PD-ABZ-005

Prepared for:
USAID-SARI/Energy Program
www.sari-energy.org

Evaluation Report

Technological Readiness of the Micro Turbines

Nexant
OCTOBER 2002

23865.813.0015

PD-ABZ-005

EVALUATION REPORT: TECHNOLOGICAL READINESS OF MICRO TURBINES

For

United States Agency for International Development

Under

South Asia Regional Initiative for Energy

Prepared by
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NEXANT SARI / Energy

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Acknowledgement

We are especially indebted to the Micro Turbine manufacturers – Capstone Turbine Corporation, Turbec AB, Bowman Power Systems, Elliott Energy Systems and Ingersoll Rand for sharing with us information on their products.

Many useful suggestions, both substantive and editorial, were provided by the manufacturers, Nexant inmates and staff at TERI, IREDA and PGCIL. Despite of all this useful assistance, the views and opinions expressed herein, and all remaining errors, are solely those of the author.

We are grateful to the USAID for its continuous technical, financial and other forms of support, which contributed immensely to the successful completion of the evaluation report.

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Executive Summary

Background

Due to the developing nature of the South Asia Regional Initiative/Energy countries, resources to provide electricity to the entire population of these countries is a daunting task. Prohibitive infrastructure development costs have deprived large segments of their population from having access to grid-connected electricity. Providing electricity to these sections of populations through innovative means especially through the off-grid systems assumes greater significance. Establishment of distributed power generation facilities in these countries will not only help provide electricity to people living in far flung areas but will also help to improve quality and reliability of supply and meet the peak-demand through cogeneration. SARI/Energy countries have a potential for utilizing distributed power, especially in the light of the slow pace of upcoming power generation projects, high T&D costs/losses, inaccessible geographic terrains and other problems that make it difficult to meet the energy demand of secluded pockets of population.

Distributed generation systems employ power systems that may be installed at the load site. Typical distributed generation systems may employ a variety of fuel based systems, out of which the Micro Turbine systems are one option, given their advantage of compact size, light weight, smaller number of moving parts, low emissions and low maintenance costs. The power generation capacity of Micro Turbines ranges from 20 kW to 500 kW. The efficiencies ranges from 15% in unrecuperated systems to 85% in waste heat recovery systems. These systems employ a capital cost typically ranging from $ 700 – 1100 /kW and an operation and maintenance cost of $ 0.005 – 0.016 /kW.

Scope of Work

The ultimate aim of this study is to evaluate the technological readiness of the Micro Turbine technology for widespread introduction in South Asia. The study will focus on reviewing the different applications, for which the various Micro Turbime systems could be used (e.g. base load, peak shaving), availability of technology and models of such systems available in the market today. The study will act as a basis to suggest whether the choice of Micro Turbine will be a technologically mature solution in the context of SARI/Energy countries. The principal terms of reference for this study were:

- Assessment of current and available technology/ techno-economic developments:
  - Generation capacities
  - Efficiencies
  - Reliability
  - Power qualityand
  - Cogeneration capability

- Investigation of cost of power generation with various fuels and application options:
  - Capital cost

- Operational cost
- Maintenance cost
- Scheduled downtimesand
  Efficiency and other performance characteristics for different applications, e.g. application to different consumer categories - household, commercial, industrial and different application options - unrecuperated, recuperated, cogeneration, heat recovery etc.

Approach Involved in the Evaluation Report

The approach employs a quantitative evaluation of the identified technologies, in terms of parameters such as cost of electricity, installed cost per kW, nett present value of project savings, nett present value of tariff, debt ratio, interest rate of borrowing, equity investment, long-term cumulative savings, internal rate of return, payback, normalized savings, normalized tariff etc.

The data provided by the vendors, regulatory bodies, public sector enterprises – oil & gas and power, non government organizations, research and development organizations and other such setups.

This evaluation report does not in any way preach the use of the Micro Turbine technology or any of its descendants' technology. This evaluation report only focuses at evaluating the applicability of the Micro Turbine technology with respect to the existing norms in the SARI countries.

Major Findings

On careful quantitative evaluation of the various Micro Turbine systems that are commercially available in the market today, and for which vendors were ready to share information for evaluative purposes, we have arrived at the decision that the Capstone Turbine Corporation's C60 High Pressure Natural Gas (HPNG) Micro Turbine system scores the highest on all fronts, closely followed by Capstone Turbine Corporation's C30 **Biogas Micro Turbine system. The Turbec AB T100 Micro Turbine system also fares** well on the evaluation but since this system can run only in the grid parallel mode, hence its economics would not be favorable. The Capstone Turbine Corporation's C30 Liquid Fuel Micro Turbine system has unfavorable economics and is not profitable in the Indian scenario. The Ingersoll Rand Energy Systems' 70LM/70SM Micro Turbine system also has unfavorable economics and is not suitable in the Indian scenario.

The Capstone C60 HPNG Micro Turbine system scores second highest on the Qualitative Analysis with 2.179 points on a scale of 3 (trailing the leader by only 0.018 points or 1%) and scores highest on the Quantitative Analysis by "DER" method, with lowest cost of electricity at $0.087 /kWh (Rs. 4.26 /kWh); whereas, it scores second on the Quantitative Analysis by "NPV" method, with cost of electricity at $ 0.0541 /kWh (Rs. 2.64 /kWh).

The Capstone C30 Biogas Micro Turbine system scores third highest on the Qualitative Analysis with 2.143 points on a scale of 3 (trailing the leader by only 0.054 points or 2%) and scores highest on the Quantitative Analysis by "NPV" method, with lowest cost of electricity at $0.046 /kWh (Rs. 2.22 /kWh); whereas, it scores fourth on the Quantitative Analysis by "DER" method, with cost of electricity at $ 0.0.111/kWh (Rs. 5.41 kWh).

The cost of electricity figures quoted here are post-tax and post-subsidy figures. For pre-tax and pre-subsidy quantitative analysis and results, refer Appendix 5, Table A.5.1 and Table A.5.2.

A sensitivity analysis was carried out to establish the correlation/dependence of the cost of electricity (both by DER and NPV Methods) on various input parameters. The various input parameters taken into account were: interest rate of borrowing, subsidy on interest rate of borrowing, grant on equity, tax exemption, average tax for utility operations, basic customs duty, debt-equity ratio, return on equity, salvage value for depreciation, additional customs duty, average electric utility demand rate ($/kW/month), FOB percentage on capital cost, custom wheeling duty, interest rate on equity, fuel price ($/MMBTU), foreign exchange rate (1 USD to INR). The sensitivity analysis employed the Monte-Carlo simulation technique (with 5,000 simulations on each parameter) to rank, in order of correlation, each of the parameters listed above to the cost of electricity for each Micro Turbine system being evaluated. Rank 1 implies greater correlation and lower ranks signify lesser correlation of that parameter with the cost of electricity. The ranking results are as shown in Table ES.1 and ES.2 below:

Table ES.1 Correlation Ranking by Monte Carlo technique for cost of electricity by NPV method

Parameters	C30 Biogas	C30 Liquid Fuel	C60 HPNG	T100	IR 70LM/70SM
Average Electric Utility Energy Rate ($/kWh)	1	7	13	13	13
Load Factor	2	1	2	2	2
Interest Rate of Borrowing	3	10	15	4	4
Subsidy on interest rate of Borrowing	4	N/A	N/A	N/A	N/A
Grant on Equity	5	N/A	N/A	N/A	N/A
Tax Exempt	6	N/A	N/A	N/A	N/A
Average Tax for Utility Operations	7	14	4	5	7
Basic Customs Duty	8	3	3	3	3
Debt-Equity Ratio	9	9	6	6	6
Return on Equity	10	12	7	8	8
Salvage Value for Depreciation	11	13	10	11	12
Additional Customs Duty	12	4	5	7	5
Average Electric Utility Demand Rate ($/kW/month)	13	8	14	14	14
FOB percentage on capital cost	14	6	8	9	9
Custom Wheeling Duty	15	5	9	10	10
Interest Rate on Equity	16	11	11	12	11
Fuel Price ($/MMBTU)	17	2	1	1	1
Foreign Exchange Rate (1 USD to INR)	18	15	15	15	15

Table ES.2 Correlation Ranking by Monte Carlo tecbnique for cost of electricity by DER method

Parameters	C30 Biogas	C30 Liquid Fuel	C60 HPNG	T100	IR 70LM/70SM
Load Factor	1	1	2	2	2
Basic Customs Duty	2	3	3	3	3
Additional Customs Duty	3	4	4	4	4
FOB percentage on capital cost	4	6	5	5	5
Salvage Value for Depreciation	5	13	13	13	13
Interest Rate of Borrowing	6	10	10	10	7
Custom Wheeling Duty	7	5	6	6	6
Return on Equity	8	12	12	12	12
Debt-Equity Ratio	9	9	9	9	10
Grant on Equity	10	N/A	N/A	N/A	N/A
Subsidy on interest rate of Borrowing	11	N/A	N/A	N/A	N/A
Foreign Exchange Rate (1 USD to INR)	12	15	15	15	15
Interest Rate on Equity	13	11	11	11	11
Fuel Price ($/MMBTU)	14	2	1	1	1
Average Electric Utility Energy Rate ($/kWh)	15	7	7	7	8
Average Electric Utility Demand Rate ($/kW/month)	16	8	8	8	9
Average Tax for Utility Operations	17	14	14	14	14
Tax Exempt	18	N/A	N/A	N/A	N/A

Challenges Ahead

The key challenges to Micro Turbine applicability in the SARI region are listed below:

- Creating awareness amongst the various regulatory, funding and public sector groups of the technological readiness and commercial viability of the Micro Turbine technology
- Availability/constant supply of Natural Gas as a fuel for the Micro Turbine systems;
- Commercial and technological challenges of setting up biogas plants for feeding Micro Turbine systems running on biogas as fuel
- Determining of market potential of the Micro Turbine technology
- Thorough cost-benefit analysis to benchmark the Micro Turbine technology with other distributed generation systems available in the market todayand
- Formulate subsidy and regulatory policies to promote distributed generation using Micro Turbine equipment in the SARI region

Key Recommendations

After conducting a thorough evaluation of the technological readiness of the Micro Turbine technology, the findings of this evaluation report strongly recommend to conduct a Phase II study, which will help determine the market potential of the Micro Turbine technology in SARI countries. As part of the Phase II, there needs to be carried out a cost-benefit analysis to benchmark the Micro Turbine technology with other distributed generation systems available in the market today. Due attention must be given to the ranking established by the Monte Carlo simulation technique to help formulate subsidy and regulatory policies to promote distributed generation using Micro Turbine equipment.

1.1 Introduction

Micro Turbines are small combustion turbines that produce between 25 kW and 500 kW of power. Micro Turbines were derived from turbocharger technologies found in large trucks or the turbines in aircraft auxiliary power units (APUs). Most Micro Turbines are single-stage, radial flow devices with high rotating speeds of 90,000 to 120,000 revolutions per minute. However, a few manufacturers have developed alternative systems with multiple stages and/or lower rotation speeds.

Micro Turbines are nearing commercial status. Capstone, for example, has delivered over 1700 Micro Turbines to customers (as of October 2001). However, many of the Micro Turbine installations are still undergoing field tests or are part of large-scale demonstrations.

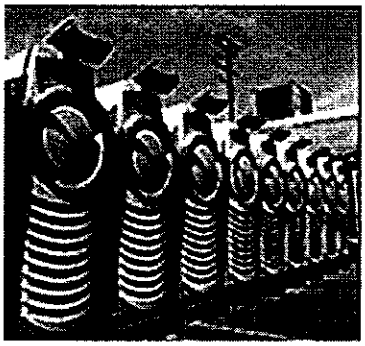

Photo source: Capstone Turbine Corporation

Fig 1.1.1 Micro Turbine

Table 1.1.1

Micro Turbine Technology Overview	
Commercially available	Yes (Limited)
Size Range	25 – 500 kW
Fuel	Natural gas, hydrogen, propane, diesel
Efficiency	20-30%
Environmental	Low (<9-50 ppm) NO_x
Other features	Cogen (50-80°C water)
Commercial Status	Small volume production, commercial prototypes now

Micro Turbine generators can be divided in two general classes:

- Recuperated Micro Turbines, which recover the heat from the exhaust gas to boost the temperature of combustion and increase the efficiencyand
- Unrecuperated (or simple cycle) Micro Turbines, which have lower efficiencies, but also lower capital costs.

While some early product introductions have featured unrecuperated designs, the bulk of developers' efforts are focused on recuperated systems. The recuperator recovers heat from the exhaust gas in order to boost the temperature of the air stream supplied to the combustor.

located at the point-of-power utilization. The combined thermal electrical efficiency of Micro Turbines in such cogeneration applications can reach as high as 85% depending on the heat process requirements. Unrecuperated Micro Turbines have lower efficiencies at around 15%.

1.4 Cost

Table 1.4.1

Micro Turbine cost	
Capital cost	$700-$1100/kW
O&M cost	$0.005-0.016/kW
Maintenance interval	5000-8000 hrs

Micro Turbine capital costs range from $700 - $1,100/kW. These costs include all hardware, associated manuals, software, and initial training. Adding heat recovery increases the cost by $75 - $350/kW. Installation costs vary significantly by location but generally add 30-50% to the total installed cost.

