COMPARATIVE TECHNO-ECONOMIC STUDY OF INCINERATORS AND THERMAL POWER PLANTS FOR DISPOSAL OF HOSPITAL WASTE

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Abstract - The article is a feasibility study to produce thermoelectric power by incineration of hospital infectious waste and search for the viability of substitution of currently functional incinerators with electric power plants. The secondary data was collected from the published and Internet. Primary data were collected from Children Hospital and Pattoki Sugar Mills. The data after collection were computed and then applied to design different projects appraised to determine the Benefit to Cost Ratio (BCR), Net Present Value (NPV) and Payback Period (PBP). The results showed that Children Hospital, Lahore currently produces approximately about 211.7 tons of infectious waste per annum that undergoes incineration. The electricity that can be produced with this amount of waste is 296,400 kWh / annum. The appraisal of the project excluding even land price showed BCR of 0.5 which is less than 1, NPV is -Rs28, 141,619 (below zero)and the payback period 4.3 years making the project non-feasible. However, after taking into account the incineration of infectious waste of three other local hospitals with Children Hospital making 730 ton/annum the project becomes feasible as BCR is equal to 2, NPV is equal to Rs. 74,403,879 and PBP is 1.2 years, if price of land is excluded.

Keywords - Comparative, Incinerator, Techno-Economic, "Thermal Power Plants"

I. INTRODUCTION

The disposal of different types of solid waste by incineration has been in practice of humanity since long. Two major objections to this practice recorded in the history of this mode of disposal have been that the incineration proceeds with liberation of a large amount of energy in the form of heat that dissipates in the air atmosphere and is wasted and the incineration process is accompanied by the liberation of a number of gaseous pollutants such as carbon dioxide, as chlorine, oxides of nitrogen, etc. To these can be added the global concept of "Sustainable Development" that preaches careful use of natural resources to keep them preserved for the use of future generations and that the waste produced as a result of resource use should be recycled or disposed with the extraction of economic benefits [1].

The disposal of Municipal Solid Waste (MSW) by incineration came into practice on the ground that burning reduces the volume of the waste tremendously and resulting ash can be disposed conveniently without being conscious that this method is a wasteful exercise because the heat produced is not harnessed and the liberated gases and smoke cause intense environmental problem. This led to the thought that this problem should be linked with economic problems such as power shortage and utilization of heat on way to wastage for central heating, etc. and also led to the idea of techno-economic disposal of solid waste by incineration with the production of electricity. Two best examples of implementation of this idea are the installation of power plants based on incineration of MSW in some states of USA and those based on incineration of sugar cane bagasse in Pakistan. It is expected that energy crises in future will become more intense because electricity shortage will reach its worst as the predicted demand in 2030 will be 177% of the demand in reference year 2011 [2]. This is the reason why experts all over the globe [3]-[7] and in Pakistan [8]-[17] are keenly engaged to find alternative sources of energy. Most research studies in different countries and some in Pakistan [8]–[12] were focused on management of disposal, chemical composition of the hospital waste, etc., or on their environmental impact. The studies on the disposal of solid waste by incineration along with the production of electricity were triggered in the Department of Environmental Science and Policy Lahore School of Economics. The effort translated into a number of standard publications starting from the first article published in International Energy Journal [13]. The center of gravity was turned to the solid hospital waste and few studies were conducted; three on waste handling to assess the effect of waste on handling labor[14]-[16] and one on production of thermoelectric power from the infectious waste of hospitals of Lahore [17]. The current study is the second in the series on production of thermoelectric power from the infectious waste of hospitals of Lahore.

This study focuses on the method of current disposal of hospital waste using incinerators and identification of environmental and economic problems associated with this practice and comparison with alternative techniques such as incineration of solid wastes by installation of thermal power plants to extract economic benefits such as production of electricity and utilization of heat produced for different purposes. The objectives of research were as follows:

1. Updating of quantification and classification of hospital waste of Lahore.

2. Carrying out the benefit –cost analysis of the incinerators used for disposal of hospital waste.
3. Carrying out the benefit–cost analysis of the disposal of hospital waste by installation of boilers and production of electricity.
4. Recommendation to decide on replacement of incinerators by boilers or power plants.
5. Exploration of ways and means to utilize heat produced in both techniques.

