-S			
	70.00	W-D-S W-D-S D-W-S		90%	D-W-S D-W-S D-W-S D-W-S			
	100.00	W-S-D W-D-S W-D-S						

Table 12
Sensitivity Test Summary Rankings
Economic Analysis

Variable:	Parameter Range	System Ranking			
Discount Rate	12-25%	S-W-D			
	30-50%	S-D-W			
Foreign Exchange Rate		Discount Rates:			
		12%	20%	25%	30%
		Equilibrium Forex at 12Ls/$			
	4.50	S-W-D	S-W-D	S-W-D	S-W-D
	12.00	S-W-D	S-W-D	S-D-W	S-W-D
	20.00	S-W-D	S-D-W	S-D-W	S-D-W
	30.00	S-D-W	S-D-W	S-D-W	S-D-W
Foreign Exchange Rate		Discount Rates:			
		12%	20%	25%	30%
		Equilibrium Forex at 18Ls/$			
	4.50	S-W-D	S-W-D	S-W-D	S-W-D
	12.00	S-W-D	S-W-D	S-W-D	S-D-W
	20.00	S-W-D	S-W-D	S-D-W	S-D-W
	30.00	S-W-D	S-D-W	S-D-W	S-D-W
Foreign Exchange Rate		Discount Rates:			
		12%	20%	25%	30%
		Equilibrium Forex at 25Ls/$			
	4.50	S-W-D	S-W-D	S-W-D	S-W-D
	12.00	S-W-D	S-W-D	S-W-D	S-D-W
	20.00	S-W-D	S-D-W	S-D-W	S-D-W
	30.00	S-D-W	S-D-W	S-D-W	S-D-W
Fuel Costs		Discount Rates:			
		12%	15%	20%	
		Foreign Exchange Rate at 4.5-30			
	11.50	S-W-D	S-W-D	S-W-D	
	15.00	S-W-D	S-W-D	S-W-D	
	25.00	S-W-D	S-W-D	S-W-D	
	30.00	S-W-D	S-W-D	S-W-D	
	45.00	S-W-D	S-W-D	S-W-D	
	60.00	S-W-D	S-W-D	S-W-D	
	70.00	S-W-D	S-W-D	S-W-D	
	100.00	S-W-D	S-W-D	S-W-D	

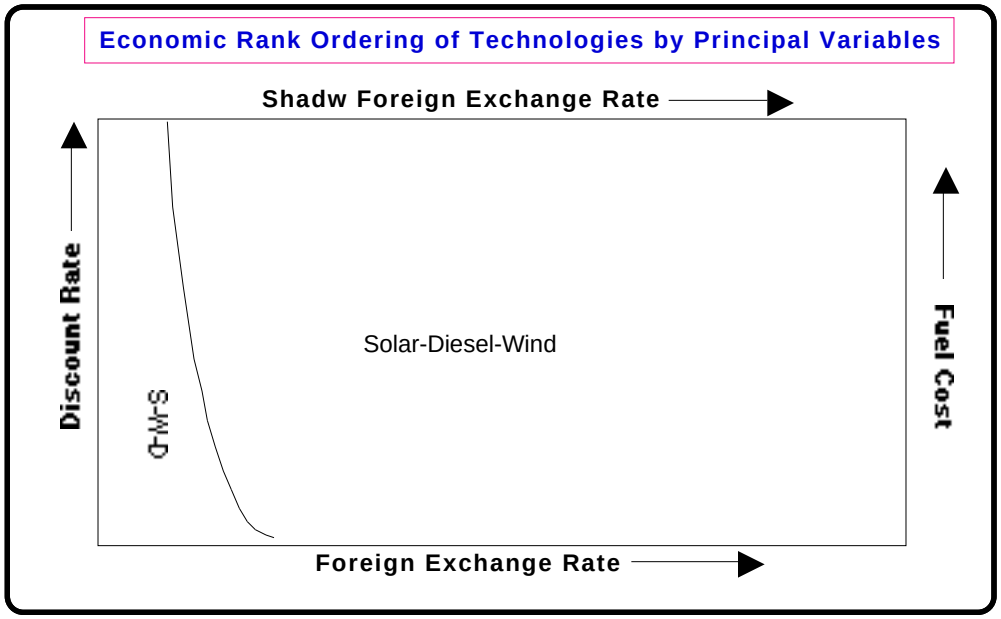
Figure 1
Financial Analysis Sensitivity Test Ranking Spacing