Micro Turbine manufacturers are targeting a future cost below $650/kW. This appears to be feasible if the market expands and sales volumes increase.

With fewer moving parts, Micro Turbine vendors hope the units can provide higher reliability than conventional reciprocating generating technologies. Manufacturers expect that initial units will require more unexpected visits, but as the products mature, a once-a-year maintenance schedule should suffice. Most manufacturers are targeting maintenance intervals of 5,000-8,000 hours.

Maintenance costs for Micro Turbine units are still based on forecasts with minimal real-life situations. Estimates range from $0.005-$0.016 per kWh, which would be comparable to that for small reciprocating engine systems.

1.5 Strengths & Weaknesses

Micro Turbines offer many potential advantages for distributed power generation. Selected strengths and weaknesses of Micro Turbine technology are listed in the following table:

Table 1.5.1

Strengths	Weaknesses
Small number of moving parts	Low fuel to electricity efficiency
Compact size	Loss of power output and efficiency with higher ambient temperature and elevation
Light-weight	
Good efficiencies in cogeneration	
Low emissions	
Can utilize waste fuels	
Low maintenance intervals	

1.6 Future Developments

Extensive field test data collected from units currently in use at commercial and industrial facilities will provide manufacturers with the ability to improve the Micro Turbine design, lowering costs and increasing performance, in order to produce a competitive distributed generation product. Utilities, government agencies, and other organizations are involved in collaborative research and field testing (see Research Initiatives Section).

Development is ongoing in a variety of areas:

- Heat recovery/cogeneration
- Fuel flexibility
- Vehicles and
- Hybrid systems (e.g., fuel cell/Micro Turbine, flywheel/Micro Turbine).

2.1 Available Technologies And Vendors

There are more than twenty companies worldwide that are involved in the development and commercialization of Micro Turbines for distributed generation applications. Below are details of five of the leading Micro Turbine manufacturers:

2.1.1 Bowman Power Systems

Bowman Power Systems is a U.K. based company that develops 80-kW Micro Turbine power generation systems for distributed generation and mobile power applications. Bowman Power Systems were unable to provide the specifications of the Micro Turbine system for the purpose of this evaluation report.

2.1.2 Capstone Turbine Corporation

Capstone Turbine Corporation, based in Chatsworth, California, is a leader in the commercialization of low-emission, high-reliability Micro Turbine power generators. The company offers 30-kW and 60-kW systems for distributed generation applications. Details of the various product offering are given below:

a) **The Capstone C60 high pressure natural gas** Micro Turbine system is a compact, ultra-low-emission generator providing up to 60 kW of power and 150 kW of heat for combined heat and power applications. Solid-state patented power electronics permit 0-60 kW load following, safe zero-hardware Direct2Grid™ interconnection, advanced communications and 2-to-20-unit stand-alone. Multi packing with no external hardware except computer cables. Automatic grid/stand-alone switching, 100-unit PowerServer™ nettworking, remote monitoring/dispatch and other functionalities are available capstone options. The system incorporates a compressor, recuperator, combustor, turbine and permanent magnett generator. The rotating components are mounted on a single shaft, supported by patented air bearings that spin at up to 96,000 rpm. This is the only moving part of the Micro Turbine. The generator is cooled by inlet air flow. The system uses no oil, no lubricants, no coolants and has no pumps, gearbox or other mechanical sub systems. The system achieves ultra-low NO_x performance with no post-combustion catalysts or other exhaust clean up devices. System output is variable frequency (50/60 Hz) 3-phase ac powerand

b) **The Capstone C30 low pressure natural gas** Micro Turbine system is a compact, ultra-low-emission generator providing up to 30 kW of power and 85 kW of heat for combined heat and power applications. Solid-state patented power electronics permit 0-30 kW load following, safe zero-hardware Direct2Grid™ interconnection, advanced communications and 2-to-20-unit stand-alone. Multi packing with no external hardware except computer cables. Automatic grid/stand-alone switching, 100-unit PowerServer™ nettworking, remote monitoring/dispatch and other functionalities are available Capstone options. The system incorporates a compressor, recuperator,

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combustor, turbine and permanent magnett generator. The rotating components are mounted on a single shaft, supported by air bearings that spin at up to 96,000 rpm. This is the only moving part of the Micro Turbine. The generator is cooled by inlet air flow. The system uses no oil, no lubricants, no coolants and has no pumps, gearbox or other mechanical sub systems. The system achieves ultra-low NO_x performance with no post-combustion catalysts or other exhaust clean up devices. System output is variable frequency (50/60 Hz) 3-phase AC power. The capstone C30 Micro Turbine system is available in the following variants:

- The Capstone C30 Low Pressure Natural Gas
- The Capstone C30 High Pressure Gaseous Fuels
- The Capstone C30 Biogasand
- The Capstone C30 Liquid Fuels

Three main products of the Capstone Turbine Corporation has been taken up for evaluation as part of this report. The detailed specifications of the same are listed below:

Table 2.1.2.1

Capstone Turbine Corporation C30 Biogas Micro Turbine system		
Specification	Units	C30 Biogas
General identification		
Turbine Type		Micro Turbine
Model number and Year		Model 330 (2002)
Power Application (standby, grid parallel, combined heat and power, peak shaving, reliability)		Grid Connect
Installation load type		Industrial
Physical Dimensions	Meters Width	0.762
	Height	1.943
	Length	1.516
Weight	Kg	405
Calibration Details		
Mean sea level	Meters	0
Relative humidity		60%
Temperature	°C	15
Performance data		
Nett electrical efficiency	%	25
Nett electrical output	kW	30
Nett total efficiency	%	-
Nett thermal output	kW	-
Heat Rate (LHV) of turbine (BTU/kWhr)	BTU/kWhr	13,100
Micro Turbine Cost data		
Capital Cost		$ 30,765
Import Duty (for FOB)		$ 10,460
Installation cost (Civil+Mech+Elec+Others)		$ 45,706
Annual maintenance cost	$/kWhr	$ 0.010
Scheduled annual downtime	HRS	2
Minor overhaul after	HRS	8,000
Major overhaul after	HRS	40,000
Emission data		
Volumetric exhaust gas	at 100% Load	
NOx	ppm/v	9
CO	ppm/v	67
Noise level	dBA @ 10m	65
Electrical data		
Voltage output		415 VAC @ 3 ph
Frequency output	Hz	50
Mains frequency variation	%	< 1
Mains voltage variation	%	< 1

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Table 2.1.2.2

Capstone Turbine Corporation C30 Liquid Fuel Micro Turbine system		
Specification	**Units**	**C30 Liquid Fuel**
General identification		
Turbine Type		Micro Turbine
Model number and Year		Model 330 (2002)
Power Application (standby, grid parallel, combined heat and power, peak shaving, reliability)		Grid Connect
Installation load type		Industrial
Physical Dimensions	Meters Width	0.762
	Height	1.943
	Length	1.516
Weight	Kg	405
Calibration Details		
Mean sea level	Meters	0
Relative humidity		60%
Temperature	°C	15
Performance data		
Nett electrical efficiency	%	25
Nett electrical output	kW	29
Nett total efficiency	%	-
Nett thermal output	kW	-
Heat Rate (LHV) of turbine (BTU/kWhr)	BTU/kWhr	13,700
Micro Turbine Cost data		
Capital Cost		$ 30,765
Import Duty (for FOB)		$ 19,936
Installation cost (Civil+Mech+Elec+Others)		$ 2,574
Annual maintenance cost	$/kWhr	$ 0.010
Scheduled annual downtime	HRS	2
Minor overhaul after	HRS	8,000
Major overhaul after	HRS	40,000
Emission data		
Volumetric exhaust gas	at 100% Load	
NOx	ppm/v	35
CO	ppm/v	
Noise level	dBA @ 10m	65
Electrical data		
Voltage output		415 VAC @ 3 ph
Frequency output	Hz	50
Mains frequency variation	%	< 1
Mains voltage variation	%	< 1

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Table 2.1.2.3

Capstone Turbine Corporation C60 High Pressure Natural Gas Micro Turbine system		
Specification	**Units**	**C60 HPNG**
General identification		
Turbine Type		Micro Turbine
Model number and Year		Model 330 (2002)
Power Application (standby, grid parallel, combined heat and power, peak shaving, reliability)		Grid Connect
Installation load type		Industrial
Physical Dimensions	Meters Width	0.762
	Height	2.108
	Length	1.956
Weight	Kg	758
Calibration Details		
Mean sea level	Meters	0
Relative humidity		60%
Temperature	°C	15
Performance data		
Nett electrical efficiency	%	28
Nett electrical output	kW	60
Nett total efficiency	%	-
Nett thermal output	kW	-
Heat Rate (LHV) of turbine (BTU/kWhr)	BTU/kWhr	12,200
Micro Turbine Cost data		
Capital Cost		$ 55,000
Import Duty (for FOB)		$ 35,640
Installation cost (Civil+Mech+Elec+Others)		$ 2,574
Annual maintenance cost	$/kWhr	$ 0.010
Scheduled annual downtime	HRS	2
Minor overhaul after	HRS	8,000
Major overhaul after	HRS	40,000
Emission data		
Volumetric exhaust gas	at 100% Load	
NOx	ppm/v	9
CO	ppm/v	
Noise level	dBA @ 10m	70
Electrical data		
Voltage output		415 VAC @ 3 ph
Frequency output	Hz	50
Mains frequency variation	%	< 1
Mains voltage variation	%	< 1

2.1.3 Elliott Energy Systems

Elliott Energy Systems, located in Stuart, Florida, develops and manufactures 80-kW Micro Turbines now, with plans for larger units later. Elliott Energy Systems were unable to provide the specifications of the Micro Turbine system for the purpose of this evaluation report.

2.1.4 Ingersoll Rand Energy Systems

Ingersoll Rand Energy Systems of Portsmouth, New Hampshire develops the PowerWorks™ line of Micro Turbine generators with output of 70-kW now with plans for larger units later.

The detailed specifications of the Ingersoll Rand product are listed below:

Table 2.1.4.1

Ingersoll Rand Energy Systems 70 LM/ 70 SM Micro Turbine system		
Specification	**Units**	**70 LM/70SM**
General identification		
Turbine Type		Micro Turbine
Model number and Year		70 LM/70 SM – 2001
Power Application (standby, grid parallel, combined heat and power, peak shaving, reliability)		All
Installation load type		Industrial/ Commercial
Physical Dimensions	meters Width	1.080
	Height	2.220
	Length	1.810
Weight	Kg	1,860
Calibration Details		
Mean sea level	metres	0
Relative humidity		60%
Temperature	°C	15
Performance data		
Nett electrical efficiency	%	28.5
Nett electrical output	kW	70
Nett total efficiency	%	70
Nett thermal output	kW	110
Heat Rate (LHV) of turbine (BTU/kWhr)	BTU/kWhr	14,290
Micro Turbine Cost data		
Capital Cost		$ 66,650
Import Duty (for FOB)		$ 43,189
Installation cost (Civil+Mech+Elec+Others)		$ 4,000
Annual maintenance cost	$/kWhr	$ 0.013
Scheduled annual downtime	HRS	8
Minor overhaul after	HRS	80,000
Major overhaul after	HRS	80,000
Emission data		
Volumetric exhaust gas	at 100% Load	
NOx	ppm/v	5
CO	ppm/v	5
Noise level	dBA @ 10m	60
Electrical data		
Voltage output		415 VAC @ 3 ph
Frequency output	Hz	50
Mains frequency variation	%	< 1
Mains voltage variation	%	< 1

2.1.5 Turbec AB

Turbec AB is a Swedish company jointly owned by ABB and Volvo Aero. The company offers a 100-kW Micro Turbine power generator for commercial distributed generation applications.

The detailed specifications of the turbine Model no. T100 is listed below:

Table 2.1.5.1

Turbec AB T100 Micro Turbine system		
Specification	**Units**	**T100**
General identification		
Turbine Type		Micro Turbine
Model number and Year		T100
Power Application (standby, grid parallel, combined heat and power, peak shaving, reliability)		Grid parallel only
Installation load type		Industrial
Physical Dimensions	Meters Width	0.870
	Height	1.900
	Length	2.920
Weight	Kg	2,000
Calibration Details		
Mean sea level	Meters	0
Relative humidity		60%
Temperature	°C	15
Performance data		
Nett electrical efficiency	%	28.5
Nett electrical output	kW	100
Nett total efficiency	%	76.5
Nett thermal output	kW	167.0
Heat Rate (LHV) of turbine (BTU/kWhr)	BTU/kWhr	11,940
Micro Turbine Cost data		
Capital Cost		$ 78,232
Import Duty (for FOB)		$ 50,694
Installation cost (Civil+Mech+Elec+Others)		$ 29,337
Annual maintenance cost	$/kWhr	$ 0.011
Scheduled annual downtime	HRS	24
Minor overhaul after	HRS	6,000
Major overhaul after	HRS	30,000
Emission data		
Volumetric exhaust gas	at 100% Load	
NOx	ppm/v	15
CO	ppm/v	15
Noise level	dBA @ 10m	70
Electrical data		
Voltage output		415 VAC @ 3 ph
Frequency output	Hz	50
Mains frequency variation	%	< 1
Mains voltage variation	%	< 1

Section 3 Quantitative Evaluation Of Available Technologies

3.1 Basis of Quantitative Evaluation

The quantitative evaluation of the Micro Turbine systems, for which the detailed specifications have been obtained from the vendors (listed in Section 3.1 of this report), has been conducted based on the following two methodologies:

- Cost of Electricity by Department of Energy, California (as stated on their website on "Distributed Energy Resource Guide (DER guide)" and
- Cost of Electricity based on Nett Present Value (NPV) analysis of tariff and savings on electricity cost as compared to electricity cost from grid connection, also taking into account the regulatory, tax, financing and aid guidelines in India.