II. METHODOLOGY OF RESEARCH

The secondary data regarding hospital waste disposal were collected from published resources and Internet. The primary data were collected from two different sources. The data regarding hospital waste generation and disposal were collected by making different visits and conducting interviews at Children Hospital. A study conducted in by Khan and Ali in 2008 [17] shows that the Children Hospital has been incinerating infectious waste of 15 government hospitals of Lahore. It stopped the practice of hosting other hospitals and is currently incinerating only its own infectious waste i.e. 580 kg/day. After giving the waste incineration contract to a private company (Environmental Consultancies and Options), it has started incineration of waste of three other hospitals; that makes 2,000 kg per day including Children Hospital waste. The data regarding the cost of thermoelectric power plant was gathered by visiting Pattoki Sugar Mill. Some local and international machinery manufacturing establishments such as DESCON Engineering, Industrial Boilers Gujranwala and Punjab Department of Industries were contacted to know exact prices of machinery such as boilers and equipment used for the utilization of the heat of incinerator and emission control: hot water boiler, economizer, and air heater, etc.

The Calorific Values

The calorific values were calculated in terms of British Thermal Units. In order to calculate, the waste was first divided into different %age components, each component' s heat was multiplied by corresponding BTU value[17]and proportionate values were added to give overall calorific value. The heat value for sharps was assumed as zero. After adding all the BTU values of each percentage, the total calorific value came out as 16438.4 BTU / 17,260 kJ per Kg.

Computation of Data: The data after collection was sorted and computed.

Designing of the Projects

The projects were then cost designed and appraised as described under Cost Analysis. Cost Analysis of both incinerator and boiler based plants was carried out based on project specifications Appendix (1 &2). The costing was done for two set ups as under:

Setup1: Incinerators currently installed for hospital waste disposal without harnessing of heat energy.

Set up 2: Boiler for installation in hospital in place of currently working incinerator for disposal of waste with recovery of heat and its transformation into electricity.

Cost Analysis of Set up 1:

The project analysis is based on the project specifications narrated in Appendix 1. The cost summary describing different cost components responsible for adding value to both expenditure and return streams is given below.

Initial Fixed Investment (IFI):

It included the cost of land, building, machinery and equipment and pre-production expenditure (Appendix 1). IFI with land was Rs 835,669,000and without land was Rs. 35,669,000.

Operating Cost (OC)

The operating cost has been computed in Appendix 1.Expenditure in the Base Year IFI =Rs 835,669,000(With Land)Operating Cost = Nil Total Expenditure = Rs 835,669,000 (With land)

Expenditure in Future Years

Assumptions and computation are given in App. 1.
OC Discounted to the Base Year = Rs. 81,269,637.4

Benefits: No benefits are associated with burning of hospital waste through the use of incinerator.

Cost Analysis for Set up 2

The project analysis is based on the project specifications narrated in Appendix 2.and the summary of different components adding value to both expenditure and return streams are as below.

Initial Fixed Investment

It included the cost of land, building, machinery and equipment and pre-production expenditure as computed in Appendix 1. Total Initial Fixed Investment with land was Rs. 834,022,000 and without land was Rs 34,022,000.

Operating Cost:

The operating cost has been computed in Appendix 2.

Expenditure in the Base Year

IFI =Rs 829,522,000 (With land)Operating Cost = NilTotal Expenditure = Rs 29,522,000 (With land)

Expenditure in Future Years

Assumptions and computation are in Appendix 2.
OC. Discounted to the Base Year =Rs. 40,740,093.8

Benefits: The benefits are computed in Appendix 2.

B/C Ratios, NPV and PBP: The values are computed in Appendix 2. The reference project later designated as Alternative 1 turned out as highly non-feasible. The major reason for high non-feasibility was skyrocketing cost of land. This formed the basis of alternative projects with and without cost of land.

