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Production of Thermoelectric Power from Solid Waste of Government College University Lahore Pakistan

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Abstract: Prospects of thermoelectric power generation by incineration of biomass of solid waste produced by Government College University Lahore (GCUL) were studied. Another objective was development of a methodology for techno-economic disposal of solid waste easily understandable in all countries. The primary data about solid waste were collected from GCUL while about technology were collected from Pattoki Sugar Mill. Different cost of land inclusive and exclusive projects were cost designed and analyzed for B/C ratio, NPV and Payback Period by application of discounted cash flow technique. The land cost inclusive alternative did not qualify criteria of project acceptability while without land cost alternative was technically sound and economically viable at the assumed heating value of the waste. Alternative scenarios were developed by revising the evaluation at half and one third of the assumed heating value and also on the basis of revised tariffs of electricity to see the impact of current price of electricity in Pakistan on the feasibility of projects. Different projects based on reduced fuel value did not turn out to be feasible while many based on current price of electricity became feasible.
Keywords: Thermo, Power, Biomass, GCUL

1. Introduction

The problem of quick depletion of energy resources and forthcoming dangers of polluting environment, have hard pressed humanity to seek some solutions to solve this problem. An important strategy being followed is an extensive hunt for the alternative/ renewable energy resources. Where the high growth rate of population is particularly a big issue, energy and environment also form the major component of the current aspect of the globe especially of the developing countries. It has lead to the concept of sustainable development, which means production, consumption; environment and energy are all interdependent and thus cannot be handled separately. These are to be so planned that the resources are conserved and environment remains clean for the future generations.

The points made above lead to the major question, "How to explore alternative resources and produce energy with simultaneous solution of environmental problems to achieve the ideals of sustainable development?" The major hurdle in the way to achieve these ideals is the lack of awareness that translates into an extensive wastage of energy resources. This may be exemplified by unnecessary air conditioning, burning of solid waste for disposal and dissipating heat and volatile pollutants in the atmosphere to cause energy and air pollution instead of its harnessing for conversion into electrical energy or its utilization for heating purpose. This leads to the conclusion that new energy resources are to be explored and available resources are to be conserved. An important aspect of sustainable development is to understand that no waste is now waste as every waste can be assigned an economic value. McDougall and P.R. White [1] viewed sustainability as a triangle, with one of the three elements (environmental, economic and social) at each of the angles. Thus it is about balancing these three elements and a stable balance requires all three elements to be considered equally. Therefore for solid waste management to be sustainable it needs to be environmentally effective, economically affordable and socially acceptable" A strong background reference for authors was Department of the Environment, UK report, "Making waste work; a strategy for sustainable waste management in England and Wales" [2]. Thus, the best way to cope with these problems seems to be through a coupling of energy and environmental problems.

Keeping this two-prong approach in mind, many avenues are being explored to appraise the production of electric power from solid. Very few research articles involving practical experimentation on solid waste disposal with production of electricity seem to have appeared in literature. Of course, a number of reports and reviews concerning policy framework of solid waste management with economic benefit of power production and implementation in different countries have appeared. A brief account of these studies is given below.

Kajikawa [3] in 1996 reviewed the status and future prospects of development of thermo-electric power generation systems by utilization of heat from the municipal solid waste in Japan. According to the report, the characteristics of heat from the solid waste processing system led to the concept of development of thermoelectric power generation system. Kajikawa [4] reviewed status and future prospects of thermoelectric power generation systems to recover electricity from the heat source referred above in Japan. The researcher introduced experimental results on three types of small-scale thermoelectric power generation systems used in the real municipal solid waste processing systems to show the technological feasibility and determine technological problems. He also presented conceptual designs of a small scale system for the next phase of the R and D program. He also presented a case study on the marginal cost estimation which showed that the cost reduction was less than 0.4 - 0.5 Million Yen/kWh to make profit on the system application. Kagawa [5] undertook a study which aimed at the utilization of low temperature thermal energy. A thermoelectric generator was applied to a municipal solid waste incinerator. Oil was used on the hot side as the heat transfer medium and water was used on the cold side. A running test was passed out with 22 times on/off heat cycles. The operating time was 115 hours. No significant degradation of the thermoelectric module was observed throughout the test period. Tsuyoshi and Matsuura [6] reported that a thermoelectric generator had been manufactured and evaluated for the purpose that the behavior of heat conduction and power generating performance can be clarified when the thermoelectric generator is powered by a high-temperature heat transfer oil medium over 500^0 K. The thermoelectric generator needed a compression fitting mechanism which holds heat sinks and thermoelectric generating modules so tight that desirable heat conduction can be maintained for thousands of heat cycles. Carbo [7] reviewed the market for Municipal Solid Waste Management Equipment in Colombia. The author reported that Colombia produced over 5.1 million tons of solid waste annually. Around 64 percent were organic biodegradable waste and the remainder had a potential recyclable content. He also described the management of solid waste in Colombia. In his opinion, though, the landfills had started to replace open-air dumps, much remained to be done to correct landfill operations. Zabaniotou and Giannoulid [8] carried out a conceptual study applying feasibility analysis to define the viability of an incineration plant with a capacity of 100 ton/day with energy recovery and environmental safety, in Greece. They used realistic estimates of waste composition and heat content and selected an appropriate incineration method as well as near optimum operating conditions of process equipment. The European and Greek legislation related to environmental protection was referred. The study concluded that the application of stricter requirements for the incineration of domestic waste resulted in increased investment and operational costs. Six emission abatement options were studied for their impact on total investment and operational cost. The study indicated that incineration with energy recovery and environmental safety is an expensive method, and the increase on cost due to the best available emission control system was 26% of the investment cost and 6.5% of the operational cost. The high costs may be compensated from the increased fuel and energy prices, the increased landfill taxes, and increased land values. Doherty et al [9] conducted a study on claimed thermoelectric devices that all were reliable energy converters with no noise or vibration. They had small size and were light in weight. As refrigerants, they were environment friendly as was CFC gas or any other refrigerant gas with this characteristic. Dubois et al [10] carried out a study on municipal solid waste treatment in the European Union. The objective of the study was the formulation of a policy line for sustainable waste management. This study focused on different ways of treating municipal solid waste; recycling, composting, incineration and land filling. They reported that yearly amount of municipal solid waste collected in Western Europe was 210 million tons/year. The authors recommended that Principle of Best Available Technology (BAT) Polluter Pays Principle (PPP) must be strictly followed for waste disposal. The study indicated that the major stress in European Union was on recycling and minor on its disposal by incineration to produce electricity. Hogg [11] compiled Leicestershire Municipal Waste Management Strategy Environmental Report. The key issues considered for Leicestershire with regard to solid waste management were air quality target and renewable energy undersupplied in the county. The report narrates that recycling rates had considerable scope for improvement and over-reliance on landfill was not advisable.