Assumptions:

Loans at 30 percent down payment for 3 year term
Base Case Technical Assumptions
$5.25 per Peak Watt for Solar
100 meter well depth
2500 Well Cost per meter, in Ls
0% Taxes on Equipment

Figure 2
Economic Analysis Sensitivity Test Rank Spacing



Assumptions:

Base Case Technical Assumptions
$5.25 per Peak Watt solar
100 meter well depth
2500 well cost per meter, in Ls
0% Taxes on Equipment
Equilibrium Foreign Exchange Rate at 20
Loans at 30 percent down payment for 3 years

Appendix C
Sensitivity Test Financial Regression Analysis

Given the parametric variations used in the sensitivity tests, one can derive the relative importance of a variable to the level of the present value per cubic meter of water. Since all variables are perfectly correlated by definition, the purpose of this comparison is only to assess the relative contribution of a variable and the direction of causation on water life cycle unit costs. Listed below are the results of linear and multipler linear OLS regressions of the sensitivity variables, with standard errors listed in parentheses.

Dependent Variable	Independent Variables							
1. Diesel	=7.0800	+1.09 (0.01)	Disc.Rate					
2. Diesel	=6.5000	+0.09 (0.01)	Forex	+1.07 (0.01)	Disc.Rate			
3. Diesel	=22.1500	+0.0630 (0.01)	Forex	+0.07 (0.001)	Fuel Cost			
4. Diesel	=7.3300	+0.995 (0.00430)	Disc.Rate	+0.057 (0.00140)	Forex	+0.057 0.00043*	Fuel	
5. Solar	= -0.5820	+1.091 (0.01858)	Disc.Rate	+0.470 (0.00579)	Foreg	-0.00075 (0.00183)	Fuel	
6. Wind	=0.6039	+1.076 (0.01389)	Disc.Rate	+0.3129 (0.00447)	Forex	-0.00053 0.00137*	Fuel	
7. Diesel	=2.3500	+1.18 (0.030)	Disc.Rate	+0.11 (0.010)	Forex	-0.22000 (0.000)	Loans	
8. Solar	= -13.7500	+1.42 (0.05)	Disc.Rate	+0.82 (0.03)	Forex	+0.267 (0.01)	Loans	
9. Wind	= -9.9200	+1.35 (0.04)	Disc.Rate	+0.57 (0.05)	Forex	+0.250 (0.02)	Loans	
10. Diesel	=0.6100	+1.08 (0.01)	Disc.Rate	+0.09 (0.00)	Forex	+0.03 (0.00)	Tax Rate	
11. Solar	= -8.3900	+1.36 (0.04)	Disc.Rate	+0.69 (0.02)	Forex	+0.09 (0.01)	Tax Rate	
12. Wind	= -5.0000	+1.27 (0.03)	Disc.Rate	+0.47 (0.01)	.Forex	+0.06 (0.01)	Tax Rate	

* Denotes variable is not significant at the 5 percent level.

Appendix D
List of Individuals Contacted

Adam, Siddig Omer, M.S., Mechanical Engineer, Sudan Renewable Energy Project, P.O. Box 4032, Khartoum, Sudan

Andrawis, Nazeih H., Manager, Monitoring and Evaluation Dept., Agricultural Bank of Sudan, P.O. Box 1363, Khartoum.