Alternative Projects: Eight alternative projects were framed on different bases: 1} Integrated waste of 4 hospitals boiler price by Gujranwala Boilers, with price ofland,2)Integrated waste of 4 hospitals, boiler, price by Gujranwala Boilers, without price of la) Integrated waste, price by DESCON Engineering, with price of land,4}Integrated waste, price by DESCON,, without price of land,5) Infectious + general waste of Children Hospital, boiler price by Gujranwala Boiler, price of land included, 6) Infectious + general waste of Children Hospital, boiler price by Gujranwala Boilers, price of land excluded,7}Infectious + general waste of Children Hospital, boiler price by DESCON, price of land included and 8} Infectious + general waste of Children Hospital, boiler price by DESCON, price of land excluded, The alternatives were apprasied as was evaluated Alternative1.Their B/Cs, NPVs and PBPs are reported in form of Table 7(App. 2) along with the decision on acceptability/feasibility.

III. RESULT

The results have been divided into two sections. The first section encompasses information regarding hospital waste, while the other part demonstrates the results of cost analysis. The results reported in the first section constitute descriptive research whereas those in other the quantitative research (cost analysis).

3.1 The Results of Descriptive Research

As told by the medical staff of Children Hospital there are two types of waste produced in in the hospital: General waste or non-infectious and the infectious waste collected in separate bags.. The non-infectious waste bags are carried away by the local municipal authorities for disposal while the infectious waste including, tissues, organs, body parts, outdated drugs and chemicals, blood and body fluids, human flesh, etc., and disposable needles, syringes, saws, blades, broken glasses etc., called sharps mostly metals, plastics such as syringes, used drips, etc. and textiles like cotton, swabs, etc., is incinerated. After incineration of infectious waste, the ash left which is 1/3 of waste is dumped in a dumpsite. The total amount of infectious waste produced per day in Children Hospital is 580 kg. The percentage of metals, plastics and textiles in the infectious hospital waste is 12, 35.2 and 52.8 respectively. The Children Hospital is equipped the Incinerator Model ATI HP 200 France installed in 2014 at a cost of Rs. 25.583 million. It has three chambers; in the first chamber burning of waste takes place at 850^{o}C and in second secondary chamber all the emitted gases are cleaned at 1100^{o}C with the help of scrubbers. The combustion of organic compounds becomes a source of emission of different gases: CO_2, nitrogen oxides, and other noxious substances.

3.2 Results of Cost Analysis

B/C Ratio is a significant standard indicator to test whether a project is profitable or not. If the ratio is more than 1, the project is considered as profitable and acceptable. If it is less than one, the project is considered as non- profitable and non-acceptable. The project is acceptable if NPV is positive and not acceptable if it is negative. The length of the PBP is also an important indicator of the recovery of the investment. A long PBP is considered a disadvantage. In case of Set up 1, zero benefits have been associated with the use of incinerator with total expenditure of Rs. 868,116,600in the base year subject to increase every year with the increase in wages of labor at 10% per annum per assumption. The details of appraisal of different alternatives of thermal power plant of Set-up2 are computed in Tables 1 to 6 (App, 1 and 2) and their indices B/C. NPV and PBP are compared in Table 7 (App. 3).with conclusions drawn about their feasibility are given in Table 7.

IV. DISCUSSION

To achieve the objectives of research following set ups were conceived to investigate:

1) Techno-economic evaluation of incinerators currently installed for hospital waste disposal without harnessing of heat energy.
2) Techno-economic evaluation of boiler for installation in hospital in place of currently working incinerator for disposal of waste with recovery of heat and production of electricity.

Keeping in view these set ups, different techno economic alternatives were identified, cost designed and appraised. The inquiry shows that set up 1 involved an Initial Fixed Investment of Rs 835,669,750with land and Rs 35,669,750 without land cost and without any monetary benefits but it accomplished the disposal of infectious hospital waste. The cost analysis shows that the use of incinerator involves heavy IFI and also significant OC with wastage of heat produced from waste incineration and it also becomes a source of air pollution. In case of Set up 2, the results show that many of the thermo-electric power plant alternatives such as 1, 3, 5, 7 and 8 turned out to be non-feasible and non-acceptable. Of course, Alternative 2, 4 and 6