3.1.1 The "DER" Cost of Electricity Calculation Methodology

In order to determine the cost-effectiveness of DER technologies, the estimated cost of electricity from a DER system may be compared with the local retail price of electricity from the electric utility or the estimated cost of electricity of another DER technology. For additional accuracy, it is recommended that the cost of electricity be calculated for a specific manufacturer's DER system, as well as for the location and application of the DER system.

The cost of electricity (COE) is comprised of three components: capital and installation (C&I), operation and maintenance (O&M), and fuel (F). The total cost of electricity from a DER device is the sum of these three components, expressed in dollars (or cents) per kilowatt-hour:

Total COE ($/kWh) = C& I + O&M+F

The breakdown of the three components will vary with the size and type of equipment. However, the figure below provides an example of the breakdown for a 4.5 MW natural gas combustion turbine. As illustrated, the fuel component is typically the largest portion of the cost of electricity in a system that utilizes fuel.

The capital cost component varies based on the capital and installation costs, as well as on the fixed charge rate and capacity factor of the DER system. These factors are described in more detail in the Decision Analysis section. The cost of electricity decreases as the amortization period of the DER device increases (e.g., as the fixed charge rate decreases). DER systems with high capacity factors (i.e., base load units) also have a lower cost of electricity.

The operation and maintenance cost component takes into account both the fixed and variable O&M costs of the DER technology. Mature technologies, like internal combustion engines, tend to have lower O&M costs due to standard product designs and established nettworks for parts and maintenance

The fuel cost component is simply the cost of the fuel required to generate electricity with the DER device. The fuel cost component varies with the efficiency (or heat rate) of the equipment and with the cost of fuel. Therefore, a specific DER technology may have a lower cost of electricity in some geographic locations than in others due to fluctuations in the cost of natural gas, propane, or diesel. Some DER equipment, such as photovoltaic systems and wind turbines, will not have a fuel cost as no fuel is required.

3.1.1.1 Decision Analysis

A wide variety of criteria play a part in the economics of distributed energy resources. The following table lists some of the questions that may be asked in the decision-making process for the implementation of DER technologies. The cost of electricity variables in the right-hand column may be defined by answering the questions on the left. The cost of electricity generated in a DER device may then be calculated based on the equations in the previous section. The cost-effectiveness of the DER system can then be determined by comparing the DER cost of electricity to the electricity price from the grid. An example is provided below for calculating the cost of electricity.

Table 3.1.1.1

"DER" Method for calculating Cost of Electricity	
DECISION ANALYSIS QUESTIONS	**COST OF ELECTRICITY VARIABLES**
Application	
Residential, commercial, or industrial? Base load, backup, or peak shaving? Grid independent or grid parallel?	Capacity Factor (CF)
Technology	
PEMFC, SOFC, ICE, CT, PV, Wind? Average electric load? Ideal power rating of the DER system? Heat rate of the DER system? Reliability of the DER system? Capital cost of the DER system? Installation cost of the DER system? O&M cost of the DER system? Method of payment for the DER system? DER system life?	Fixed Charge Rate (FCR) Total Installed Cost (TIC) Operation & Maintenance Cost (O&M) Average Annual Nett Plant Heat Rate (NPHR)
Fuel	
Natural gas, propane, or diesel?	Natural Gas Price (NGP) Diesel Oil Price (DOP) Propane Price (PP)

The cost of electricity calculated based on the above criteria may be affected by additional economic factors, such as:

- Utility stand-by charge
- Nett metering
- Incentives or rebates for DER
- Energy efficiency credits for DER

In addition to economic factors, there are a number of intangible issues that may have a role in the DER decision analysis:

- Prestige/status of early adopters
- Global warming concerns
- Emissions concerns
- Green/renewable power advocacy
- Strong feelings for or against utility
- Desire to have independence from the grid
- Safety concerns
- Fuel price instability/volatilityand
- Special sitting and permitting requirements

3.1.1.2 Example

The following example utilizes a simplistic method for determining the cost of electricity. The cost of electricity (COE) is comprised of three components: capital and installation (C&I), operation and maintenance (O&M), and fuel (F) per the following equation.

Total COE ($/kWh) = C&I + O&M + F

As an example, a small convenience store may utilize a significant amount of electricity during peak daytime hours. The installation of a DER system in a base load configuration may be a money-saving alternative for the business owner. For this example, the following assumptions are made:

- A natural gas-fueled, 30 kW Micro Turbine is the chosen DER technology
- The price of natural gas is $6/MMBtu
- The Micro Turbine will operate 19.2 hours per day, 365 days per year
- The Micro Turbine has a five-year life
- The electrical efficiency of the Micro Turbine (based on the lower heating value of the fuel) is 27%
- The total installed cost (TIC) of the Micro Turbine system is $1,000 per kW or $30,000. The interest rate is 0%
- The total operation and maintenance (O&M) cost of the Micro Turbine system is 0.5 cents per kW. (The total O&M cost is the sum of fixed O&M and variable O&M costs.)
- The price of electricity purchased from the utility is 12 cents per kWand
- The waste heat WILL NOT be utilized for cogeneration

Based on the above information, we can determine the total cost of electricity generated by the Micro Turbine :

- The Self-Generation Incentive Program provides a credit of $1.00 per watt, up to 30% of the project cost. In this case, the maximum credit is $9,000 (30% of $30,000), reducing the total installed cost (TIC) to $700 per kW or $21,000.

- The capacity factor (CF) is equal to the number of hours per year that the DER system operates divided by the total number of hours per year (8,760).

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$$CF = \frac{19.2 \text{ hours per day x 365 days per year}}{8{,}760 \text{ hours per year}} = 0.80$$

- The fixed charge rate (FCR) is equal to the annual amortized installed cost ($/yr) divided by the total installed cost ($). In this example, the cost of money was not included. Therefore, the amortized installed cost is simply one-fifth (or one over the amortization period) of the total installed cost.

$$FCR = \frac{\$700 \text{ per kW x } 30 / 5 \text{ years}}{\$700 \text{ per kW x } 30 \text{ kW}}$$

- The heat rate (HR) of the DER system is based on the higher heating value of the fuel. It is assumed that the lower heating value is equal to 0.904 times the higher heating value.

$$HR = \frac{3{,}413\, Btu / kWh \,/\, 27\%}{0.904} = 13{,}983\, Btu / kWh$$

- The total cost of electricity (COE) is equal to sum of the components for capital and installation (C&I), operation and maintenance (O&M), and fuel (F).

$$C \,\&\, I\ (\$ / kWh) = \frac{TIC \text{ per } kW \times FCR}{CF \times 8{,}760 \text{ hours per year}} = \frac{\$700 \times 0.20}{0.80 \times 8{,}760} = \$0.020$$

$$O \,\&\, M\ (\$ / kWh) = \$0.005$$

$$F\ (\$ / kWh) = \frac{FP}{1{,}000{,}000 \text{ Btu per MMBtu}} \times HR = \frac{\$6.00}{1{,}000{,}000} \times 13{,}983 = \$0.084$$

$$COE\ (\$ / kWh) = C \,\&\, I + O \,\&\, M + F = \$0.020 + \$0.005 + \$0.084 = \$0.109$$

At a price of 10.9 cents per kilowatt-hour, the electricity generated from the Micro Turbine in this example is less expensive than the 12 cents per kilowatt-hour from the grid. Therefore, in this case, the installation of the Micro Turbine would be cost-effective for the business owner.

3.1.1.3 The "DER" Cost of Electricity Quantitative Evaluation

Based on the "DER" cost of electricity calculation methodology, the cost of electricity was calculated for each of the Micro Turbine systems being considered for evaluation. The various parameters listed in the "DER" methodology were calculated or else obtained, in some cases, from the specific companies/bodies (e.g., price of fuel in $/BTU units, see

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Appendix 2, Table 2.1.1). After calculating the Capital and Installation cost, Operation and Maintenance cost, and Fuel cost, the total cost of electricity for that particular turbine was arrived at, the results of which are compiled in Table 3.1.1.3 below:

Table 3.1.1.3

"DER" Cost of Electricity Quantitative Evaluation

Vendor	**Capstone turbine**			**Turbec**	**IR**
Calculations for Cost of Electricity	**C30 Biogas**	**C30 Liquid fuel**	**C60 HPNG**	**T100**	**70LM / 70 SM - 2001**
@ base load operation only		Diesel (HSD)			
Hours/day	*19.2*	*19.2*	*19.2*	*19.2*	*19.2*
Days/year	*365*	*365*	*365*	*365*	*365*
Operational hours/year	*7,000*	*7,000*	*7,000*	*7,000*	*7,000*
Total hours/year	*8,760*	*8,760*	*8,760*	*8,760*	*8,760*
Capacity Factor (CF)	**0.8**	**0.8**	**0.8**	**0.8**	**0.8**
Capital Cost ($/kW)	*$1,374.20*	*$1,748.30*	*$1,510.70*	*$1,289.30*	*$1,569.10*
Capacity (kW)	*30*	*29*	*60*	*100*	*70*
Life of Machine (in years)	*5*	*5*	*5*	*5*	*5*
Fixed Charge Rate (FCR)	**0.2**	**0.2**	**0.2**	**0.2**	**0.2**
Efficiency	*25.0%*	*25.0%*	*28.0%*	*28.5%*	*28.5%*
Heat Rate of Gen system (in BTU/kWh)	**13,100**	**13,700**	**12,200**	**11,940**	**14,290**
Total installed cost per kW ($/kW)	*2,897.70*	*1,837.10*	*1,553.60*	*1,582.60*	*1,626.30*
Capital Cost and Installation Cost($/kWhr)	**0.083**	**0.052**	**0.044**	**0.045**	**0.046**
	75%	*25%*	*51%*	*51%*	*48%*
Operational and Maintenance Cost ($/kWhr)	**0.010**	**0.010**	**0.010**	**0.011**	**0.013**
	9%	*5%*	*11%*	*12%*	*13%*
Fuel price (FP, in $/BTU)	*0.0000014*	*0.0000106*	*0.0000027*	*0.0000027*	*0.0000027*
Fuel Cost ($/kWh)	**0.018**	**0.145**	**0.033**	**0.032**	**0.039**
	16%	*70%*	*38%*	*36%*	*39%*
COST OF ELECTRICITY (COE) in USD	**0.111**	**0.208**	**0.087**	**0.088**	**0.098**
Current Foreign Exchange Rate	*48.73*	*As on date*	*8-Aug-2002*		
COST OF ELECTRICITY (COE) in INR	**Rs 5.41**	**Rs 10.12**	**Rs 4.26**	**Rs 4.31**	**Rs 4.77**
COST OF ELECTRICITY (COE) in INR from Grid	*Rs4.40*				
EXCEEDS COST OF ELECTRICITY FROM GRID BY	Rs 1.01	Rs 5.72	Rs	Rs (0.09)	Rs 0.37

3.1.2 The "NPV" Cost of Electricity Calculation Methodology

In order to determine the cost of electricity from distributed generation systems, the difference between the Nett Present Value (NPV) of the tariff for such systems and the NPV of savings, which may be gained as against the grid tariff, must be computed. This will provide us with a fair picture of the cost of electricity that may be arrived at, given the Indian investment, regulatory, subsidies, taxation/duties and technological scenario.