David Suzuki Foundation [12] has published Fact Sheet 3 which highlights that incineration of solid waste is a reasonable option for energy in Canada and thus the municipalities have to develop their waste management plans for the next 20-30 years as for them it is imperative that they be armed with accurate information to better the process. Of course, reporting about how efficient is it to burn waste for energy. The fact sheet compares extensive life cycle inventories for Canada and the energy gained from recycling versus combustion. The results show that recycling paper materials saves 2.4 to 7 times the energy gained from combustion, and recycling plastics saves 10 to 26 times the energy gained from combustion alone. From a thermal treatment of a ton of mixed waste in a modern incineration electricity facility, if compared recycling, would result in about 5.4, 1.6 and 2.6 times the energy savings than incinerating with electricity recovery.

Similarly, Swithenbank et al [13] have recently studied the status of solid waste power generation in UK. The experts reported that the total heat content of municipal waste in a developed country like UK totaled

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about 30% of that of coal used for the current need. The major hurdle on processing of coal and solid waste for power generation was the low energy efficiency of incineration that is 37 and 20% for coal and solid waste respectively. It was further added that the simple boiler-steam-turbine system and various pyrotechnology systems can be considered some of which integrate the use of fossil fuels with waste processing to provide superior electrical production efficiencies.

Xiulian, et al [14] analyzed and evaluated the production and resource of municipal solid waste (MSW) in China and the application of technology of waste incineration for electricity generation at home and abroad. They highlighted the main factors that restricted the application of MSW incineration technology and application potential of waste incineration technologies in China was reported. In case of generation by waste-incineration technology based on three baselines determined applying the incremental cost analysis approach, the researchers calculated the unit carbon-mitigation cost of generation by waste-incineration technology and conducted the sensitivity analysis. They suggested that generation by MSW-incineration technology should be a priority technology for cooperation.

The work being reported in this article forms a part of work undertaken on micro-level to study the techno-economic disposal of solid waste of some educational institutions including GCUL to accomplish an effective solid waste disposal and also generate thermo-electric power by incineration of its biomass. It may be pertinent to highlight that the concept was solely of the corresponding author that he tried to implement with his associates. Its major aim was downscaling of production of electricity from solid waste produced in different institutions (educational, here) to meet their in-house requirement and form a base for further studies at higher levels: village, town/city, country and global level

Since long after creation of Pakistan, no thermo-electric power plants based on solid waste are encountered. The pioneers in this field were some sugar mills who started this activity by burning of sugar cane bagasse. Many mills these days are applying this process to produce electricity for their local needs. Unfortunately, no study with special reference to thermoelectric power from solid waste has been undertaken in Pakistan. Some studies, of course, have been undertaken in foreign countries in different contexts. The target mostly has been the municipal solid waste. This work was carried on Lahore School of Economics [15], Lahore University of Management Sciences [16] and Kinnaird College [17] has been published or presented. Here the subject of study was Government College University Lahore. The objectives of research undertaken were as follows:

1. Safe and techno-economic disposal of GCUL solid waste.
2. Study of the feasibility of production of thermo-electric power from the biomass of solid waste of GCUL to meet its in-house needs.
3. Later extension of the study to higher levels such as village, town and city level.
4. Recommendations to the concerned agencies for effective solid waste management.

2. Methodology of Research

The methodology of research is already described in the published papers by Khan and associates [15]-[17]. Here only a summary is given with the addition of specific features concerning GCUL.

2.1 Collection of Data

The secondary data was collected as usual while primary data were collected from two concerned establishments related to the study: GCUL for assessment of the solid waste it produced and Pattoki Sugar Mills for data concerning thermoelectric power. as narrated below. The setups of GCUL contacted to supply the requisite data initially included Administration, Accounts Office and the personnel engaged in the generation of electricity locally using diesel as a fuel in GCUL when there is a stoppage of the supply of power from the Lahore Electricity Supply Corporation (LESCO). The contact spectrum was later extended to almost all people concerned with management of solid waste in GCUL.

Before visiting GCUL, a comprehensive questionnaire was designed, developed and pretested for gathering responses of the concerned officials and workers engaged at different spots of this study institution. The questionnaire was served to all concerned and the responses were collected and subsequently computed. The solid waste produced at different sites is computed in Table1.

The other establishment from where the data were collected was the Pattoki Sugar Mill. Its choice was on the basis that it was producing electricity for its in-house needs by incineration of bagasse and thus it was in a position to provide the researchers complete technological details of the process. A comprehensive questionnaire was also designed, developed and served to concerned people for collection of primary data.

Keeping in view some places within the University Campus not reached by the surveyors, the overall solid waste was considered as 600 metric tons per annum. However, some officials interviewed told that the trunk filled with the solid waste daily lifted by Metropolitan Corporation of Lahore contained approximately two tons of solid waste. The balance may account for the waste on some sites where researchers could not have an access. Thus, the primary calculation was done on the basis of processing of 720 tons per annum.

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Table 1: Solid waste produced at different sites of GCUL.