make the projects feasible and acceptable if fixed at Children Hospital incineration site. For these alternatives the Benefit to Cost ratio is greater than 1, the Net Present value is positive and Payback Period is very short (Table 7) which qualify the projects as acceptable. The factors that are responsible for feasibility of these projects are the quantity of waste and non-involvement of land cost. The amount of electricity that may be produced in alternatives 2 and 4 is 1,022,000 kWh annually from 730 ton/annum waste with benefits Rs. 23,506,000. Khan and Ali (2008) conducted similar work where 1,400,000 kWh per annum electricity was reported from 793 ton/annum hospital waste by installing thermoelectric power plant. The amount of electricity produced in this study is almost same that was reported by these authors. In the current study, the revenue return/annum was Rs. 23,506,000 while in their study the revenue return was Rs. 4,482,324. The reason behind increase in revenue is the increase in price of electricity that was Rs.7 in 2008 and is Rs.23 in 2018 (More than threefold). The cost of machinery and equipment has not increased that much as has increased the revenue. The reason behind the feasibility of alternative 6 is the amount of waste i.e. 394 ton/annum, non-involvement of cost of land and low price of boiler. This 394 ton/annum waste includes both general and infectious waste of Children Hospital. Alternatives such as 1,3,5,7 and 8 turned out to be non-feasible and non-acceptable. The factors which are responsible for non-feasibility of projects are the low quantity of waste and sky-rocketing price of land at main Ferozepur Road. For these alternatives, the Benefit to Cost ratio is less than 1, the Net Present value is negative and Payback Period is very high which pull the projects poles apart from acceptability. There are many negative impacts associated with use of incinerator such as involvement of high IFI and OC, emission of CO and CO_2 which, are well-known greenhouse gases that contribute to global warming and dissipation of heat energy in the environment. However, the heat energy that is dissipated in the atmosphere can be utilized by installation of equipment like economizer, air heater or hot water boiler for central heating or central air conditioning of Children Hospital. The cost of this installation is Rs. 3,000,000. The attachment of this equipment with incinerator including ten year operating cost, made the incinerator cost Rs. 122,897,063. A large number of secondary pollutants such as dioxin produced during incineration that pollute air inside and around the site of incineration pose more harm to human health than primary pollutants. It was viewed that environment protection equipment's such as electrostatic precipitator, scrubbers and bag filters if installed on incinerators, emissions can be blocked at a number of points. The cost of these installations is Rs. 2,200,000 and their addition will increase the cost of incinerator to Rs. 125,097,063. Therefore, by using incinerator with all these components the use of thermo-electric power plant involves the IFI of Rs.29, 522,000 (Without land cost). Thus, it is economically advantageous to install thermo-electric power plant in place of currently working incinerator as it costs less with large number of benefits such as production of electricity. The proposal may be extended to the concerned medical authorities and government for instructing all the hospitals to install hospital waste based power plants instead of incinerators in future. If the Children Hospital management is not in favor of installing thermoelectric power plant for production of electricity for hospital then the second option is that they can attach with currently working incinerator the required equipment in order to reduce emissions along with heat recovery and its utilization in hospital.

V. CONCLUSION

The research work presented here is a study, techno-economic disposal of infectious waste generated by different hospitals of Lahore with the extraction of some economic benefits such as production of electricity that is otherwise wasted during incineration and utilization of heat for other purposes. The appraisal of different projects with the involvement and non-involvement of cost of land shows that some are feasible and thus acceptable because the quantity of waste is significantly high i.e.; 730 ton/annum. The reason behind the acceptability of projects is the requisite amount of waste and non-involvement of cost of land. The cause behind the non-feasibility of remaining projects is the low amount of waste and involvement of very high cost of land. The results and discussion concludes that the objectives of the reported work have been well achieved.

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APPENDIX 1

Cost Analysis for Setup 1 (Incinerator)
Project Specifications Project life: 10 years Financial year: July 1 to June 30Base year: 2017Discount rate: 10%Exchange rate 1US $=Rs 150Computation of Infectious Waste Total estimate per day= 2,000 kgTotal infectious waste produced annually= 2,000 x 365 =730,000kg/year=730 ton

Computation of Initial Fixed Investment
Land: The actual rate of land was inquired from the estate agents in the nearby area of Gulberg. Land requirement and cost is mentioned below.
Total area = 8 kanal (36,000 sq. ft) Constructed area=5 kanal (22,500sq. ft) Open area = 3 kanal (13,500sq. ft)Cost of land per sq. ft= Rs 22,222.23 Cost of total land (36000sq. ft) = Rs 800, 000,000