The cost of electricity calculated by the NPV method takes into account the following parameters in the context of the local Indian regulatory environment:

- Debt Equity Ratio guidelines (refer appendix 4, section A.4.1 and A.4.2)
- Return on Equity guidelines (refer appendix 4, section A.4.1)
- Current Borrowing/Lending Rates (refer appendix 4, section A.4.3)
- Subsidies On Interest Rates (refer appendix 4, section A.4.3)
- Subsidies/Grant On Equity Investment
- Import Duty Tariffs (refer appendix 4, section A.4.5)
- Freight-On-Board Charges (refer appendix 4, section A.4.5)
- Depreciation/Salvage And Other Accounting Guidelines (refer appendix 4, section A.4.1 and A.4.1, Table A.4.1.3, section A.4.4)
- Mode Value Of Electric Energy Rates (refer Appendix 3, Table A.3.1.1)
- Mode Value Of Electric Energy Demand Rates (refer Appendix 3, Table A.3.1.1)
- Current Fuel Prices (refer Appendix 2, Table A.2.1.1)and
- Average Income Tax at rates paid by power utilities across India (refer Appendix 4, Table A.4.1.6)

Based on the above parameters, the NPV method calculates the Cash Inflows and the Cash Outflows and subsequently the Nett Cash Flow starting from the year in which the investment is made to the end of the tenth year from the investment date. The cash inflows are:

- Avoided Site Electric Energy Costs
- Avoided Site Electric Demand Chargeand
- Depreciation

And the Cash Outflows are:

- Fuel Cost
- Maintenance Cost
- Interest on loan
- Repayment of loan
- Equity investmentand
- Income Tax

From the NPV method, we arrive at the Nett Present Value of savings in cost of electricity (S_1) as compared to the avoided cost of electricity from the grid. Using the following formula, we arrive at the annual normalized savings in cost of electricity (A_1):

$$A_1 = \frac{S_1 \times i \times (1+i)^{n-1}}{(1+i)^n - 1}$$

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Similarly, the NPV method calculates the tariff inflows from the consumer, based on the following parameters:

- Return on Equity
- Interest Loan
- Depreciation
- Operation costs (Fuel cost)and
- Maintenance Cost

We arrive at the NPV of tariff from consumers (S_2), from the total annual tariff figures obtained from the parameters listed above. Using the following formula, we arrive at the annual normalized tariff (A_2):

$$A_2 = \frac{S_2 \text{ x i x } (1+i)^{n-1}}{(1+i)^n - 1}$$

The annual normalized savings in cost of electricity (A_1) and the annual normalized tariff (A_2) are averaged over the total annual units of electricity produced to give the average normalized savings in cost of electricity (A_{1av}) and the average normalized tariff (A_{2av})and the difference between A_{1av} and A_{2av} gives the average normalized cost of electricity per unit of electricity produced (A_{nc}), which is inclusive of taxes, since income tax was taken into account in the nett cash flow calculation. In other words,

$$A_{nc} = \frac{A_{2av} - A_{1av}}{\text{kWh generated per annum}}$$

The NPV method helps us arrive at the following output parameters:

- Average normalized savings in cost of electricity (A_{1av})
- Average normalized tariff (A_{2av})
- Average normalized cost of electricity per unit of electricity produced (A_{nc}), inclusive of tax
- Internal Rate of Return (IRR %)
- Payback period on investment (in years)
- Cumulative savings in cost of electricity in 5 years
- Cumulative savings in cost of electricity in 10 yearsand
- Ratio of NPV of savings in cost of electricity to equity invested

The NPV analysis was carried out for each of the Micro Turbine systems being evaluated as part of this study. The details of the analyses are compiled in the following Table 3.1.2.1, 3.1.2.2, 3.1.2.3, 3.1.2.4, 3.1.2.5 and the detailed , payback analysis graphs for each of the Micro Turbine systems being evaluated are shown in Fig 3.1.2.1, 3.1.2.2, 3.1.2.3, 3.1.2.4, 3.1.2.5

Table 3.1.2.1

Capstone Turbine Corporation C30 Biogas NPV Method Quantitative Analysis

Inputs											
Installed cost of turbine	[redacted]										
Installed cost of biogas plant	[redacted]										
Total Equipment Installed Cost	[redacted]										
Installed Cost per kWe	[redacted]										
Maintenance Cost	[redacted]	per kWh									
Average Electric Utility Energy Rate	[redacted]	per kWh									
Average Electric Utility Demand Rate	[redacted]	per kW per Month									
Average Gas Rate	[redacted]	per MM BTU (HHV)									
Nominal kWe Rating	[redacted]	kW									
Hours of Operation	[redacted]	hours per year									
Heat Rate	[redacted]	BTU per kWh (HHV)									
Year	0	1	2	3	4	5	6	7	8	9	10
CASH FLOW ANALYSIS											
Cash Inflow	$86,931	Salvage	40%	as per MNES sops			3%	rate of depreciation			
Avoided Site Electric Energy Costs		$18,962	$18,962	$18,962	$18,962	$18,962	$18,962	$18,962	$18,962	$18,962	$18,962
Avoided Site Electric Demand Charge		$1,181	$1,181	$1,181	$1,181	$1,181	$1,181	$1,181	$1,181	$1,181	$1,181
Depreciation on turbine		$2,474	$2,474	$2,474	$2,474	$2,474	$2,474	$2,474	$2,474	$2,474	$2,474
Depreciation on biogas plant		$2,742	$2,742	$2,742	$2,742	$2,742	$2,742	$2,742	$2,742	$2,742	$2,742
Cash Outflow											
Fuel		($3,832)	($3,832)	($3,832)	($3,832)	($3,832)	($3,832)	($3,832)	($3,832)	($3,832)	($3,832)
Maintenance Costs		($2,100)	($2,100)	($2,100)	($2,100)	($2,100)	($2,100)	($2,100)	($2,100)	($2,100)	($2,100)
Interest on loan		($6,194)	($6,194)	($5,807)	($5,032)	($4,258)	($3,484)	($2,710)	($1,936)	($1,161)	($387)
Repayment of loan	$0	$0	$0	($8,150)	($8,150)	($8,150)	($8,150)	($8,150)	($8,150)	($8,150)	($8,150)

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Equity investment with 40% grant on equity	($13,040)										
Nett cash flow	($13,040)	$13,232	$13,232	$5,470	$6,244	$7,018	$7,792	$8,567	$9,341	$10,115	$10,889
tax @ 35% after a tax holiday of 10 years as per 80 (IA) of INCOME TAX ACT											
Tax @ 40% after a tax holiday of 5 years	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Nett Cash flow after taxes	**($13,040)**	**$13,232**	**$13,232**	**$5,470**	**$6,244**	**$7,018**	**$7,792**	**$8,567**	**$9,341**	**$10,115**	**$10,889**
				5 year cumulative savings		$47,835			10year cumulative savings		$97,266
NPV of project savings	$40,459										
Normalized project savings	$6,215										
Per unit cost savings based on normalized tariff	[redacted]	per kWh									
IRR	[redacted]										
Payback Period	[redacted]	years									
TARIFF CALCULATIONS											
Return on Equity		$2,086	$2,086	$2,086	$2,086	$2,086	$2,086	$2,086	$2,086	$2,086	$2,086
Interest Loan		$6,194	$6,194	$5,807	$5,032	$4,258	$3,484	$2,710	$1,936	$1,161	$387
Depreciation		$5,216	$5,216	$5,216	$5,216	$5,216	$5,216	$5,216	$5,216	$5,216	$5,216
Operation costs (Fuel cost)		$3,832	$3,832	$3,832	$3,832	$3,832	$3,832	$3,832	$3,832	$3,832	$3,832
Maintenance Cost		$2,100	$2,100	$2,100	$2,100	$2,100	$2,100	$2,100	$2,100	$2,100	$2,100
Total tariff		$19,428	$19,428	$19,041	$18,267	$17,493	$16,718	$15,944	$15,170	$14,396	$13,621
NPV of tariff	$102,728										
Normalized tariff	$15,780										
Per unit tariff from consumers	[redacted]	per kWh									
Savings	[redacted]	per kWh									

Cost of Capital	Debt	Equity	ROE
Debt Equity Ratio for investment (nominal)	75	25	
Interest Rate	10.0%	16.0%	16%
Subsidy on interest	0.5%	0.0%	
Nett Interest Rate	9.5%	16.0%	
Weighted Debt Equity	7.1	4	
Weighted average interest	[redacted]		

Table 3.1.2.2

Capstone Turbine Corporation C30 Liquid Fuel NPV Method Quantitative Analysis

Inputs		
Equipment Installed Cost	[redacted]	
Installed Cost per kWe	[redacted]	
Maintenance Cost	[redacted]	per kWh
Average Electric Utility Energy Rate	[redacted]	per kWh
Average Electric Utility Demand Rate	[redacted]	per kW per Month
Average Gas Rate	[redacted]	per MM BTU (HHV)
Nominal kWe Rating	[redacted]	kW
Hours of Operation	[redacted]	hours per year
Heat Rate	[redacted]	BTU per kWh (HHV)

Year	0	1	2	3	4	5	6	7	8	9	10
CASH FLOW ANALYSIS											
Cash Inflow	$53,276	Salvage	10%	as per AS-6		9%	rate of depreciation				
Avoided Site Electric Energy Costs		$18,330	$18,330	$18,330	$18,330	$18,330	$18,330	$18,330	$18,330	$18,330	$18,330
Avoided Site Electric Demand Charge		$1,141	$1,141	$1,141	$1,141	$1,141	$1,141	$1,141	$1,141	$1,141	$1,141
Depreciation		$4,795	$4,795	$4,795	$4,795	$4,795	$4,795	$4,795	$4,795	$4,795	$4,795
Cash Outflow											
Fuel		($29,480)	($29,480)	($29,480)	($29,480)	($29,480)	($29,480)	($29,480)	($29,480)	($29,480)	($29,480)
Maintenance Costs		($2,030)	($2,030)	($2,030)	($2,030)	($2,030)	($2,030)	($2,030)	($2,030)	($2,030)	($2,030)
Interest on loan		($3,543)	($3,170)	($2,797)	($2,424)	($2,051)	($1,678)	($1,305)	($932)	($559)	($186)
Repayment of loan	$0	($3,729)	($3,729)	($3,729)	($3,729)	($3,729)	($3,729)	($3,729)	($3,729)	($3,729)	($3,729)
Equity investment	($15,983)										
Nett cash flow	($15,983)	($14,516)	($14,143)	($13,770)	($13,397)	($13,024)	($12,651)	($12,279)	($11,906)	($11,533)	($11,160)
Tax at 24%											
Tax at utility rates	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Nett cash flow after tax	**($15,983)**	**($14,516)**	**($14,143)**	**($13,770)**	**($13,397)**	**($13,024)**	**($12,651)**	**($12,279)**	**($11,906)**	**($11,533)**	**($11,160)**

5 year cumulative savings ($68,851) 10 year cumulative savings ($128,379)

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NPV of project savings	$(81,425)	
Normalized project savings	($12,785)	
Per unit cost savings based on normalized tariff	[redacted]	per kWh
IRR	[redacted]	
Payback Period	[redacted]	years

TARIFF CALCULATIONS											
Return on Equity		$2,557	$2,557	$2,557	$2,557	$2,557	$2,557	$2,557	$2,557	$2,557	$2,557
Interest Loan		$3,543	$3,170	$2,797	$2,424	$2,051	$1,678	$1,305	$932	$559	$186
Depreciation		$4,795	$4,795	$4,795	$4,795	$4,795	$4,795	$4,795	$4,795	$4,795	$4,795
Operation costs (Fuel cost)		$29,480	$29,480	$29,480	$29,480	$29,480	$29,480	$29,480	$29,480	$29,480	$29,480
Maintenance Cost		$2,030	$2,030	$2,030	$2,030	$2,030	$2,030	$2,030	$2,030	$2,030	$2,030
Total tariff		$42,405	$42,032	$41,659	$41,286	$40,913	$40,540	$40,167	$39,794	$39,421	$39,048

NPV of tariff	$ 233,925	
Normalized tariff	$36,729	
Per unit tariff from consumers	[redacted]	per kWh
Savings	[redacted]	per kWh

Cost of Capital	Debt	Equity	ROE
Debt Equity Ratio for investment (nominal)	70	30	
Interest Rate	10.0%	16.0%	16%
Subsidy on interest	0.0%	0.0%	
Nett Interest Rate	10.0%	16.0%	
Weighted Debt Equity	7.0	4.8	
Weighted average interest	[redacted]		

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Table 3.1.2.3

Capstone Turbine Corporation C60 High Pressure Natural Gas NPV Method Quantitative Analysis

Inputs											
Equipment Installed Cost	[redacted]										
Installed Cost per kWe	[redacted]										
Maintenance Cost	[redacted]	per kWh									
Average Electric Utility Energy Rate	[redacted]	per kWh									
Average Electric Utility Demand Rate	[redacted]	per kW per Month									
Average Gas Rate	[redacted]	per MM BTU (HHV)									
Nominal kWe Rating	[redacted]	kW									
Hours of Operation	[redacted]	hours per year									
Heat Rate	[redacted]	BTU per kWh (HHV)									
Year	0	1	2	3	4	5	6	7	8	9	10
CASH FLOW ANALYSIS											
Cash Inflow	$93,216	Salvage	10%	as per AS-6		9%	rate of depreciation				
Avoided Site Electric Energy Costs		$37,923	$37,923	$37,923	$37,923	$37,923	$37,923	$37,923	$37,923	$37,923	$37,923
Avoided Site Electric Demand Charge		$2,361	$2,361	$2,361	$2,361	$2,361	$2,361	$2,361	$2,361	$2,361	$2,361
Depreciation		$8,389	$8,389	$8,389	$8,389	$8,389	$8,389	$8,389	$8,389	$8,389	$8,389
Cash Outflow											
Fuel		($13,835)	($13,835)	($13,835)	($13,835)	($13,835)	($13,835)	($13,835)	($13,835)	($13,835)	($13,835)
Maintenance Costs		($4,200)	($4,200)	($4,200)	($4,200)	($4,200)	($4,200)	($4,200)	($4,200)	($4,200)	($4,200)
Interest on loan		($6,199)	($5,546)	($4,894)	($4,241)	($3,589)	($2,936)	($2,284)	($1,631)	($979)	($326)
Repayment of loan	$0	($6,525)	($6,525)	($6,525)	($6,525)	($6,525)	($6,525)	($6,525)	($6,525)	($6,525)	($6,525)
Equity investment	($27,965)										
Nett cash flow	($27,965)	$17,915	$18,568	$19,220	$19,873	$20,525	$21,178	$21,830	$22,483	$23,135	$23,788
Tax at 24%											
Tax at utility rates	$0	($4,329)	($4,486)	($4,644)	($4,802)	($4,959)	($5,117)	($5,275)	($5,432)	($5,590)	($5,748)
Nett cash flow after tax	($27,965)	**$13,587**	**$14,081**	**$14,576**	**$15,071**	**$15,566**	**$16,061**	**$16,556**	**$17,051**	**$17,545**	**$18,040**
				5 year cumulative savings		$72,882				10 year cumulative savings	$158,135
NPV of project savings	$53,291										
Normalized project savings	$8,367										
Per unit cost savings based on normalized tariff	[redacted]	per kWh									