Site	Basis of Measurement	Solid Waste Produced per Day (kg)	Solid Waste Produced per Month (kg)	Solid Waste Produced per Annum (kg)
Cafeteria 1	20 pales,; each 18-20 kg/day	20×19 = 380	380×26 = 9880	9880×12= 118560
Cafeteria 2	16 pales,; each 18-20 kg/day	16×19 = 304	304×26 = 7904	7904×12= 94848
New hostel	15 rubbish bins 20 Kg in each	20×15=300	300×30 = 9000	9000×12 = 108000
Iqbal hostel	8 rubbish bins 20 kg in each	20×8=160	160×30 = 4,800	4,800×12 = 57600
Quaid-e-azam hostel	10 rubbish bins 20 kg in each	20×10=200	200×30 = 6000	6000×12 = 72000
Girls hostel	5 rubbish bins 20 kg in each	20×5=100	100×30 = 3,000	3000×12 = 36000
Central library	1 rubbish bin 1-2 kg/day	1×1.5=1.5	1.5x26=39	39x12=468
PG library	1 rubbish bin 1-2 Kg	1×1.5=1.5	1.5x26=39	39x12=468
Departmental libraries (10)	1-2 rubbish bin kg/day	10×1.5=15	15x26=390	390x12=4680
Computer lab	3 rubbish bins 5 kg/ each	5×3=15	15×26=390	390×12=4680
Botany lab	1 rubbish bin 5-6 kg/ day	5.5	5.5x26=143	143x12=1716
Chemistry lab	1 rubbish bin 5-6 kg/ day	5.5	5.5x26=143	143x12=1716
Physics lab	1 rubbish bin 5-6 kg/ day	5.5	5.5x26=143	143x12=1716
Geology lab	1 rubbish bin 5-6 kg/ day	5.5	5.5x26=143	143x12=1716
Zoology lab	1 rubbish bin 5-6 kg/ day	5.5	5.5x26=143	143x12=1716
SDS lab	1 rubbish bin 2-3 kg/ day	2.5	2.5x26=65	65x12=780
Bio- Tech lab	1 rubbish bin 2-3 kg/ day	2.5	2.5x26=65	65x12=780
Statistics lab	1 rubbish bin 2-3 kg/ day	2.5	2.5x26=65	65x12=780
Political science lab	1 rubbish bin 1-2 kg/ day	1.5	1.5x26=39	39x12=468
Central library photocopier	5 box that is full with 10kg waste	50	50×26 = 1300	1300×12= 15600
Departmental library photocopier	1 box that is full with 10kg waste	10	10×26 = 260 260 x 10= 2600	2600×12= 31200
Lawns and Trees	3 bale each 10 kg	3×10 = 30 30×10=300	30×30=900 300×30=9,000	9,00× 10=9,000 (For 10 Months) 9,000×2=18,000 (For 2 Months of Fall)
Total				**582492**

Diesel, etc, provided by the Accounts Office (Appendix 1). It turned out to be 1,580, 308 kWh per annum

2.2 Data Analysis

The data were analyzed to record components of the project and the project was cost designed. The NPV Model based on discounted cash flow techniques used by the Asian Development Bank 2001, 2003 [18, 19] was applied for the appraisal of the project under study. Both expenditure and returns were projected over ten years that was the project life and discounted to the Base Year (2000 – 2001) at 10% discount rate. NPV, B/C Ratio and Payback Period were computed.

*2.4. Interpretation of the Result***:**

The results were interpreted as described in the results section.

2.5. Cost Analysis

The project analysis is based on the project specifications given in Appendix 1.

Different cost components responsible for adding value to both expenditure and return streams are outlined below.

2.5.1. Initial Fixed Investment

It includes the cost of land, building, machinery, equipment, pre-production expenditure, etc. It was initially computed including cost of land as given in Appendix 1. It turned out be $6,930,833.33

The cost of land in vicinity of GCUL, being very high, there was no likelihood of feasibility of the project. Thus an alternative project excluding cost of land from the expenditure stream was designed for appraisal. The without cost projection was subject to the condition if the institution could spare some land in its present Campus or it may think in terms of installation of a power plant at its new site where land may be relatively cheap. The initial fixed investment without cost of land of this alternative came out to be $264,167.

2.5.2. Expenditure in the Base Year

Initial fixed Investment = $6,930,833.33

Operating Cost = Nil

Total Expenditure = $6,930,833.33

Expenditure in Future Years and Operating Cost

The operating cost was computed as given in Appendix 1. The cost of machinery and equipment and labor, etc is given in Table 2 and Table 3

Assumptions and computation for expenditure in future years are also given in Appendix 1. The computation of operating cost over 10 years is displayed in Table 4. Total Operating Cost Discounted to the Base Year = $275765.86

2.5,3.. *Computation of Benefits*

The benefits would be as computed in Appendix 1

2.5.4. B/C Ratios, NPV and PBP

The values are computed in Appendix 1.

2.5.5. Alternative Projects

The results of Project1 indicated that the project is not economically feasible. The major causes of failure of the project to qualify as acceptable were thought to be the cost of land that was very high in and around GCUL and less than required solid waste. The alternative projects were framed and evaluated exactly the same way as is done in Alternative 1. The framework bases are computed in Table 6 and the results in Table 7. While computing, the common requisites such as the steam boiler as it remains the same at scales of processing from 200 to 1000 tons/annum and also the heating value, which is also the same as the composition of fuel is the same.

2.5.6. Alternative Scenarios

Both primary project and the alternative projects were based on the assumed heating value of the solid waste of the educational institutions of Lahore City. The heating value of the solid waste of educational institutions studied by the group was thought to be much higher as compared to the municipal waste. Their waste have a high content of plastics including the PTN bottles used for packing of drinking water which have very high heating value (Around 3,500 calories per kg). Thus alternative scenarios based on lower heating values i.e. half and one third of the assumed were developed to highlight the importance of the primary study based on assumed value. In these scenarios, the costs remain the same but the benefits will be halved/divided by three respectively. This transformation involves a few arithmetical steps. The results of alternative scenarios are exhibited in Table 8 and 9.

The work on production of electricity from solid waste was initiated in 2008. Since then the prices of electricity have been drastically increased in Pakistan while no significant change has occurred in the prices of the machinery involved in the production of thermal power. Thus different scenarios based on enhanced prices of electricity were developed to see the impact of this increase on feasibility of the projects carried in 2008. In these scenarios the costs remain the same but returns will be increased proportionately with 2.46 times increase in prices. The results are exhibited in Table 10,11and 12.

3. Results

The results are reported at two levels. At the first level, the results pertaining to the situation of production of solid waste in GCUL and thermo-electric power technology in operation are reported as descriptive research, while at the second level, the results of the cost analysis of the designed project are reported.

3.1. Nature of Solid Wastes in GCUL

There are two cafeterias in GCUL. The Incharge of Cafeteria told that the solid waste produced primarily consists mainly of paper glasses, plastic glasses, straws, shopping bags, vegetable and fruit peel offs, plastic bottles dominated by PTN bottles, leftover food, packaging material, plastic boxes, empty cartons, glass bottles, aluminum foil, etc. The collection is done in pales that weigh 18-20 kg. The calculated production is shown in Table 1.

There are four hostels in GCUL (Table 1).The waste from the rooms is collected in small rubbish bins placed inside each room. The waste is composed of packaging material, tissue papers, writing paper, disposable plates and left over food. The total waste collected from all hostels is 273,600 kg (Table 1).