Building: Cost of construction at Rs 448.3 /sq. ft at installation time =Rs.22500*448.3= Rs, 10,086,750
Cost of machinery and equipment = Rs25, 583,000
IFI (With Land) =Cost of Land+ Cost of Building+ Cost of Machinery and Equipment= Rs 835,669,000IFI (Without Land) =Cost of Building+ Cost of Machinery and Equipment=Rs 35,669,750

Computation of Operating Cost (OC)

Raw material cost: The raw material being the solid waste to dispose of, its cost was zero. Total Electricity Consumption and Cost
Total consumption per day/ year = 100 kW/36,500 kWh
Cost of electricity/Annum at Rs 23/kwh= Rs 25,185,000

Cost of water: The cost of water was negligibly small.

Labor cost: The nature and number of employees engaged to run the plant along with their salaries is computed in Table 1.

Labor	No	Salary per employee	Salary per month
Operators	2	Rs 40,000	80,000
Workers	7	Rs 35,000	245,000
	1	Rs40,000	40,000
Guard	1	Rs25,000	25,000
Senior In charge	1	Rs 100,000	100,000
Helper	1	Rs25,000	25,000

Table 1: Breakdown of the Labor and Labor cost

Total= Rs 515,000/month/ = Rs 6,180,000/year Maintenance cost at 10% of the purchase price of machinery (incinerator) = Rs 2,558,300Depreciation cost at 10% of the purchase price of machinery = Rs 2,558,300 Total Operating cost = Cost of Electricity + Labor Cost + Maintenance Cost + Depreciation Cost

Total Operating cost = 25,185,000 + 6,180,000 + 2,558,300 + 2,558,300 = Rs 36,481,600

Years	Calculations	Operating Cost (Rs)
2017-18	6,180,000+ 5,116,600	11,296,600
2018-19	6,798,000 + 5,116,600	11,914,600
2019-20	7,477,800 + 5,116,600	12,594,400
2020-21	8,225,580 + 5,116,600	13,342,180
2021-22	9,048,138 + 5,116,600	14,164,738
2022-23	9,952,951.8 +5,116,600	15,069,551

2023-24	10,948,247 + 5,116,600	16,064,847
2024-25	12,043,071.7+ 5116,600	17,159,671
2025-26	13,247,378. + 5,116,600	18,363,978
2026-27	14,572,116. + 5,116,600	19,688,716

Table 2: Total operating cost (OC) over years.

Expenditures in the Base Year
IFI =Rs 35,669,750

Expenditure in future years
The operating cost was supposed to change with the increase in labor cost at 10%, etc. over years. The operating cost was calculated as shown in Table 2.

Benefits
No benefits are associated with burning of hospital waste using incinerator.

Years	Calculations	Operating Cost (Rs.)
2017-18	11,296,600*0.909091	10,269,637.4
2018-19	11,914,600*0.826446	9,846,773.5
2019-20	12,594,400*0.751315	9,462,361.6
2020-21	13,342,180*0.683013	9,112,882.3
2021-22	14,164,738*0.620921	8,795,183.2
2022-23	15,069,551*0.564474	8,506,369.7
2023-24	16,064,847*0.513158	8,243,804.7
2024-25	17,159,671*0.466507	8,005,106.6
2025-26	18,363,978*0.424098	7,788,126.3
2026-27	19,688,716*0.365543	7,197,072.3

Table 3: Total operating costs discounted at 10%

PV of operating cost = Rs. 87,227,313
PV of Cost= IFI+PV of operating cost = Rs 35,669,750+ Rs.87,227,313= Rs. 122,897,063

APPENDIX 2

Cost Analysis for Setup 2 (Thermal power plant)

Project Specification:
Project life: 10 yearsFinancial year: July 1 to June 30Base year: 2017Discount rate: 10%
Exchange rate: 1US$= Rs 150

Computation of Initial Fixed Investment(IFI)

Land: The actual rate of land was inquired from the estate agents in the nearby area of Gulberg. Land requirement and cost is mentioned below:Total area= 8 kanal (36000 s.q. ft)Constructed area=5 kanal (22500sq. ft)Open area = 3 kanal (13500sq. ft)Cost of land per sq. ft= Rs22222.23 Cost of total land (36000sq. ft) = Rs. 800, 000,000