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IRR	[redacted]	
Payback Period	[redacted]	years

TARIFF CALCULATIONS											
Return on Equity		$4,474	$4,474	$4,474	$4,474	$4,474	$4,474	$4,474	$4,474	$4,474	$4,474
Interest Loan		$6,199	$5,546	$4,894	$4,241	$3,589	$2,936	$2,284	$1,631	$979	$326
Depreciation		$8,389	$8,389	$8,389	$8,389	$8,389	$8,389	$8,389	$8,389	$8,389	$8,389
Operation costs (Fuel cost)		$13,835	$13,835	$13,835	$13,835	$13,835	$13,835	$13,835	$13,835	$13,835	$13,835
Maintenance Cost		$4,200	$4,200	$4,200	$4,200	$4,200	$4,200	$4,200	$4,200	$4,200	$4,200
Total tariff		$37,097	$36,445	$35,792	$35,140	$34,487	$33,835	$33,182	$32,530	$31,877	$31,225

NPV of tariff	$197,960	
Normalized tariff	$31,082	
Per unit tariff from consumers	[redacted]	per kWh
Savings	[redacted]	per kWh

Cost of Capital	Debt	Equity	ROE
Debt Equity Ratio for investment (nominal)	70	30	
Interest Rate	10.0%	16.0%	16%
Subsidy on interest	0.0%	0.0%	
Nett Interest Rate	10.0%	16.0%	
Weighted Debt Equity	7.0	4.8	
Weighted average interest	[redacted]		

Table 3.1.2.4

Turbec AB T100 Natural Gas NPV Method Quantitative Analysis

Inputs

Equipment Installed Cost	[redacted]	
~~Installed Cost per kWe~~	[redacted]	
Maintenance Cost	[redacted]	per kWh
Average Electric Utility Energy Rate	[redacted]	per kWh
Average Electric Utility Demand Rate	[redacted]	per kW per Month
Average Gas Rate	[redacted]	per MM BTU (HHV)
Nominal kWe Rating	[redacted]	kW
Hours of Operation	[redacted]	hours per year
Heat Rate	[redacted]	BTU per kWh (HHV)

Year	0	1	2	3	4	5	6	7	8	9	10
CASH FLOW ANALYSIS											
Cash Inflow	$158,260	Salvage	10%	as per AS-6		9%	rate of depreciation				
Avoided Site Electric Energy Costs		$63,205	$63,205	$63,205	$63,205	$63,205	$63,205	$63,205	$63,205	$63,205	$63,205
Avoided Site Electric Demand Charge		$3,936	$3,936	$3,936	$3,936	$3,936	$3,936	$3,936	$3,936	$3,936	$3,936
Depreciation		$14,243	$14,243	$14,243	$14,243	$14,243	$14,243	$14,243	$14,243	$14,243	$14,243
Cash Outflow											
Fuel		($22,567)	($22,567)	($22,567)	($22,567)	($22,567)	($22,567)	($22,567)	($22,567)	($22,567)	($22,567)
Maintenance Costs		($7,700)	($7,700)	($7,700)	($7,700)	($7,700)	($7,700)	($7,700)	($7,700)	($7,700)	($7,700)
Interest on loan		($10,524)	($9,416)	($8,309)	($7,201)	($6,093)	($4,985)	($3,877)	($2,770)	($1,662)	($554)
Repayment of loan	$0	($11,078)	($11,078)	($11,078)	($11,078)	($11,078)	($11,078)	($11,078)	($11,078)	($11,078)	($11,078)
Equity investment	($47,478)										
Nett cash flow	($47,478)	$29,515	$30,623	$31,731	$32,839	$33,947	$35,054	$36,162	$37,270	$38,378	$39,486
Tax at 24%											
Tax at utility rates	$0	($7,131)	($7,399)	($7,667)	($7,934)	($8,202)	($8,470)	($8,737)	($9,005)	($9,273)	($9,540)
Nett cash flow after tax	**($47,478)**	**$22,384**	**$23,224**	**$24,064**	**$24,904**	**$25,745**	**$26,585**	**$27,425**	**$28,265**	**$29,105**	**$29,945**
				5 year cumulative savings		$120,321			10 year cumulative savings		$261,646
NPV of project savings	$86,996										

Normalized project savings	$13,659	
Per unit cost savings based on normalized tariff	[redacted]	per kWh
IRR	[redacted]	
Payback Period	[redacted]	years

TARIFF CALCULATIONS											
Return on Equity		$7,596	$7,596	$7,596	$7,596	$7,596	$7,596	$7,596	$7,596	$7,596	$7,596
Interest Loan		$10,524	$9,416	$8,309	$7,201	$6,093	$4,985	$3,877	$2,770	$1,662	$554
Depreciation		$14,243	$14,243	$14,243	$14,243	$14,243	$14,243	$14,243	$14,243	$14,243	$14,243
Operation costs (Fuel cost)		$22,567	$22,567	$22,567	$22,567	$22,567	$22,567	$22,567	$22,567	$22,567	$22,567
Maintenance Cost		$7,700	$7,700	$7,700	$7,700	$7,700	$7,700	$7,700	$7,700	$7,700	$7,700
Total tariff		$62,631	$61,523	$60,415	$59,307	$58,199	$57,092	$55,984	$54,876	$53,768	$52,660

NPV of tariff	$334,084	
Normalized tariff	$52,455	
Per unit tariff from consumers	[redacted]	per kWh
Savings	[redacted]	per kWh

Cost of Capital	Debt	Equity	ROE
Debt Equity Ratio for investment (nominal)	70	30	
Interest Rate	10.0%	16.0%	16%
Subsidy on interest	0.0%	0.0%	
Nett Interest Rate	10.0%	16.0%	
Weighted Debt Equity	7.0	4.8	
Weighted average interest	[redacted]		

Table 3.1.2.5

Ingersoll Rand Energy Systems 70 LM/70 SM Natural Gas NPV Method Quantitative Analysis

Inputs		
Equipment Installed Cost	[redacted]	
Installed Cost per kWe	[redacted]	
Maintenance Cost	[redacted]	per kWh
Average Electric Utility Energy Rate	[redacted]	per kWh
Average Electric Utility Demand Rate	[redacted]	per kW per Month
Average Gas Rate	[redacted]	per MM BTU (HHV)
Nominal kWe Rating	[redacted]	kW
Hours of Operation	[redacted]	hours per year
Heat Rate	[redacted]	BTU per kWh (HHV)

Year	0	1	2	3	4	5	6	7	8	9	10
CASH FLOW ANALYSIS											
Cash Inflow	$113,841	Salvage	10%	as per AS-6		9%	rate of depreciation				
Avoided Site Electric Energy Costs		$44,244	$44,244	$44,244	$44,244	$44,244	$44,244	$44,244	$44,244	$44,244	$44,244
Avoided Site Electric Demand Charge		$2,755	$2,755	$2,755	$2,755	$2,755	$2,755	$2,755	$2,755	$2,755	$2,755
Depreciation		$10,246	$10,246	$10,246	$10,246	$10,246	$10,246	$10,246	$10,246	$10,246	$10,246
Cash Outflow											
Fuel		($18,906)	($18,906)	($18,906)	($18,906)	($18,906)	($18,906)	($18,906)	($18,906)	($18,906)	($18,906)
Maintenance Costs		($6,250)	($6,250)	($6,250)	($6,250)	($6,250)	($6,250)	($6,250)	($6,250)	($6,250)	($6,250)
Interest on loan		($7,570)	($6,774)	($5,977)	($5,180)	($4,383)	($3,586)	($2,789)	($1,992)	($1,195)	($398)
Repayment of loan	$0	($7,969)	($7,969)	($7,969)	($7,969)	($7,969)	($7,969)	($7,969)	($7,969)	($7,969)	($7,969)
Equity investment	($34,152)										
Nett cash flow	($34,152)	$16,549	$17,346	$18,143	$18,940	$19,737	$20,534	$21,331	$22,128	$22,925	$23,721
Tax at 24%											
Tax at utility rates	$0	($3,999)	($4,191)	($4,384)	($4,576)	($4,769)	($4,961)	($5,154)	($5,346)	($5,539)	($5,732)
Nett cash flow after tax	**($34,152)**	**$12,551**	**$13,155**	**$13,759**	**$14,364**	**$14,968**	**$15,573**	**$16,177**	**$16,781**	**$17,386**	**$17,990**
				5 year cumulative savings		$68,797			10 year cumulative savings		$152,703
NPV of project savings	$ 44,486										
Normalized project savings	$										

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	6,985	
Per unit cost savings based on normalized tariff	[redacted]	per kWh
IRR	[redacted]	
Payback Period	[redacted]	years

TARIFF CALCULATIONS											
Return on Equity		$5,464	$5,464	$5,464	$5,464	$5,464	$5,464	$5,464	$5,464	$5,464	$5,464
Interest Loan		$7,570	$6,774	$5,977	$5,180	$4,383	$3,586	$2,789	$1,992	$1,195	$398
Depreciation		$10,246	$10,246	$10,246	$10,246	$10,246	$10,246	$10,246	$10,246	$10,246	$10,246
Operation costs (Fuel cost)		$18,906	$18,906	$18,906	$18,906	$18,906	$18,906	$18,906	$18,906	$18,906	$18,906
Maintenance Cost		$6,250	$6,250	$6,250	$6,250	$6,250	$6,250	$6,250	$6,250	$6,250	$6,250
Total tariff		$48,436	$47,639	$46,842	$46,045	$45,249	$44,452	$43,655	$42,858	$42,061	$41,264
NPV of tariff	$ 259,594										
Normalized tariff	$ 40,759										
Per unit tariff from consumers	[redacted]	per kWh									
Savings	[redacted]	per kWh									

Cost of Capital	Debt	Equity	ROE
Debt Equity Ratio for investment (nominal)	70	30	
Interest Rate	10.0%	16.0%	16%
Subsidy on interest	0.0%	0.0%	
Nett Interest Rate	10.0%	16.0%	
Weighted Debt Equity	7.0	4.8	
Weighted average interest	[redacted]		

4.1 Findings Drawn From "DER" Quantitative Analysis

The "DER" method takes into account the Capital and Installation cost (C&I), Operation and Maintenance cost (O&M) and the Fuel Cost to arrive at the cost of electricity figure for each of the Micro Turbine systems.

Table 4.1.1 Results of "DER" method Quantitative Analysis

Quantitative Rank	Micro Turbine System	Cost of Electricity ($/kWh)
1	Capstone C30 HPNG Micro Turbine system	0.087
2	Turbec AB T100 Micro Turbine system	0.088
3	Ingersoll Rand 70LM.70SM Micro Turbine system	0.098
4	Capstone C30 Biogas Micro Turbine system	0.111
5	Capstone C30 Liquid Fuel Micro Turbine system	0.208

4.2 Findings Drawn From "NPV" Quantitative Analysis

As discussed in section 4.1.2, the NPV analysis helps us obtain the following ouput parameters, to decide the most cost-effective solution:

- Average normalized savings in cost of electricity (A_{1av})
- Average normalized tariff (A_{2av})
- Average normalized cost of electricity per unit of electricity produced (A_{nc}), inclusive of tax
- Internal Rate of Return (IRR %)
- Payback period on investment (in years)
- Cumulative savings in cost of electricity in 5 years
- Cumulative savings in cost of electricity in 10 yearsand
- Ratio of NPV of savings in cost of electricity to equity invested

First, we will discuss the Micro Turbine systems in terms of these parameters individually and then summarize the findings to quantitatively arrive at the most cost-effective solution.

4.2.1 Capstone Turbine Corporation C30 Biogas NPV Method Findings

The NPV of cost savings for setting up this project at a site which already uses electric energy from the grid is positive and with the **smallest of equity investment** ($13,040) yields positive nett cash flow (Figure 6.3.1). This project pays back in 9.1 years, but uses a renewable source of energy. The incentives for setting up a project using renewable sources of energy are high, with the MNES and IREDA providing extremely attractive sops. The MNES provides a 40% subsidy on equity investment in addition to the 0.5% to 5% interest subsidy from IREDA, along with a two principal repayment moratorium.