There are two main libraries: Central Library and Post-graduate Library. In addition, there are 10 departmental libraries. The libraries don't have any special kind of waste. Still, the bins are placed in the libraries that get filled with general waste. The quantity produced is reported in Table 1.

There are 10 laboratories in GCUL (Table 1). The only form of solid waste in these labs is paper and fiberboard. The collected waste is reported in Table 1.

The person deployed at the photocopier pointed out that basically there are two types of waste produced at the photocopying facility. These are the emptied cartons and the paper waste by the photocopying machine. There are also some used cartridges which are recycled.

GCUL is spread over a large area. It has two lawns/gardens, administrative area and a central lawn worldwide renowned as Oval. Thus, there is a lot of green waste in the form of grass, off cuts, leaves, etc, that fill a trolley every day. The waste is taken to a GCUL trunk placed out of University Campus and is transferred there. Total weight is reported in Table 1.

Large waste bins are placed all around the campus for collection and disposal of waste. The waste collected in these bins is mostly paper and packaging material. The bins are not emptied daily and thus the waste collected in them is not shown in Table 1, but they contribute significantly to the big trunk lifted by LMC.

All the waste collected daily except the glass bottles that are recycled by the companies that supply soft drinks is transferred to the big trunk that is filled with 2 metric ton waste daily. As it gets filled every day, concerned authority empties it daily on regular basis

3.1.1. Technology for Thermoelectric Power Production at Pattoki Sugar Mill

The technology for production of thermoelectric power is already described in published articles by Khan and associates [14]-[16]. The principle of production of electricity by incineration of solid waste is well known. The fuel is incinerated in a boiler containing pretreated water to raise superheated steam that is passed through a turbine that runs to produce electric current due to the change of flux between two magnets and a revolving metallic coil. The operations and sub-processes involved in the production of thermo-electricity from solid waste are shown in Fig.1.

3.2. Results of Cost Analysis

The fundamental criterion for project acceptability is that the B/C ratio should be either 1 or more than one and the NPV should be positive or more than zero.

*3.2.1. Alternative 1 (With Land, 720tpa)***:** The value of B/C ratio in this alternative comes out to be 0.09, which is far less than 1, NPV is **–** $6,531,795 and payback period is about 102.5 years. The cost of land in and around GCUL being very high, the indicators are far apart from the standards. Thus, Alternative 1 is not feasible because B/C is far less than 1, NPV is highly negative and payback is highly abnormal for a commercial option.

*3.2.2. Alternative 2 (Without Land, 720tpa)***:** In Alternative 2, the value of B/C comes out to be 1.24, NPV is $134,865 and payback period is 4 years. This alternative is better than the first one since the values of B/C, NPV and PBP meet the acceptability criteria..

*3 2.3. Alternative 3 (With Land, 600 tpa)***:** This alternative was investigated as it was based on the assessment of the researchers in the group and was also nearest to Alternative 1with respect to weight of the solid waste. The value of B/C in this alternative comes out to be 0.07, which is still far less than 1, NPV is **–**$6,643,626 and PBP is about 140 years. This is again not acceptable due to high cost of land in and around GCUL. Thus, Alternative 3 (with land) is not feasible because B/C is less than 1, NPV is highly negative and payback is highly abnormal.

*3.2.4. Alternative 4 (Without Land, 600tpa)***:** In Alternative 4 (without land), the value of B/C comes out to be 1.04, NPV is $23,034 and payback period is 5.3 years. This alternative is better than Alternatives 1 and 3 since the values of B/C, NPV and PBP meet the appraisal criteria. It, of course, is less profitable as compared to Alternative 2.

3.2.5 Alternative 5: This with cost of land alternative was investigated as it involved the same boiler and the same turbine. In spite of the fact that GCUL was quite away from production of 1,000 metric tons per annum waste, this scale of processing was investigated to provide a base for evaluation at a little higher level. The calculation was repeated to determine the values of the indicators. The values obtained were evaluated as B/C = 0.12, NPV= **-**$6,270,855 and Payback Period = 63 years. These values don't qualify the project for acceptability even if the amount of solid waste is increased to 1,000tpa.

3.2.6. Alternative 6: This without cost of land alternative was investigated as above. The values were evaluated as B/C =1.73, NPV= $379,138 and Payback Period = 2.39 years. This alternative makes the project most feasible on the basis of all the criterions cited above.

3.2 .7. Alternative scenarios at half and one third of assumed heating value

If the values of parameters computed in for all alternative primary projects (Table 7) are compared with the parameters of corresponding alternative, it is observed that both B/C and NPV undergo drastic reduction (Table 8 and 9) while PBP undergoes a drastic increase moving them further away from the standards. Thus none of the alternatives is acceptable at one half or one third of the heating value of solid waste.

3.2.8. Alternative scenarios at 2011 price equal to 2.46 times 2008 price:

If the values of parameters computed in for all alternative primary projects (Table 7, assumed heating value) are compared with the parameters of corresponding alternatives at enhanced price (Table 10, assumed heating value), it is observed that both B/C and NPV undergo some increase while PBP undergoes a proportionate decrease pulling the project to somewhat nearer to the standards. Thus none of the alternatives is acceptable even at enhanced price of electricity. The B/C and NPV for without land projects exhibit a drastic increase and PBP a proportionate increase, these projects turn out to be much more profitable than the primary projects.

If the values of parameters computed for all alternative projects (Table 8, half assumed heating value) are compared with the parameters of corresponding alternatives at enhanced price (Table 11, half assumed

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heating value), it is observed that both B/C and NPV for with cost of land projects undergo some increase while PBP undergoes a drastic increase pulling them away from the standards. Thus none of these alternatives is acceptable even at enhanced price of solid waste. The B/C and NPV for without land projects exhibit a significant increase and PBP a proportionate decrease and thus these projects turn out to be more profitable.

If the values of parameters computed for all alternative projects (Table 9, one third assumed heating value) are compared with the parameters of corresponding alternatives at enhanced price (Table 12, one third assumed heating value), it is observed that both B/C and NPV for all alternative projects undergo some increase while PBP undergoes a decrease from infinite to finite values pulling them towards the standards but none of these alternatives is acceptable even at enhanced price of solid waste. The B/C and NPV for without land projects exhibit a significant increase and PBP a proportionate decrease and thus these projects turn out to be profitable.