El-Dishoumi, Sharif, Ph.D., Department of Econoics, University of Khartoum, Sudan

Al Hassan, Sheikh Mohammed, Assistant manager for Operations, Agricultural Bank of the Sudan, P.O. Box 1363, Khartoum.

Faki Ali, Gaafar El, Msc, Forest Economist, Assistant Coordinator, SREP, P.O. Box 4032, Khartoum, Sudan.

Bush, Martin, Project Director, SREP/AID/ARD, P.O. Box 4032, Khartoum, Sudan.

El Din, Ahmed Safi, Ph.D., Associate professor, Department of Economics, University of Khartoum, Sudan.

Deshpande, Abhay, Resident Representative, the World Bank, P.O. Box 2211, Khartoum, Sudan.

Hamza, Ali Abdelrhaman, Mechanical Engineer, Sudan Renewable Energy Project, Energy Research Council, P.O. Box 4032, Khartoum, Sudan.

Hart, Terence J., Directgor, IT Power Ltd., B.P. 7088, Bamaki, Mali.

Jones, Tim, Project Manager, Intermediate Technology Development Group, Rugby, United Kingdom.

Koepsell, Edgar, Ph.D., Economist, Advisor, Deutsche Gesellschaft fuer Technische Zusammenarbeit, Special Energy Program, Renewable Energy Research Institute, P.O. Box 8192, Khartoum, Sudan.

Omer, Ali, Economist, Sudan Renewable Energy Project, Energy Research Council, P.O. Box 4032, Khartoum, Sudan.

Yassih, Nourella, Agriculturalist, Sudan Renewable Energy Project, Energy Research council, P.O. Box 4032, Khartoum, Sudan.

Appendix E

Cost-Effectiveness Model Spreadsheet Base Case Settings

Diesel, Solar, Imported Windmil

13.9 Cubic Meters/day water delivery

Diesel pump

3.5 Pumping Rate, in cubic meters per hour

5.00% Overall efficiency

4.00 hours per day operation

Solar Pump

6.00 Watts per square meter per day solar radiation on

31.00% Daily energy efficiency

1508 Wp Design efficiency

1505 Wp Actual performance level

Wind Pump

5.4 Meter per second average wind speed

5.00% Overall efficiency

Cubic Meter daily output:

13.90 Diesel

13.90 Solar

14.00 Windmill

Diesel, Solar, Imported Wind

13.9 Cubic meters per day water delivery

50 meters total delivery head

	Diesel	Solar	Wind
Financial			
PV per m3	22.1	26.29	22.3
per jerican	0.40	0.47	0.40
Total Inst.Costs			
	185986	291913	258300
PV Rec.Costs			
	768618	841019	710398
Economic			
PV per m3	22.54	25.93	25.26
Total Inst.Costs			
	589953	985066	1040500
PV Rec.Costs			
	383476	132538	60487

Well cost

250000 Ls

Diesel

13.9 cubic meters per cay

5.00% Overall efficiency

3.6 liters per day of fuel consumption

4.00 hours per day of operation

Solar

13.9 cubic meters per day

1505 Wp

6 Megajoules per square meter per day

Wind

14 cubic meters per day

5.00 meters r.diameter

Assumptions:

Engine operates 365 days at head and output

20 year term of analysis

No salvage value for any components

Solar array will last 20 years

PV calculated on delivery for each pump

Installed Costs should include taxes, if any

Waster is discounted at the rate given below:

0.1 Discount rate

0.5 Shadow prie

1.5 Shadow foreign exchange rate

0% taxes on equipment

35 SL fuel cost per imperial gallon

$5.25 per perak watt for solar modules

0.15 Loan rate

100 meter well depth

2500 well cost per meter, in Ls

Secondary technical information

10 Life of engine, in years

20 Life of engine pump, in years

10 Life of Solar pump (only), in years

20 Life of windmill

5 Life of windmill pump, in years

60 Cell temperature (degrees celsius)

1.03 kg per cubic meter, air density

Loan information

(financial only)