Building: The area of the building was calculated on the basis of the dimensions of the machinery to be installed. The current cost of construction per unit such as square meter or square foot was asked from the contractors involved in the construction business. Cost/sq. ft= Rs 1,000 Total cost of construction (22500sq.ft): Rs 22,500,000

Machinery and equipment: The cost of machinery and equipment was worked out from the prices supplied by machinery manufacturers and producers of thermoelectric power from solid fibrous waste. The contributing elements are shown in Table 4:

Pre-Production Expenditures (PEP)

It will take one full year to install the plant. Thus, the expenditure involved includes salaries of the staff and consultants, etc. Consultant Fee = Rs. 220,000/annum
Project Head = Rs. 330,000/annum
Power House In charge = Rs.264, 000/annum
Boiler Foreman = Rs. 198,000/annumTotal Pre-Production Expenditure (PPE) =Rs. 1,012,000

Plant PME	Capacity	Quantity	Cost (Rs)
Steam Boiler	1Ton/Hour	1	2,500,000
Water Treatment plant	1Ton/Hour	1	110,000
Feed Water Storage Tank	25 Tons	1	90,000
Multi Stage Turbine	100/kWh	1	1,000,000
Electric Pumps	-	6	55,000
Distribution Panel	-	1	55,000
Transformer	-	1	700,000
Vehicle (Truck)	-	1	1,500,000
Total			6,010,000

Table 4: Plant Machinery and Equipment(PME)

Total Cost of Machinery and Equipment = Rs. 6,010,000

IFI (With Land) =Cost of (Land, Building, PME and PPE)=800, 000,000+22,500+6010, 000+ 1, 012,000 = Rs.829, 522,000 (Alternative 1)IFI (Without Land) =Cost of (Building, PME and PPE) = 22,500,000+6,010,000+1,012,000=Rs.29, 522,000 (Alternative 2)

Operating Cost

Raw Material Cost: As raw material was the solid waste to dispose of so its cost was zero. Cost of other **Inputs:** Other inputs included electricity and labor. Cost of Electricity: Minor cost was involved in the initial running of the pumps which will be self supplied within the set up after the plant will become functional. Thus, it is neglected.

Labor cost: The nature and number of employees engaged to run the plant along with their salaries

were given by Pattoki Sugar Mill and are computed in Table 4:

Labor	No.	Salary per Month- Rs
Senior Engineer	1	35,000
Assistant / foreman	3	75,000
Assist. Foreman	3	55,000
Senior Fireman	3	54,000
Waterman	3	46,500
Mason	1	21,000
Helper	1	15,000

Table 4: Breakdown of Labor and Labor cost

Total = Rs. 301,500/ month = Rs. 3,618,000/year Maintenance cost at 10% of the purchase price of machinery= Rs. 601,000Depreciationat 10% of purchase price= Rs. 601,000Total Operating cost = Labor, Maintenance and Depreciation Cost=3,618,000+601,000+601,000 =Rs. 4,820,000

Expenditure in the Base Year

Initial Fixed Investment =Rs. 829, 522,000Operating Cost = Nil Total Expenditures = Rs. 829, 522,000

Expenditure in Future Years

Apart from the initial investment, no other capital expenditure was assumed over the project life. The operating cost in the base year was nil. However, it was subject to alter with changes in labor cost, operating capacity, etc. However, Pattoki Sugar Mill Thermoelectric Plant was working at 80% of its plant capacity and did not intend to increase it in near future. The operating cost was calculated as shown in Table 5 and Table 6.

Benefits

The benefits were calculated on the basis of the units of electricity produced from the burnt waste and that depended on its calorific value. The calorific value of hospital waste was calculated on the basis of the percentage composition of the waste from the calorific values of individual components reported in literature by Khan and Ali [17].