4. Discussion

The purpose of work reported here was searching out a method for disposal of solid waste in an advanced educational institution like GCU Lahore with two aims in mind:

1. Disposal of solid waste produced in the University for keeping its environment clean
2. Exploration of a method for disposal of solid waste economically and profitably.

Before proceeding towards techno-economic assessment, it was imperative to see whether the electricity produced by incineration of the quantity of solid waste was sufficient to meet the institutional consumption of electricity per annum. The electricity consumed per annum by GCU L was 1,476,923 kWh, which is supplied by the Lahore Electric Supply Organization (LESCO). In addition it consumes 103,385 kWh from the locally installed generators. This makes an overall consumption of 1,580,308kWh.

The electricity produced from 720 metric ton solid waste (Alternative 1, Without Land) is 1, 008,000 kWh per annum. It is clear from the comparison of the figures that the supply of electricity from solid waste is about 68 % of the supply by LESCO and 64% of total consumption. Thus, the electricity demand of GCUL can be partially fulfilled by burning of solid waste currently being produced at its different sites at assumed heating value of the waste. The good point is that this production is techno-economically feasible provided GCUL can spare the requisite piece of land in the present Campus (Alternative 2: BCR= 1.24: More than 1, NPV= $1348, 865: Positive, PBP= 4 years). The deficiency can be made up by purchase of electricity from LESCO and/or production from the generators.

The electricity produced from 600 metric ton solid waste (Alternative 4, without land) is 840,000 kWh per annum at assumed value. It is clear from the comparison of the figures that the supply of electricity from solid waste is about 57 % of the supply by LESCO and 53% of total consumption. Thus, the electricity demand of GCUL can be fulfilled to some extent by burning of 600 metric tons of solid waste. Even at this level of waste, this production is techno-economically viable (B/C= 1.04: More than 1, NPV=$23,034.50**:** Positive, PBP= 5.3 years). Again, the deficiency can be met by purchase of electricity from LESCO and/or production from the generators.

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The electricity produced from 1000 metric ton solid waste (Alternative 6, without land) is 1,400, 000 kWh per annum at the assumed value. It is comprehensible from the evaluation of the figures that the supply of electricity from solid waste is about 95 % of the supply by LESCO and 89% of total consumption. Thus, the electricity demand of GCUL can be satisfied by burning of solid waste. This alternative is by far the best one, (B/C= 1.1.73: More than 1, NPV= $379,138: Positive, PBP= 2.4 years), since it covers 89% of the electricity requirement of GCUL. Unfortunately, this alternative cannot be based on the scale of processing of waste being currently produced in GCUL. Two hopeful points can be made to this end. Firstly, GCUL has been recently converted into a University and thus it is a growing institution and thus, there is every likelihood that it may touch the target of 1,000 per annum in near future. Secondly, GCUL can obtain solid waste from the nearby localities i.e. Urdu bazaar and Anarkali, for increasing its waste to 1000 metric tons

To conclude all with land alternatives present a depressing picture but without land alternatives are economically viable. The without land alternative at the scale of 1,000 metric ton scale of processing seems to be technically sound and economically viable.

Let us now talk a little about the worth of this study. It, in the first instance, will provide a base for installation of thermoelectric plants for the supply of thermoelectric power to different educational institutions in different localities. It may be pertinent to record here that some schools and colleges particularly those located in small cities or towns have a lot of extra land to invest on the basis of which even the with land alternatives may become worth opting. Even for GCUL, if it is not possible to install this facility now, it may be valuable as a future option when it will shift to its new campus for which the land has been already allotted to it by Government.

One of the major conclusions is that the major constraint on the economic viability of the projects is the cost of land that is skyrocketing in and around CGUL. That is why all the with cost of land projects turn out to be non-viable in all scenarios but without cost land projects turn out to be economically viable in all scenarios except at reduced heating values. The best point about them is that these are viable at the enhanced price. In other words if they were not viable in 2008, these are viable in the current situation. Thus these can be safely opted by the entrepreneurs now.

An objection currently being made to the exploitation of this resource by some circles is its toxicity. The answer to this objection will be whatever is in use as a fuel for producing thermoelectric power is toxic. Some fossil fuels in current use for this objective are even more toxic than solid waste. Moreover, this can be overcome in two ways:

1. Sorting of solid waste at source to eliminate toxic materials such as PVC, etc and unwanted materials such as construction waste to increase fuel value of solid waste.
2. Development of cheap indigenous toxicity trap systems in future plans. That is not difficult for capable chemists of a country like Pakistan. Here, it may be pertinent to point out here that the powerhouses currently functional for production of electricity are mostly throwing their exhausts in the atmosphere. If exhaust is there from a solid waste powerhouse also then why to object it.

Finally, the project can be extended by assessment of solid waste produced at higher levels such as village, town and city levels to study their feasibilities with an objective to clean the environment and create thermo-electric power for local use. The researchers of Lahore School of Economics have carried out significant work in this context.

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5. References

[1] F.R. McDougall and P.R. White .Integrated waste management and the tool of life cycle inventory: a route to sustainable waste management [Online -Accessed on September 18 2012] http://www.environmental-expert.com/Files/0/articles/2160/2160.pdf

[2] Department of the Environment. (1995). Making waste work : a strategy for sustainable waste management in England and Wales HMSO London (1995) 117 [Online, Accesses on September 28 2012]

[3] T. Kajikawa,Thermoelectric Power Generation Systems: Recovering Heat from 8 Combustible Solid Waste in Japan. *In Proceedings of Fifteenth* International Conference on Thermoelectrics, 26-29 March, Pasadena, USA, IEEE Publications, NJ, (1996.) 343-351

[4]T. Kajikawa**.** Status and Future Prospects on the Development of Thermoelectric Power Generation Systems Utilizing Combustion Heat from Municipal Solid Waste. *In Proceedings ICT'97.XVI-International Conference on Thermoelectrics,* 26-29 August, Dresden, any, IEEE Publications, NJ, (1997) 28-36

[5**] S.** Kagawa, K. Matsuura, M. Sakamoto and A. Tsuyoshi,. A Study of Commercial Thermoelectric Generation in a Processing Plant of Combustible Solid Waste**.** Proceedings ICT apos; 97. XVI International Conference Volume, Issue, 26-29 Aug (1997) 555–558 [Online, Accessed on September 28 2012]

http://ieeexplore.ieee.org/Xplore/login.jsp?url=/iel4/5432/14677/00667590.pdf?arnumber=667590