Diesel

433967.1 Loan amount

0.15 Loan interest rate

3 Loan term, in years

Solar

681130.6 Loan amount

0.15 Loan interest rate

3 Loan term, in years

Wind

602700 Loan amount

0.15 Loan interest rate

3 Loan term, in years

Financial and Economic Capital and Recurrent Costs

Financial Analysis				Economic Analysis			
Diesel System				**Diesel System**			
Capital Costs		**Recurrent Costs**		**Capital Costs**		**Recurrent Costs**	
engine	24000		annual	engine	36000		annual
pump	24000	operator(s)	3600	pump	36000	operator(s)	1800
other offshore	$2,000.00	fuel	0	other offshore	$3,000.00	fuel	0
site preparation	1000	parts/materials	10000	site preparation	1000	parts/materials	15000
pumphouse & civil works	4000	skilled labor	5000	pumphouse & civil works	4000	skilled labor	5000
storage tank	100000	unskilled labor	1000	storage tank	100000	unskilled labor	500
other (includ.fence)	25000	transportation	4000	other (includ.fence)	25000	transportation	6000
installation			non-annual	installation			non-annual
skilled labor	70000	replace engine	24000	skilled labor	70000	replace engine	36000
unskilled labor	10000	replace pump	24000	unskilled labor	5000	replace pump	36000
transport	40000			transport	60000		
Total installed cost (exclusive of loan, if any)	323953			Total installed cost (exclusive of loan, if any)	339953		
Solar System				**Solar System**			
Capital Costs		**Recurrent Costs**		**Capital Costs**		**Recurrent Costs**	
solar array	$7,901.25		annual	solar array	$11,851.88		annual
pump	$5,000.00	operator(s)	1800	pump	$7,500.00	operator(s)	900
other offshore	$1,500.00	fuel	0	other offshore	$2,250.00	fuel	90
site preparation	1000	parts/materials	500	site preparation	1000	parts/materials	750
civil works	3000	module repl.(l.cost)	275	civil works	3000	module repl.(l.cost)	413
storage tank	100000	skilled labor	100	storage tank	100000	skilled labor	50
other offshore	25000	unskilled labor	50	other offshore	25000	unskilled labor	75
installation		transportation	1000	installation		transportation	1500
skilled labor	50000		non-annual	skilled labor	50000		non-annual
unskilled labor	10000	replace pump only	60000	unskilled labor	5000	replace pump only	90000
transport	30000			transport	45000		
Total installed cost (exclusive of loan, if any)	391815			Total installed cost (exclusive of loan, if any)	488223		
Wind System				**Wind System**			
Capital Costs		**Recurrent Costs**		**Capital Costs**		**Recurrent Costs**	
windmill	$8,000.00		annual	windmill	$12,000.00		annual
tower	$1,000.00	operator(s)	1800	tower	$1,500.00	operator(s)	900
pmu	$300.00	fuel	0	pmu	$450.00	fuel	0
other offshore	$1,000.00	parts/materials	1000	other offshore	$1,500.00	parts/materials	1500
site preparation	1500	skilled labor	800	site preparation	1500	skilled labor	800
civil works	4000	unskilled labor	200	civil works	4000	unskilled labor	100
storage tank	100000	transportation	1000	storage tank	100000	transportation	1500
other	25000		non-annual	other	250000		non-annual
installation		replace windmill	96000	installation		replace windmill	144000
skilled labor	70000	replace pump	3600	skilled labor	70000	replace pump	5400
unskilled labor	10000			unskilled labor	5000		
transport	40000			transport	60000		
Total installed cost (exclusive of loan, if any)	374100			Total installed cost (exclusive of loan, if any)	445500		