We have based our analysis on 40% equity subsidy from MNES, 0.5% interest subsidy from IREDA and two years principal repayment moratorium. In addition to the above, MNES allows a debt-equity ratio of 75:25, which lowers the equity investment for promoters even further. The MNES allows 40% salvage value to be considered for calculating depreciation over ten years.

The **savings per unit of electricity generated** is the **highest,** as compared to the other solutions being evaluated, at $ 0.030 (Rs.1.44) and the savings percentage per unit of electricity generated is highest at 39%. The ***cost of electricity*** per unit generated is lowest at ***$0.046*** (Rs. 2.22).

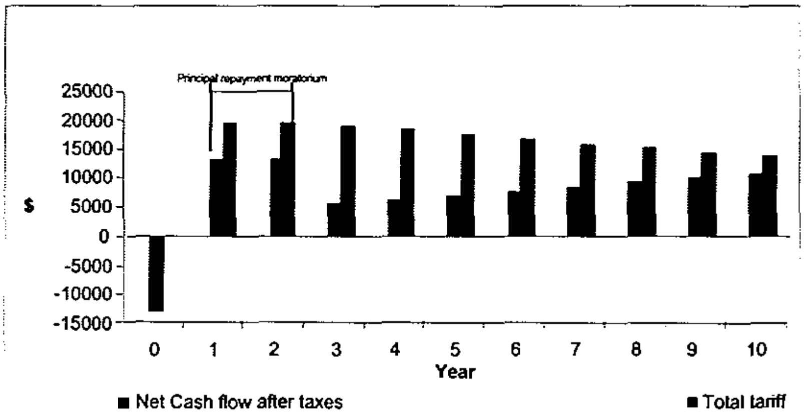

Figure 4.2.1 Capstone C30 Biogas Payback graph

4.2.2 Capstone Turbine Corporation C30 Liquid Fuel NPV Method Findings

This system has been evaluated for running on high speed diesel (HSD). The **price** for HSD is **highest** at $ 10.60 per BTU. Given the low efficiency of the turbine and the high price of HSD, setting up such a project at a site which already uses electricity from the grid **is not feasible.** This is substantiated by the negative value of NPV of cost savings, negative nett cash flow and negative 5 year and 10 year cumulative savings (Fig 4.2.2)

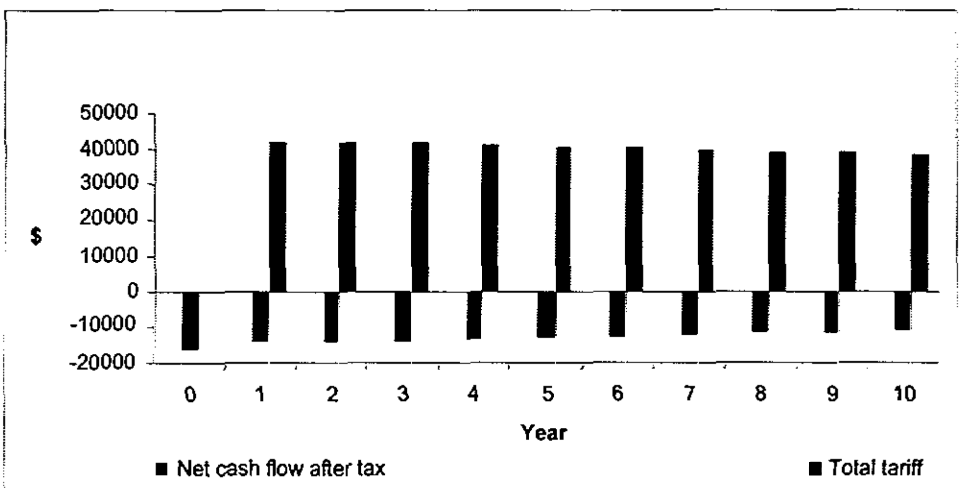

Figure 4.2.2 Capstone C30 Liquid Fuel Payback Graph

4.2.3 Capstone Turbine Corporation C60 High Pressure Natural Gas NPV Method Findings

The **payback** from setting up this project for a site already using grid power is **fastest**, at **6.4 years**. Investing in this project would yield a positive NPV of savings (Fig 4.2.3), which is substantially high at $ 53,291 (Rs. 2.60 MM). The cumulative five year and ten year savings are $ 72,882 (Rs. 3.55 MM) and $ 158,135 (Rs. 7.71 MM), respectively. The percentage savings per unit of electricity generated is 27%, with normalized savings at $ 0.020 /kWh and normalized tariff at $ 0.074 /kWh. The cost of electricity per unit of electricity generated for this solution is $ 0.054 (Rs. 2.64).

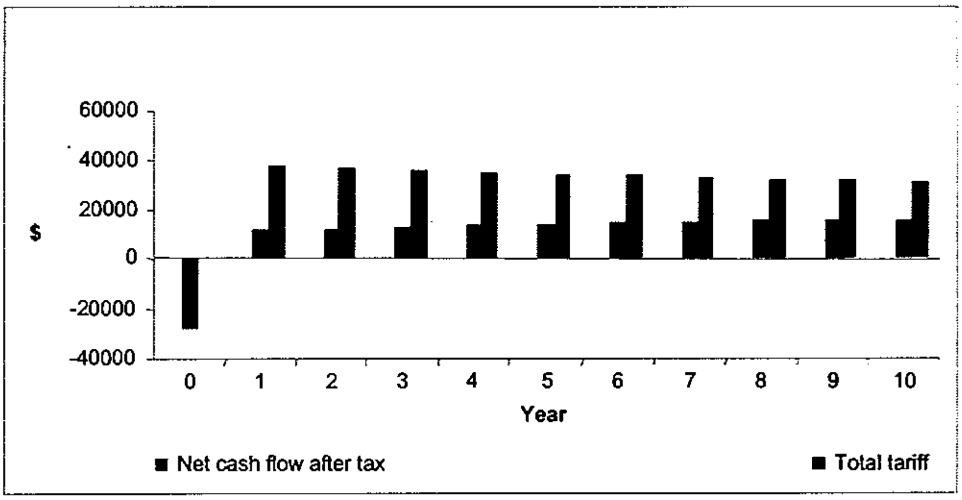

Figure 4.2.3 Capstone C60 High Pressure Natural Gas Payback Graph

4.2.4 Turbec AB T100 Natural Gas NPV Method Findings

The **NPV of savings** for this project is **highest** at $ 86,996 (Rs.4.24 MM) and **NPV of tariff** from consumers is **highest** at $ 334,084 (Rs. 16.28 MM). The **cumulative 5 year** and **10 year savings** from investment in this project are also the**highest**, amongst the solutions being evaluated, at $ 120,321 (Rs. 5.86 MM) and $261,646 (Rs. 12.75MM), respectively. The project pays back in 6.6 years, which is the second highest amongst the solutions being evaluated. This investment creates positive nett cash flow, but employs the highest equity investment of $ 47,478 (Rs. 2.3 MM).The cost of electricity from this solution is $ 0.055 /kWh (Rs. 2.7 /kWh)

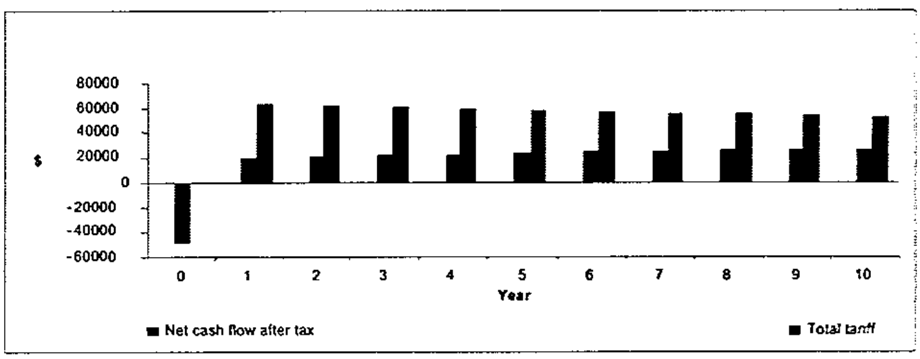

Figure 4.2.4 Turbec T100 Natural Gas payback Graph

4.2.5 Ingersoll Rand 70LM/70SM Natural Gas NPV Method findings

The Ingersoll Rand solution employs an equity investment of $ 34,152 (Rs. 1.66MM) and pays back in 8.3 years. The 5 and 10 year cumulative savings are $68,797 (Rs. 3.35MM) and 152,703 (Rs. 7.44MM). The normalized savings is $ 0.014 /kWh and the normalized tariff from consumers is $ 0.083, with the percentage savings at 17%.

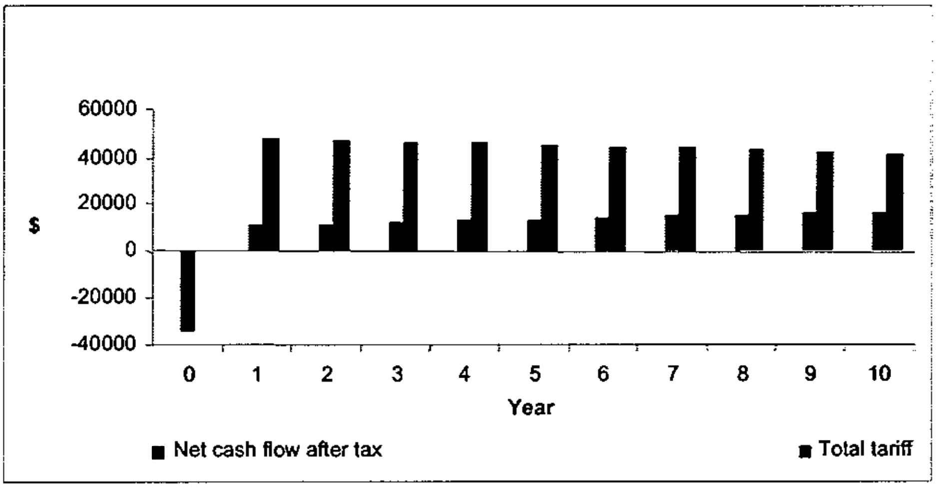

Figure 4.2.5 Ingersoll Rand 70LM/70SM Natural Gas Payback Graph

The detailed table of NPV findings and results is listed in Table 4.2.1 and Table 4.2.2 below,

Table 4.2.1

Detailed quantitative analysis "NPV" method findings					
Vendor	**Capstone turbine**			**Turbec**	**Ingersoll Rand**
Calculations for Cost of Electricity	**C30 Biogas**	**C30 Liquid fuel**	**C60 HPNG**	**T100**	**70LM / 70 SM - 2001**
@ base load operation only		Diesel (HSD)			
Capacity of Generating unit (kW)	*30*	*29*	*60*	*100*	*70*
Installed Cost ($)	*86,931*	*53,276*	*93,216*	*158,260*	*113,841*
Nett Present Value of Project Savings	*$40,459*	*($81,425)*	*$53,291*	*$86,996*	*$44,486*
Nett Present Value of Tariff	*$102,728*	*$233,925*	*$197,960*	*$334,084*	*$259,594*
Debt Ratio	*75.0%*	*70.0%*	*70.0%*	*70.0%*	*70.0%*
Weighted Average Interest Rate of Borrowing	*11.1%*	*11.8%*	*11.8%*	*11.8%*	*11.8%*
Equity Investment	*$13,040*	*$15,983*	*$27,965*	*$47,478*	*$34,152*
Ratio of Project savings NPV to Equity investment	3.1	(5.1)	1.9	1.8	1.3
5 year Cummulative savings	*$47,835*	*($68,851)*	*$72,882*	*$120,321*	*$68,797*
10 year Cummulative savings	*$97,266*	*($128,379)*	*$158,135*	*$261,646*	*$152,703*
Internal Rate of Return	*92%*	*Negative returns*	*51%*	*49%*	*39%*
Payback period (years)	***9.1***	*Negative returns*	*6.4*	***6.6***	***8.3***
Normalized savings ($/kWh) nett of taxes	*0.030*	*(0.063)*	*0.020*	*0.020*	*0.014*
Rs./kWh	*1.44*	*(3.07)*	*0.97*	*0.95*	*0.69*
Normalized tariff ($/kWh)	*0.075*	*0.181*	*0.074*	*0.075*	*0.083*
Rs./kWh	*3.66*	*8.82*	*3.61*	*3.65*	*4.05*
Percentage Savings nett of taxes	*39%*	*(35%)*	***27%***	***26%***	***17%***
Cost of Electricty ($/kWh) by NPV	0.046	**0.244**	**0.054**	**0.055**	**0.069**
Cost of Electricity (Rs/kWh) by NPV*	**2.22**	**11.89**	**2.64**	**2.70**	**3.36**

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Table 4.2.2

Quantitative Analysis results by NPV method										
	Ranks									
System	Cost of Electricity	Tariff $/kWh	Savings ($/kWh)	Payback	IRR	5 yr savings	10 yr savings	Equity investment	NPV of savings	NPV os tariff
Capstone C30 Biogas	1	3	1	4	1	4	4	1	4	5
Capstone C30 Liquid fuel	5	1	5	5	5	5	5	2	5	3
Capstone C60 HPNG	2	5	2	1	2	2	2	3	2	4
Turbec AB T100	3	3	2	2	3	1	1	5	1	1
Ingersoll Rand 70LM / 70 SM - 2001	4	2	4	3	4	3	3	4	3	2

We observe from Table 4.3.1 and 4.3.2 that the **Capstone Turbine Corporation C30 Biogas Micro Turbine system** has the lowest cost of electricity and is thus the best ranked Micro Turbine system.