[6] Tsuyoshi, A and Matsuura, K. A trial manufacture of a thermoelectric generator powered by high-temperature heat transfer medium oil, Electrical Engineering in Japan, 141(1) (2002)36-44 http://onlinelibrary.wiley.com/doi/10.1002/eej.10042/abstract

[7] J. Carbo. Colombia: Electric Power Generating Equipment Bogotá: U.S. Commercial Service and U.S. Department of State, June15, 2006 [Online- Accessed September 18, 2012], http://www.stat-usa.gov/mrd.nsf/ vwNoteIDLookup/NT00FE8C3A/$File/X_990233.PDF?OpenElemen

[8] A. Zabaniotou & N. Giannoulid .Incineration of Municipal Solid Waste with Electricity Production and Environmental Safety: The Case of a Small Capacityt in Greece, Energy Sources 24 (2) (2002) [Online, Accessed Sept18 2012]

[http://www.eolss.net/Sample-Chapters/C09/E4-13-04-02.pdf

[9] P.S. Doherty, S. Al-Huthaili, S.B. Riffat, N. Abodahab, Ground source heat pump--description and preliminary results of the Eco House system Applied Thermal Engineering, 24(17-18), December 2004, Pages 2627-2641
.
[10] Dubois, M., Gonzalez, A.M.M., and Knadel, M.. Municipal Solid Waste Treatment in the EU, Publisher: Centre for Environmental Studies University Of Aarhus Finlandsgade Denmark (2004).

ISSN 2348 – 7968

[11] Hogg, Leicestershire Municipal Waste Management Strategy Environmental Report LMWMS

[12] David Suzuki Foundation; Seirra Legal. Incineration of Municipal Solid Waste; A reasonable energy option? Fact Sheet 3 Online Accessed on September 28,2012]
http://www.glu.org/en/system/files/FS3energy.pdf. Accessed 20 September 2012

[13] J. Swithenbank, V. Nasserzadeb and R. Goh. Solid waste for power generation [Online Accessed on September 28, 20123]
http://www.eolss.net/Sample-Chapters/C09/E4-13-04-02.pdf

[14] H. Xiulian J. Kejun and C. Cheng. Municipal Solid Waste Incineration for Electricity Generation— A CDM Case Study
http://en.cnki.com.cn/Article_en/CJFDTOTAL-ZGLN200207007.htm

[15] Khan, MR and Kamal, M. Production of Thermo-electric Power from the Solid Wastes of LUMS. Presented in International Conference on Environment held in Malaysia (2007). Proceedings in press.

[16] Khan MR and Pervez, F. Production of Thermoelectric Power from the Solid Wastes of Kinnaird College. Environ Monitor, IX(9&10) (2009) 14-28

[17] Khan, MR and Sheikh, S (Expected). Production of Thermoelectric Power from Solid Waste: A Case of Lahore School of Economics. Accepted for publication in International Energy Journal (2010) 51-64

[18] Asian Development Bank.2001.Guidelines for the Financial Governance and Management of Investment Projects Financed by Asian Development Bank, 1989 Guidelines were reviewed and re-released in November (2001), Publisher ADB. http://www.adb.org/Documents/Guidelines/ Fin_Analysis?p=ecopubs
[19] Asian Development Bank. Guidelines for the Economic sis of Projects(2003), Publisher ADB.

http://www.adb.org/Documents/Guidelines/Eco_Analysis

APPENDIX 1

COMPUTATIONS

Computation of Total Solid Waste Produced by GCUL

Total Estimate per Day = Calculated from Table1 = 600,000 kg

Total area of GCUL= 202,350 m^2

Solid waste produced per square meter/ annum = 2.96 kg / m^2

Total Estimate per Day = Calculated Lifted from Final Lifting Point = 720,000 kg

Total area of GCUL= 202,350 m^2

Solid waste produced per square meter/ annum = 3.55 kg / m^2

Total number of Students and Employees in LSE (Full Day) = 4,500
Solid waste per Head = 600,000/4500 = 133.33 kg/Ann and 720,000/4500 = 160 kg/Ann.

Computation of Total Consumption of Electricity by GCUL

Payments of electricity bills paid per annum**=** $160,00**0**

Cost of the raw material used (Diesel)/Annum**:** $11,200

Total cost: $(160,00**0**+11,200) **=** $171,200

Average price of electricity per kWh in 2007 =Rs 6.5

Electricity consumed per annum = 10,272,000/6.5= 1,580,308 kWh

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Project Specifications

Project Life; 10 Years

Base Year: 2007

Financial Year: July 1 to June 30

Discount Rate: 10%

Computation of Initial Fixed Investment

Land: The current price of land on Katchery Road area where GCU is situated was asked from the estate agents in the market. It had the components given below.

Total Area: 4047 m^2

Constructed Area: 2529 m^2

Open Space: 1518 m^2

Cost of Land/ m^2: $1,647.31

Cost of Land: $ 6,666,666.67

The total cost of land was determined by adding the costs of all above cost elements.

Building

The area of the building was calculated on the basis of the dimensions of the machinery to be installed which was collected from the Pattoki Sugar Mill and the machinery manufacturers. The cost of construction per unit such as square foot or square meter was asked from the contractors involved in the construction business. It was approximately $59.31 per square meter for shed construction in Lahore Market.

Total Cost of Construction = 2,529 ×59.31= $150,000

Plant Machinery and Equipment: The cost of machinery and equipment was worked out from the prices supplied by the machinery manufacturers and producers of thermo- electric power from solid fibrous wastes. The contributors were as recorded in Table 2.

Pre-Production Expenditure: It will take one full year to install the plant. Thus, the expenditure involved includes salaries of the staff and consultants, etc.

Consultant Fee: $3,333.33/Ann.

Project Director: $5,000/Ann.

Power House In charge:$4,000/Ann.

Boiler Foreman: $3,000/Ann.

Total Pre-Production Expenditure= $15,333.33

Total Initial Fixed Investment (With Land)

$(6,666,666.67 + 150,000 + 98,833.33 + 15,333.33) = $6,930,833

Total Initial Fixed Investment (Without Land)

$(150,000 + 98,833.33 +15,333.33) = $264,167

Assumptions of Expenditure in Future Years and Computation of Operating Cost

Apart from the initial investment, no other capital expenditure is assumed over the project life under consideration. The operating cost in the base year (2007 - 2008) is nil. However, it can change with

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changes in labor costs, operating capacity, etc. The possibility of capacity change was ruled out with reference to the practice at Pattoki Sugar Mill Thermoelectric Plant. It is working at 80% of its plant capacity and its engineers do not intend to increase it in near future. Currently, the optimal plant capacity is said to be 80% which allows for desirable levels of efficiency needed to produce electric power. It is predicted that the salaries of labor are subject to an increase of 15% after every three years.