Cost-Effectiveness Model Spreadsheet Base Case Annual Settings

Diesel Financial Analysis																						
Recurrent Costs		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
fuel	3310	3310	3310	3310	3310	3310	3310	3310	3310	3310	3310	3310	3310	3310	3310	3310	3310	3310	3310	3310	3310	3310
operator (s)	3600	3600	3600	3600	3600	3600	3600	3600	3600	3600	3600	3600	3600	3600	3600	3600	3600	3600	3600	3600	3600	3600
parts/materials	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000
engine replacement	24000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
pump replacement	24000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
skilled labor	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000
unskilled labor	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000
transportation	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000
Loan repayment																						
Sum		26910	26910	26910	26910	26910	26910	26910	26910	26910	26910	26910	26910	26910	26910	26910	26910	26910	26910	26910	26910	26910
Diesel Economic Analysis																						
Recurrent Costs		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	
fuel	4966	4966	4966	4966	4966	4966	4966	4966	4966	4966	4966	4966	4966	4966	4966	4966	4966	4966	4966	4966	4966	
operator (s)	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	
parts/materials	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000	
engine replacement	36000																					
pump replacement	36000																					
skilled labor	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	
unskilled labor	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	
transportation	6000	6000	6000	6000	6000	6000	6000	6000	6000	6000	6000	6000	6000	6000	6000	6000	6000	6000	6000	6000	6000	
Loan repayment																						
Sum		33266	33266	33266	33266	33266	33266	33266	33266	33266	33266	33266	33266	33266	33266	33266	33266	33266	33266	33266	33266	
Solar Financial Analysis																						
Recurrent Costs		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	
fuel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
operator(s)	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	
parts/materials	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	
module replacement	275	275	275	275	275	275	275	275	275	275	275	275	275	275	275	275	275	275	275	275	275	
pump replacement	60000	0	0	0	0	0	0	0	0	0	60000	0	0	0	0	0	0	0	0	0	0	
skilled labor	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	
unskilled labor	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	
transportation	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	
Loan repayment		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Sum		3725	3725	3725	3725	3725	3725	3725	3725	3725	63725	3725	3725	3725	3725	3725	3725	3725	3725	3725	3725	
Solar Economic Analysis		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	
Recurrent Costs																						
fuel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
operator(s)	900	900	900	900	900	900	900	900	900	900	900	900	900	900	900	900	900	900	900	900	900	
parts/materials	750	750	750	750	750	750	750	750	750	750	750	750	750	750	750	750	750	750	750	750	750	
module replacement	412.5	412.5	412.5	412.5	412.5	412.5	412.5	412.5	412.5	412.5	412.5	412.5	412.5	412.5	412.5	412.5	412.5	412.5	412.5	412.5	412.5	
pump replacement	90000																					
skilled labor	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	
unskilled labor	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	
transportation	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	
Loan repayment		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Sum		3688	3688	3688	3688	3688	3688	3688	3688	3688	3688	3688	3688	3688	3688	3688	3688	3688	3688	3688	3688	
Windmill Financial Analysis																						
Recurrent Costs		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	
fuel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
operator(s)	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	
parts/materials	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	
windmill replacement	96000																					
pump replacement	3600					3600					3600					3600						
skilled labor	800	800	800	800	800	800	800	800	800	800	800	800	800	800	800	800	800	800	800	800	800	
unskilled labor	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	
transportation	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	
Loan repayment																						
Sum		4800	4800	4800	4800	8400	4800	4800	4800	4800	8400	4800	4800	4800	4800	8400	4800	4800	4800	4800	4800	
Windmill Economic Analysis		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	
Recurrent Costs																						
fuel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
operator(s)	900	900	900	900	900	900	900	900	900	900	900	900	900	900	900	900	900	900	900	900	900	
parts/materials	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	
windmill replacement	144000																					
pump replacement	5400					5400					5400					5400						
skilled labor	800	800	800	800	800	800	800	800	800	800	800	800	800	800	800	800	800	800	800	800	800	
unskilled labor	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	
transportation	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	
Loan repayment																						
Sum		4800	4800	4800	4800	10200	4800	4800	4800	4800	10200	4800	4800	4800	4800	10200	4800	4800	4800	4800	4800	