4.3 Findings Summary

On careful qualitative and quantitative evaluation of the various Micro Turbine systems that are commercially available in the market today, and for which vendors were ready to share information for evaluative purposes, we have arrived at the decision that the Capstone Turbine Corporation's C60 High Pressure Natural Gas Micro Turbine system scores the highest on all fronts, closely followed by Capstone Turbine Corporation's C30 Biogas Micro Turbine system. The Turbec AB T100 Micro Turbine system also fares well on the evaluation but since this system can run only in the grid parallel mode, hence its economics would not be favorable. The Capstone Turbine Corporation's C30 Liquid Fuel Micro Turbine system has unfavorable economics and is not profitable in the Indian scenario. The Ingersoll Rand Energy Systems' 70LM/70SM Micro Turbine system also has unfavorable economics and is not suitable in the Indian scenario.

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A. 1.1 Emission Guidelines

General conditions of consent for emission under air (PREVENTION and control of pollution) act, 1981 as ammended to date:

1. The applicant shall not change or alter the quantity, quality, the rate of discharge, temperature or the mode of the effluent/emission or control equipments provided for without previous written permission of Haryana pollution control committee.
2. The applicant shall not cause nuisance in the premises and the surroundings by way of noise/vibrations and the ambient noise level shall not be allowed to exceed 75 dBA Leg. during daytime and 70 dBA Leg. during night time in commercial areas.
3. The applicant shall comply with the norms laid down vide Gazette Notification of Ministry of Environment and Forests, Government of India dated 02.01.99 for the diesel generators set(s) (5kVA and above) as below:

    - Acoustic enclosure/acoustic treatment of room for control of noise from the diesel generators sets shall be controlled by providing an acoustic enclosure or by treating the rooms acoustically.
    - The acoustic enclosure/acoustic treatment of room should be designed for a minimum 25dBA, Insertion loss or for meeting the ambient noise standards, whichever is higher. The measurement for insertion loss may be done at different points at 0.5 meters from the acoustic enclosure/room, and then averaged.
    - The diesel generator sets should also be provided with proper exhaust muffler with insertion loss off minimum 25 dBA.
    - This stack height for the diesel generator sets shall be as below:

Height of stack (in meters) = Height of the building (in meters) + 0.2 kVA of DG Set

- The existing units having diesel generator set shall comply with the above notification within two months and submit the air emission/noise report from any of the approved laboratory of Haryana Pollution Control Committee. Eco-friendly/ with in-built acoustic enclosure diesel generators set(s) are recommended for new installations.
- The applicant shall maintain the following emission standard from diesel generators set:

Suspended particulate matter:	Less than 100 mg/Nm^3
SO_X:	Less than 50 mg/Nm^3
NO_X:	Less than 100 mg/Nm^3
HC:	Nil

4. The industry shall ensure proper channelization/control system for fugitive emission from the activity so as to maintain clean and safe environment in and around the factory premises.

5. The applicant shall provide facilities for collection of environmental samples and samples of trade and sewage effluents air emission and hazardous wastes to the committee's staff at the terminal or designed points. Adequate facilities shall be provided for sampling with sampling holes at specified locations and dimensions, platform of specific size and strength, full arrangement of electrical connections etc.
6. The applicant shall maintain good housekeeping and take adequate measures for control of pollution from all sources so as not to cause nuisance to surrounding area/inhabitants.
7. The applicant/company shall comply with and carry out directives/orders issued by the committee in the consent order and at all subsequent time without any negligence on his/its part. The applicant/company shall be liable for such legal action against him as per provision of the law/acts in case of violation of any order/ directives issues at any time and/or non compliance of the terms and conditions of the consent order.
8. The above general conditions may be modified by the Haryana Pollution Control Committee from time to time and copies of such modified conditions will be communicated to the parties concerned by registered post.

Note: General/specific industrial effluent/emission standards are mentioned in Environment Protection Rules, 1986 as amended to date.

A.2.1 Fuel Prices (RS/BTU) And Heating Value (BTU/LB)

Fuel prices as obtained from the Indian Oil Corporation Ltd. as on August 2nd, 2002

Table A.2.1.1

Fuel Prices			
	Fuel	Price Rs./BTU	Heating Value BTU/lb
1.	High Speed Diesel	515.20	18,200
2.	Special Kerosene Oil	271.60	18,700
3.	Natural Gas	133.80	22,060
4.	Biogas	67.88[1]	650 BTU/scf

1BTU/lb = 0.556 kcal/kg

1 kcal = 3.968 BTU

1 Calculated on the basis of setting up a Greenfield biogas plant of 500 cu.m/day of installed capacity. Methodology used for calculating tariff is the Nett Present Value (NPV) of investments. The calculations take into account purely Indian prices for setting up the plant, Indian investment scenario (lending rates, subsidies etc.), and Indian tax norms and then calculates the NPV of tariff (S) for the Biogas produced over a year or 8,760 hours. Based on Indian investment scenario (weighted average interest, i), the normalized tariff (A) is calculated using the following formula:

$$A = \frac{S \times i \times (1+i)^{n-1}}{(1+i)^n - 1}$$

The normalized tariff (A) is averaged over the total heat required (BTU) to arrive at a Price figure in $/BTU or Rs/BTU.

The detailed calculation by NPV method is shown in Table A.2.1.2 below:

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Table A.2.1.2

Fuel price analysis for 5 x 100 cu.m. biogas plant using NPV method

Inputs					
Equipment Installed Cost	[redacted]		Cost of 1 plant	[redacted]	
Fuel intake required by turbine	[redacted]	BTU/hr	Daily dung requirement for 6 cum gas	[redacted]	kg
Heat Rate	[redacted]	BTU/scf	Yearly dung requirement	[redacted]	kg
or	[redacted]	BTU/cu.m.	Heat required in one year	[redacted]	BTU/year
Gas Rate for turbine	[redacted]	cum/hr	Average Gas Rate	[redacted]	perMMBTU(HHV)
Per day Gas Rate for turbine	[redacted]	cum/day	Hours of Operation	[redacted]	hoursperyear
Rating of 100 cum/day biogas plant	[redacted]	cum/day	Heat Rate of turbine	[redacted]	BTUperkWh(HHV)
No of biogas plants required	[redacted]	plants	Cost of dung	[redacted]	perkg

Year	0	1	2	3	4	5	6	7	8	9	10
CASH FLOW ANALYSIS											
Cash Inflow		Salvage	40%	as per MNES sops		6%	rate of depreciation				
Avoided Site Fuel Costs if on natural gas		$10,241	$10,241	$10,241	$10,241	$10,241	$10,241	$10,241	$10,241	$10,241	$10,241
Depreciation		$2,588	$2,588	$2,588	$2,588	$2,588	$2,588	$2,588	$2,588	$2,588	$2,588
Cash Outflow											
Fuel cost		($4,869)	($4,869)	($4,869)	($4,869)	($4,869)	($4,869)	($4,869)	($4,869)	($4,869)	($4,869)
Variable cost		($114)	($114)	($114)	($114)	($114)	($114)	($114)	($114)	($114)	($114)
Maintenance Costs		$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Interest on loan		($3,073)	($3,073)	($2,881)	($2,497)	($2,113)	($1,729)	($1,345)	($960)	($576)	($192)
Repayment of loan	$0	$0	$0	($4,044)	($4,044)	($4,044)	($4,044)	($4,044)	($4,044)	($4,044)	($4,044)
Equity investment with 40% grant on equity	($6,470)	2 year moratorium									
TARIFF CALCULATIONS											
Return on Equity		$1,035	$1,035	$1,035	$1,035	$1,035	$1,035	$1,035	$1,035	$1,035	$1,035
Interest Loan		$3,073	$3,073	$2,881	$2,497	$2,113	$1,729	$1,345	$960	$576	$192
Depreciation		$2,588	$2,588	$2,588	$2,588	$2,588	$2,588	$2,588	$2,588	$2,588	$2,588
Operation costs (Fuel cost)		$114	$114	$114	$114	$114	$114	$114	$114	$114	$114
Maintenance Cost		$0	$0	$0	$0	$0	$0	$0	$0	$0	$0

Y/a

Total Tariff Flow		$6,811	$6,811	$6,619	$6,234	$5,850	$5,466	$5,082	$4,698	$4,314	$3,930
NPV of tariff	$34,397										
Normalized tariff	$5,284										
Per unit tariff from consumers	[illegible]	per MMBTU	[illegible]	per MMBTU							

Cost of Capital	**Debt**	**Equity**	**ROE**
Debt Equity Ratio for investment (nominal)	75	25	
Interest Rate	10.0%	16.0%	16%
Subsidy on interest	0.5%	0.0%	
Nett Interest Rate	9.5%	16.0%	
Weighted Debt Equity	7.1	4	
Weighted average interest	[illegible]		

A.3.1 Tariffs Charged by Power Utilities in India

Grid tariffs for *commercial consumer category* connections as obtained from the national council of power utilities (TARIFF schedules of electric power supply utilities in India 2002 as on 31.03.2002)

Table A.3.1.1

Grid Tariffs			
	State	Energy Rate (Rs./kWh)	Energy Demand Rate (Rs./kW/month)
1.	New Delhi	4.40	200
2.	Haryana	4.25	120
3.	Uttar Pradesh	4.40	60
4.	Gujarat	4.70	75
5.	Madhya Pradesh	4.34	90
6.	Maharashtra	3.90	60
7.	BSES	5.15	20
8.	Ahmedabad Electric Company	2.75	30
9.	Tata Power Company	2.72	400
10	Andhra Pradesh	7.45	200
11	Karnataka	4.30	180
12	Kerala	2.65	290
13	Tamil Nadu	4.35	25
14	Bihar	2.90	120
15	Orissa	3.20	250
16	West Bengal	4.90	80
17	Sikkim	4.00	250
18	Andaman and Nicobar	4.30	0
19	Meghalaya	3.40	110
20	Nagaland	3.80	75
21	Tripura	3.60	363
Mode value		**4.40**	**200**

A.4.1 CERC (Central Electricity Regulatory Commission) Tariff Guidelines

Debt Equity Ratio for investments in project:	**70:30**
Return on Equity	**16%**
Depreciation	**Over 10 yrs.**
Salvage	**10%**

(Depreciation is also in agreement with Indian Accounting Standard – 6)

A.4.1.1 Ministry of Non-Conventional Energy Sources (MNES) Guidelines

Percentage aid on equity invested	**40%**
Depreciation Salvage value	**40%**

A.4.1.2 IREDA Lending/Financing Guidelines (2002-03)

Table A.4.1.3

IREDA Lending Norms

Category	Interest Rate % p.a.	Repayment (years)	Moratorium (max) (years)	Promoter's Contribution (%)	Lending Norms
Project Financing					
Biogas plants Based on Animal Dung/Agro residues and other Wastes					
Financial Intermediaries	9.5	8	2	25	upto 75% of total project cost
Direct Users	9.5	8	2	25	upto 75% of total project cost
Biogas plants Based on Human Excreta/Night Soil					
Financial Intermediaries	3.0	8	2	25	upto 75% of total project cost
Direct Users	3.0	8	2	25	upto 75% of total project cost

A.4.1.3 Indian Accounting Standard – 6

Statements of Accounting Standards (AS 6) Revised

Depreciation Accounting

The following is the text of the revised Accounting Standard (AS) 6, 'Depreciation Accounting', issued by the Council of the Institute of Chartered Accountants of India.

Introduction

1. This Statement deals with depreciation accounting and applies to all depreciable assets, except the following items to which special considerations apply:

   (i) forests, plantations and similar regenerative natural resources
   (ii) wasting assets including expenditure on the exploration for and extraction of minerals, oils, natural gas and similar non-regenerative resources
   (iii)expenditure on research and development
   (iv)goodwill
   (v) live stock

   This statement also does not apply to land unless it has a limited useful life for the enterprise.

2. Different accounting policies for depreciation are adopted by different enterprises. Disclosure of accounting policies for depreciation followed by an enterprise are necessary to appreciate the view presented in the financial statements of the enterprise.

Definitions

3. The following terms are used in this Statement with the meanings specified:

3.1 Depreciation is a measure of the wearing out, consumption or other loss of value of a depreciable asset arising from use, effluxion of time or obsolescence through technology and market changes. Depreciation is allocated so as to charge a fair proportion of the depreciable amount in each accounting period during the expected useful life of the asset. Depreciation includes amortization of assets whose useful life is predetermined.

3.2 Depreciable assets are assets which

   (i) are expected to be used during more than one accounting period
   (ii) have a limited useful life and
   (iii)are held by an enterprise for use in the production or supply of goods and services, for rental to others, or for administrative purposes and not for the purpose of sale in the ordinary course of business.