Raw Material Cost: This will include the cost of the solid waste from GCUL and will be zero because we have to dispose it off.

Cost of Electricity: Minor cost of electricity will be involved in the initial running of the pumps. The required electricity will be self supplied within the set up when the plant will become functional. Thus, it was neglected

Labor Cost: The nature and number of employees engaged to run the plant along with their salaries is computed in Table 3 (App. 2).

Maintenance Cost: The maintenance cost was calculated at the rate of 10% of the purchase price of machinery and equipment. Thus,

Maintenance Cost = $9,883.33

Depreciation: Both plant machinery and equipment was depreciated on straight line basis at the rate of 10% of the purchase price.

Depreciation Cost = $9,883.33

Total Operating Cost in Year 2008-09 = $ (21,800 + 9,883.33+9,883.33) = $41,566.66

The operating cost was calculated as in Table 4 (App. 2), while that was discounted to the Base Year as in Table 5 (App. 2). It turned out to be Rs. 16,545,952**.**

Computation of Benefits

The benefits were calculated, in the first instance, at the scale of processing 720-metric tons per annum. The computation was then extended to 600 metric tons and 1,000 metric tons; former being the alternative nearest to 720 and latter being the upper limit to which the same boiler for minimum waste processing could be used. Thus alternative technologies may be made available for practical implementations in case of deviation from the estimates reported here.

The benefits were calculated on the basis of the following assumptions:

1. The calorific value of rubbish (Polyethylene bags, papers, card boards and plastic bottles, etc) was assumed in between the values of bagasse (17,937 kJ) and furnace oil (42,202 kJ). Thus, the calorific value of rubbish taken as 30, 069 kJ.
2. Process requisites were as given below

   Wt: of rubbish= 720 metric tons/Ann.

   Calorific value= 30, 069 kJ

   Live steam temp.=600ºC- 650ºC

   Live steam pressure =70 – 80 kg/cm²

   Fuel steam ratio = 1: 7
3. Steam produced from available fuel5, 040 metric tons /Ann.

4. Turbine for electricity generation =Multistage-condensing Type with LT generator(400 Volt)
5. Steam consumption per kWh by turbine=5 kg/kWh
6. Electricity produced = 1,008,000 kWh/Ann.
7. calculation based on hourly basis

   Steam produced = 0.5832 metric ton/hr

   Electricity produced=116.7 kWh

Electricity Produced per Year = 1,008,000 kWh

Price of electricity/ kWh = $0.1083333
Return per Ann. = $1,008,000 ×0.1083333=$109,200

Benefits Discounted to the Base Year

The revenue returns from thermo-electric plant are in the form of constant periodic cash flows of $ 109,200. The total receipts after discounting at 10% can be calculated by applying Annuity Table. Thus, Present Value of Rs 1 received constantly per annum for 10 years at 10 % discount rate = Rs 6.14457 (From Annuity Tables)

Present Value of 6,552,000 received constantly per annum for 10 years at 10 % discount rate = $109,200 * 6.14457 = $670,987

Present Value of the Benefits = $ 670,987

Scrap Value of the Machinery and Equipment

The residual value of the machinery and equipment at the end of the project life is estimated at 10 % of the purchase price

Therefore, the worth of the asset at which it can be sold or disposed off will be:

Scrap value = $ 9883.33

Total Expenditure and Total Returns Discounted to Base Year
Present Value of Cash Outlays = Initial Fixed Investment +Operating Cost

Initial Fixed Investment = $6,930,833.33

Operating Cost-Year 1999-2000 = Nil

Present Value of Operating Cost = $275,759.56

Present Value of Cash Outlays (Cost)

$(275,759.56 +6,930,833.33) = $7,206,593

Returns = Savings + Scrap Value

Present Value of Returns = $670,987

Present Value of Scrap = $9,883.33*0.385543 = $3, 810. 45

Present Value of Cash Flows (Benefits) =US$$ (670,987+3, 810. 45) = $674,798

Return per Annum = Rs 1,008,000×0.1083333= US$109,200

Total Revenue Return per Annum = $109,200

Net Annual Return = Annual Revenue – Operating Cost Year 1 = $(109,200- 41,567) = $67,633

Alternative 1: (With Land)

Present Value of Benefits 674,798

Present Value Cost 7,206,593

Benefit / Cost (B/C) Ratio =

$$B/C = \frac{674,798}{7,206,593} = 0.09$$

Net Present Value = $ (674,798 -7,206593) = - $6,531,795

Payback Period

The data requisite for costing by payback period method can be computed from the data given above.

$$\text{Payback Period} = \frac{\text{Total Investment}}{\text{Net Annual Return}} = \frac{6,930,833}{67,633} = 102.5 \text{ years}$$

Alternative 2: (Without Land)

Present Value of Cash Outlays = Initial Fixed Investment +Operating Cost

Initial Fixed Investment = $254,167

Operating Cost-Year 1999-2000 = Nil

Present Value of Operating Cost = $275,766

Present Value of Cash Outlays (Cost) = $ (275,766+264,167) = $539,933

Present Value of Benefits

$$\text{Benefit / Cost (B/C) Ratio} = \frac{674,798}{539,933} = 1.24$$

Net Present Value = $(674,798 -539,933) = $134,865

Payback Period

The data requisite for costing by payback period method can be computed from the data given above.

$$\text{Payback Period} = \frac{272,500}{67633} = 4 \text{ Years}$$

APPENDIX 2

TABLES AND FIGURES

Table 2: Total Cost of Machinery and Equipment

Labor	Number	Salary per Month
Boiler/Turbine attendant	3	116,66
Boiler/Turbine Helper	3	83.33
Turbine Foreman	1	259
Water Treatment Plant Labor	2	100
Electrician	3	116.66
Transport of Waste to Storage	5	83.33
Total	**98833.33**	

Table 3: Total cost of Labor

Labor	No.	Salary per Month	Salary per Month
Boiler/Turbine attendant	3	7000	21000
Boiler/Turbine Helper	3	5000	15000
Turbine Foreman	1	15000	15000
Water Treatment Plant Labor	2	6000	12,000
Electrician	3	7000	21,000
Transport of Waste to Storage	5	5000	25,000
Total			**109,000/ Month**