Years	Calculations (Operating + Maintenance + Depreciation cost)	Operating Cost (Rs.)
2017-18	0	0
2018-19	3,618,000+1,202,000	4,820,000
2019-20	3,979,800+1,202,000	5,181,800
2020-21	4,377,780+1,202,000	5,579,780
2021-22	4,815,558+1,202,000	6,017,558
2022-23	5,297,113.8+1,202,000	6,499,113.8
2023-24	5,826,825.18+1,202,000	7,028,825.18
2024-25	6,409,507.7+1,202,000	7,611,507.7
2025-26	7,050,458.47+1,202,000	8,252,458.47
2026-27	7,755,504.32+1,202,000	8,957,504.32
2027-28	8,531,054.75+1,202,000	10,935,054.8

Table 5: Operating cost over years

Benefits

Weight of Children Hospital Lahore = 730 ton/annum
Calorific value = 16438 BTU / kg or 17260 kJ / kg
Live steam temperature = 600-650^{o}C
Live steam pressure = 70-80 kg/cm^{2}
Fuel steam ratio = 1:7
Production of electricity was calculated as under:

1) Steam produced from available fuel = 5,110 ton/annum
2) Turbine for electricity generation Multistage condensing turbine with LT generator (400 Volt)
3) Steam consumption per kWh by Turbine = 5 kg/kWh
4) Electricity produced = 1,022,000 kWh/annum
5) Electricity produced/hour = 118.3 kWh

Years	Calculations	Operating Cost (Rs)
2017-18	0	0
2018-19	4,820,000*0.909091	4,381,818.62
2019-20	5,181,800*0.826446	4,282,477.88
2020-21	5,579,780*0.751315	4,192,172.41
2021-22	6,017,558*0.683013	4,110,070.34
2022-23	6,499,113.8*0.620921	4,035,436.24
2023-24	7,028,825.18*0.564474	3,967,589.06
2024-25	7,611,507.7*0.513158	3,905,906.07
2025-26	8,252,458.47*0.466507	3,849,829.64
2026-27	8,957,504.32*0.424098	Rs. 3,798,859.67
2027-28	10,935,054.8*0.385543	Rs. 4,215,933.83
Total		**Rs. 40,740,093.8**

Table 6: OC Discounted at 10% to the base year

Present Value of Total Operating Cost = Rs. 40,740,093.8

Price of electricity per kWh = Rs. 23Revenue Return per Annum = Rs 1,022,000*23= Rs. 23,506,000 Scrap value of the machinery and equipment at 10% of the purchase price=Rs. 601,000

Benefits discounted to the base year: The total revenue return per year were computed over project life and discounted to the base year applying. Annuity Tables to calculate the total receipts after 10% discount rate. The sum of revenue receipts collected at the rate of Rs 1 per year turned over Rs. 6.14457 for the next 10 years. Present Value of the Benefits =3,506,000*6.14457 = Rs. 144,434,262

Total Expenditure and Total Returns Discounted to Base Year Present Value of Cash Outlays (Cost) = IFI + PV of OCRs. 829, 522,000+Rs. 40,740,093.8=Rs. 870,262,094

Returns = Savings + Scrap Value Present Value of Returns = Rs. 144,434,262Present Value of Scrap = Rs. 601,000*0.385543 = 231,711Present Value of Cash Flows (Benefits) = 144,434,262 + 231,711 = Rs. 144,665,973 (B/C) = PV of benefits/ PV of Cost=144,665,973/870,262,094 = 0.16NPV =PV of

Benefits –PV of Cost= Rs. 144,665,973 - Rs. 870,262,094 = Rs. -725,596,121 PBP = Total Investment /Annual Return – OC of year 1 = 829, 522,000 /23,506,000-4.381,819.3 =43 .3 years

APPENDIX 3

The comparison of results of different alternatives with indices and feasibility is made in Table 7.

Alts.	BCR	NPV (Rs)	PBP(Yrs.)	Feasibility
1	0.16	-725,596,121	43	Non-feasible
2	2	74,403,879	1.5	**Feasible**
3	0.16	-734,989,306	42	Non-feasible
4	1.8	65,010,694	1.6	**Feasible**
5	0.08	-92,075,453	68	Non-feasible
6	1.1	7,924,547	2.7	**Feasible**
7	0.08	-01,468,638	69	Non-feasible
8	0.9	-1,468,638	2.9	Non-feasible

Table 7: Comparison of different alternatives for thermal-power plant

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