Table 4: Operating cost per annum

Calculations (US$) Operating Cost = Cost of Labor+ Cost of (Utilities & Chemicals + Maintenance & Depreciation)		
Year	**Cost of components**	**Op. Cost**
2007-2008	**0**	**0**
2008-2009	**21,800+19,766.66**	**41,566.66**
2009-2010	**21,800+19,766.66**	**41,566.66**
2010-2011	**21,800+19,766.66**	**41,566.66**
2011-2012	**25,070 + 19,766.66**	**44,836.66**
2012-2013	**25,070 + 19,766.66**	**44,836.66**
2013-2014	**25,070 + 19,766.66**	**44,836.66**
2014-2015	**28,830.50+ 19,766.66**	**48,597.16**
2015-2016	**28,830.50+ 19,766.66**	**48,597.16**
2016-2017	**28,830.50+ 19,766.66**	**48,597.16**
2017-2018	**33,155 + 19,766.66**	**52,921.75**

Table 5: Total Operating Costs Discounted

Years	Calculations (US$)	Operating Cost (US$)
2007-2008	**0**	**0**
2008-2009	**2,494,000*0.909091**	**2,267,273**
2009-2010	**2,494,000*0.826446**	**2,061,156**
2010-2011	**2,494,000*0.751315**	**1,873,779**
2011-2012	**2,690,200*0.683013**	**1,837,304**
2012-2013	**2,690,200*0.620921**	**1,670,277**
2013-2014	**2,690,200*0.564474**	**1,518,435**
2014-2015	**2,915,830*0.513158**	**1,496,281**
2015-2016	**2,915,830*0.466507**	**1,360,255**
2016-2017	**2,915,830*0.424098**	**1,236,597**
2017-2018	**3,175,305*0.385543**	**1,224,217**
Present Value of Total Operating Cost		**16,545,952**

Table 6: Bases and Requisites of Different Alternative Projects

Alternatives	1	2	3	4	5	6
Solid Waste-Tons/Annum	720	720	600	600	1,000	1,000
Cost of Land	Included	Excluded	Included	Excluded	Included	Excluded
Live Steam Temperature	600C° to 650C°		600C° to 650C°		600C° to 650C°	
Live Steam Pressure	70–80 kg/cm²		70–80 kg/cm²		70–80 kg/cm²	
Fuel Steam Ratio	1:07		1:07		1:07	
Steam Produced	4200 Ton/Annum		4,200 Ton/Annum		7,000 Ton/Annum	
Multistage Turbine	Light Duty		Light Duty		Heavy Duty	
Steam Consumption/ KW	5 kg/kWh		5 kg/kWh		5 kg/kWh	
Electricity Produced	1,008,000 kWh/Ann.		840,000 kWh/Annum		1,400,000 kWh/Annum	
Steam Produced /Hr	0.5832 Ton/Hr		0.486 Ton		0.81Ton/Hr	
Electricity Produced/Hr	116.7 kWh		97.22 kWh		162kWh	

Table 7: Computation of results of evaluation of alternatives at assumed heating value (US$)

Alternative	PV of Benefits	PV of Costs	BCR	NPV	PBP-Years
1	674,798	7,206,593	.0.09	6,531,792	102.5
2	674,798	539,933	1.24	134,865	4
3	562,967	7,206,593	0.07	-6,643,626	140
4	562,967	539,933	1.04	23,034	5.3
5	935,738	7,206,593	0.12	-6,270,855	63
6	935,738	539,933	1.73	379,138	2.4

Note: Due to involvement of the same level machinery, equipment and labor the expected PV of costs may be the same.

Table 8: Computation of results of evaluation of alternatives at half of assumed heating value (US$)

Alternative	PV of Benefits	PV of Costs	BCR	NPV	PBP-Years
1	337,399	7,206,593	.0.05	6,869,194	532
2	337,399	539,933	0.62	-202,534	20
3	281,484	7,206,593	0.04	6,925,109	1,762
4	281,484	539,933	0.52	-25,748	69
5	467,869	7,206,593	0.06	6,738,724	390
6	467,869	539,933	0.86	-72,064	15

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Table 9: Computation of results of evaluation of alternatives at one third of assumed heating value (US$)

Alternative	PV of Benefits	PV of Costs	BCR	NPV	PBP-Years
1	224,933	7,206,593	.0.03	–6,981,660	Infinite
2	224,933	539,933	0.41	-126,532	Infinite
3	187,656	7,206,593	0.02	-6,643,632	Infinite
4	187,656	539,933	0.34	-352,277	Infinite
5	311,913	7,206,593	0.04	-6,894, 680	Infinite
6	311,913	539,933	0.57	-228,020	Infinite

Table 10: Computation of results of evaluation of alternatives at current prices (US$) -Assumed heating value

Alternative	PV of Benefits	PV of Costs	BCR	NPV	PBP-Years
1	1,660,003	7,206,593	.0.23	–5,546,590	30.5
2	1,660.00	539,933	3.07	1,120,070	1.2
3	1,384,899	7,206,593	0.19	-5,821,694	38
4	1,384,899	539,933	2.56	844,966	1.49
5	2,301,915	7,206,593	0.31	-4,904,678	21
6	2,301,915	539,933	4.26	1,761,982	0.82

Table 11: Computation of results of evaluation of alternatives at current prices (US$) – Half assumed heating value

Alternative	PV of Benefits	PV of Costs	BCR	NPV	PBP-Years
1	830,001	7,206,593	.0.11	–6,376,592	74.6
2	830,001	539,933	1.53	290,068	2.93
3	692,450	7,206,593	0.09	-6,514,143	98.6
4	692,450	539,933	1.28	152,517	3.9
5	1,150,958	7,206,593	0.07	-6,055,635	47.9
6	1,150,958	539,933	2.13	611,025	1.9

Table 12: Computation of results of evaluation of alternatives at current prices (US$) – One third assumed value

Alternative	PV of Benefits	PV of Costs	B/C	NPV	PBP-Years
1	553,334	7,206,593	.0.07	–6,653,259	144.3
2	553,334	539,933	1.02	13,401	5.7
3	461,633	7,206,593	0.06	-6,744,960	209.3
4	461,633	539,933	0.85	78,300	8.2
5	767,305	7,206,593	0.1	-4,904,678	83.6
6	767,305	539,933	4.26	227,372	3.3