3.3 Useful life is either (i) the period over which a depreciable asset is expected to be used by the enterprise or (ii) the number of production or similar units expected to be obtained from the use of the asset by the enterprise.

3.4 Depreciable amount of a depreciable asset is its historical cost, or other amount substituted for historical cost in the financial statements, less the estimated residual value.

Explanation

4. Depreciation has a significant effect in determining and presenting the financial position and results of operations of an enterprise. Depreciation is charged in each accounting period by reference to the extent of the depreciable amount, irrespective of an increase in the market value of the assets.

5. Assessment of depreciation and the amount to be charged in respect thereof in an accounting period are usually based on the following three factors:

   (i) historical cost or other amount substituted for the historical cost of the depreciable asset when the asset has been revalued
   (ii) expected useful life of the depreciable asset and
   (iii)estimated residual value of the depreciable asset

6. Historical cost of a depreciable asset represents its money outlay or its equivalent in connection with its acquisition, installation and commissioning as well as for additions to or improvement thereof. The historical cost of a depreciable asset may undergo subsequent changes arising as a result of increase or decrease in long term liability on account of exchange fluctuations, price adjustments, changes in duties or similar factors.

7. The useful life of a depreciable asset is shorter than its physical life and is:

   (i) pre-determined by legal or contractual limits, such as the expiry dates of related leases
   (ii) directly governed by extraction or consumption
   (iii) dependent on the extent of use and physical deterioration on account of wear and tear which again depends on operational factors, such as, the number of shifts for which the asset is to be used, repair and maintenance policy of the enterprise etc.and
   (iv) reduced by obsolescence arising from such factors as:

      (a) technological changes
      (b) improvement in production methods
      (c) change in market demand for the product or service output of the asset or
      (d) legal or other restrictions

8. Determination of the useful life of a depreciable asset is a matter of estimation and is normally based on various factors including experience with similar types of assets. Such estimation is more difficult for an asset using new technology or used in the production of a new product or in the provision of a new service but is nevertheless required on some reasonable basis.

9. Any addition or extension to an existing asset which is of a capital nature and which becomes an integral part of the existing asset is depreciated over the remaining useful life of that asset. As a practical measure, however, depreciation is sometimes provided on such addition or extension at the rate which is applied to an existing asset. Any addition or extension which retains a separate identity and is capable of being used after the existing asset is disposed of, is depreciated independently on the basis of an estimate of its own useful life.

10. Determination of residual value of an asset is normally a difficult matter. If such a value is considered insignificant, it is normally regarded as nil. On the contrary, if the residual value is likely to be significant, it is estimated at the time of acquisition/installation, or at the time of subsequent revaluation of the asset. One of the bases for determining the residual value would be the realizable value of similar assets which have reached the end

of their useful lives and have operated under conditions similar to those in which the asset will be used.

11. The quantum of depreciation to be provided in an accounting period involves the exercise of judgment by management in the light of technical, commercial, accounting and legal requirements and accordingly may need periodical review. If it is considered that the original estimate of useful life of an asset requires any revision, the unamortized depreciable amount of the asset is charged to revenue over the revised remaining useful life.

12. There are several methods of allocating depreciation over the useful life of the assets. Those most commonly employed in industrial and commercial enterprises are the straight-line method and the reducing balance method. The management of a business selects the most appropriate method(s) based on various important factors e.g., (i) type of asset, (ii) the nature of the use of such asset and (iii) circumstances prevailing in the business. A combination of more than one method is sometimes used. In respect of depreciable assets which do not have material value, depreciation is often allocated fully in the accounting period in which they are acquired.

13. The statute governing an enterprise may provide the basis for computation of the depreciation. For example, the Companies Act, 1956 lays down the rates of depreciation in respect of various assets. Where the management's estimate of the useful life of an asset of the enterprise is shorter than that envisaged under the provisions of the relevant statute, the depreciation provision is appropriately computed by applying a higher rate. If the management's estimate of the useful life of the asset is longer than that envisaged under the statute, depreciation rate lower than that envisaged by the statute can be applied only in accordance with requirements of the statute.

14. Where depreciable assets are disposed of, discarded, demolished or destroyed, the nett surplus or deficiency, if material, is disclosed separately.

15. The method of depreciation is applied consistently to provide comparability of the results of the operations of the enterprise from period to period. A change from one method of providing depreciation to another is made only if the adoption of the new method is required by statute or for compliance with an accounting standard or if it is considered that the change would result in a more appropriate preparation or presentation of the financial statements of the enterprise. When such a change in the method of depreciation is made, depreciation is recalculated in accordance with the new method from the date of the asset coming into use. The deficiency or surplus arising from retrospective recompilation of depreciation in accordance with the new method is adjusted in the accounts in the year in which the method of depreciation is changed. In case the change in the method results in deficiency in depreciation in respect of past years, the deficiency is charged in the statement of profit and loss. In case the change in the method results in surplus, the surplus is credited to the statement of profit and loss. Such a change is treated as a change in accounting policy and its effect is quantified and disclosed.

16. Where the historical cost of an asset has undergone a change due to circumstances specified in Paragraph 6 above, the depreciation on the revised unamortized depreciable amount is provided prospectively over the residual useful life of the asset.

Disclosure

17. The depreciation methods used, the total depreciation for the period for each class of assets, the gross amount of each class of depreciable assets and the related accumulated depreciation are disclosed in the financial statements along with the disclosure of other accounting policies. The depreciation rates or the useful lives of the assets are disclosed only if they are different from the principal rates specified in the statute governing the enterprise.

18. In case the depreciable assets are revalued, the provision for depreciation is based on the revalued amount on the estimate of the remaining useful life of such assets. In case the revaluation has a material effect on the amount of depreciation, the same is disclosed separately in the year in which revaluation is carried out.

19. A change in the method of depreciation is treated as a change in an accounting policy and is disclosed accordingly.

Accounting Standard

(The Accounting Standard comprises paragraphs 20-29 of this statement. The Standard should be read in the context of paragraphs 1-19 of this statement and of the 'Preface to the Statements of Accounting Standards'.)

20. The depreciable amount of a depreciable asset should be allocated on a systematic basis to each accounting period during the useful life of the asset.

21. The depreciation method selected should be applied consistently from period to period. A change from one method of providing depreciation to another should be made only if the adoption of the new method is required by statute or for compliance with an accounting standard or if it is considered that the change would result in a more appropriate preparation or presentation of the financial statements of the enterprise. When such a change in the method of depreciation is made, depreciation should be recalculated in accordance with the new method from the date of the asset coming into use. The deficiency or surplus arising from retrospective recompilation of depreciation in accordance with the new method should be adjusted in the accounts in the year in which the method of depreciation is changed. In case the change in the method results in deficiency in depreciation in respect of past years, the deficiency should be charged in the statement of profit and loss. In case the change in the method results in surplus, the surplus should be credited to the statement of profit and loss. Such a change should be treated as a change in accounting policy and its effect should be quantified and disclosed.

22. The useful life of a depreciable asset should be estimated after considering the following factors:

    (i) expected physical wear and tear
    (ii) obsolescence
    (iii)legal or other limits on the use of the asset

23. The useful lives of major depreciable assets or classes of depreciable assets may be reviewed periodically. Where there is a revision of the estimated useful life of an asset,

the unamortized depreciable amount should be charged over the revised remaining useful life.

24. Any addition or extension which becomes an integral part of the existing asset should be depreciated over the remaining useful life of that asset. The depreciation on such addition or extension may also be provided at the rate applied to the existing asset. Where an addition or extension retains a separate identity and is capable of being used after the existing asset is disposed of, depreciation should be provided independently on the basis of an estimate of its own useful life.

25. Where the historical cost of a depreciable asset has undergone a change due to increase or decrease in long term liability on account of exchange fluctuations, price adjustments, changes in duties or similar factors, the depreciation on the revised unamortized depreciable amount should be provided prospectively over the residual useful life of the asset.

26. Where the depreciable assets are revalued, the provision for depreciation should be based on the revalued amount and on the estimate of the remaining useful lives of such assets. In case the revaluation has a material effect on the amount of depreciation, the same should be disclosed separately in the year in which revaluation is carried out.

27. If any depreciable asset is disposed of, discarded, demolished or destroyed, the nett surplus or deficiency, if material, should be disclosed separately.

28. The following information should be disclosed in the financial statements:

    (i) the historical cost or other amount substituted for historical cost of each class of depreciable assets;
    (ii) total depreciation for the period for each class of assetsand
    (iii)the related accumulated depreciation.

29. The following information should also be disclosed in the financial statements along with the disclosure of other accounting policies:

    (i) depreciation methods usedand
    (ii) depreciation rates or the useful lives of the assets, if they are different from the principal rates specified in the statute governing the enterprise.

A.4.1.4 Customs and Import Duty Tariff

Basic Import duty (cumulative)	25%
Additional Import duty (cumulative)	16%
Custom wheeling duty (cumulative)	4%
Additional FOB (freight-on-board charge)	14%

Note: A basic import duty of 20% is levied on equipment imported as renewable energy source, only; the additional import duty and custom wheeling duty are not to be levied.

A.4.1.5 Income Tax

Tax @ 35% after a tax holiday of 10 years as per 80 (IA) of Income Tax Act for Biogas/ Renewable sources of energy
Absolute tax rate has been calculated on mean value of tax liability incurred by electric utility companies.

Table A.4.1.6

Average Tax liability for Power Utilities			
Utility Company	Income before taxes (A) INR Crore	Tax incurred (B) INR Crore	Tax =(A/B)%
BSES Ltd.	301.83	32.04	10.6%
Tata Power Ltd.	671.84	163.61	24.4%
Ahmedabad Electric Co.	3,458.00	1,759.00	51.0%
NTPC Ltd.	4,115.81	199.04	4.8%
PGCIL	779.91	99.97	12.8%
Mean Value	Ó(A) 9,327.39	Ó(B) 2,253.66	24.2%

Year Ended March 31, 2002

A.4.1.6 Foreign Exchange Rate

1 US $ = **48.73** Indian Rupee
As on August 7, 2002

A.5.1 PRE-TAX AND PRE-SUBSIDY QUANTITATIVE RESULTS AND FINDINGS BY "DER" METHOD

Table A.5.1

Pre-Tax and pre-subsidy "DER" Cost of Electricity quantitative evaluation					
Vendor	Capstone turbine			Turbec	IR
Calculations for Cost of Electricity @ base load operation only	C30 Biogas	C30 Liquid fuel Diesel (HSD)	C60 HPNG	T100	70LM / 70 SM - 2001
Hours/day	19.2	19.2	19.2	19.2	19.2
Days/year	365	365	365	365	365
Operational hours/year	7,008	7,008	7,008	7,008	7,008
Total hours/year	8,760	8,760	8,760	8,760	8,760
Capacity Factor (CF)	0.8	0.8	0.8	0.8	0.8
Capital Cost ($/kW)	$ 1,374.20	$ 1,748.30	$ 1,510.70	$ 1,289.30	$ 1,569.10
Capacity (kW)	30	29	60	100	70
Life of Machine (in years)	5	5	5	5	5
Fixed Charge Rate (FCR)	0.2	0.2	0.2	0.2	0.2
Efficiency	25.0%	25.0%	28.0%	28.5%	28.5%
Heat Rate of Gen system (in BTU/kWh)	13,100	13,700	12,200	11,940	14,290
Total installed cost per kW ($/kW)	$ 2,897.70	$ 1,837.10	$ 1,553.60	$ 1,582.60	$ 1,626.30
Capital Cost and Installation Cost($/kWhr)	0.083	0.052	0.044	0.045	0.046
	75%	25%	51%	51%	47%
Operational and Maintenance Cost ($/kWhr)	0.010	0.010	0.010	0.011	0.013
	9%	5%	11%	12%	13%
Fuel price (FP, in $/BTU)	0.0000014	0.0000106	0.0000027	0.0000027	0.0000027
Fuel Cost ($/kWh)		0.145	0.033	0.032	0.039
	16%	70%	38%	36%	39%
COST OF ELECTRICITY (COE) in USD	$ 0.111	$ 0.208	$ 0.087	$ 0.088	$ 0.098
Current Foreign Exchange Rate	48.73	*as on date*	*12-Aug-2002*		
COST OF ELECTRICITY (COE) in INR	Rs 5.41	Rs 10.12	Rs 4.25	Rs 4.31	Rs 4.76
EXCEEDS COST OF ELECTRICITY FROM GRID BY	Rs 1.01	Rs 5.72		Rs (0.09)	Rs 0.36

A.5.2 PRE-TAX AND PRE-SUBSIDY QUANTITATIVE RESULTS AND FINDINGS BY "NPV" METHOD

Table A.5.2

Pre-Tax and pre-subsidy "NPV" Cost of Electricity quantitative evaluation

Vendor	**Capstone turbine**			**Turbec**	**IR**
Calculations for Cost of Electricity	**C30 Biogas**	**C30 Liquid fuel**	**C60 HPNG**	**T100**	**70LM / 70 SM - 2001**
@ base load operation only		Diesel (HSD)			
Capacity of Generating unit (kW)	*30*	*29*	*60*	*100*	*70*
Installed Cost ($)	*86,931*	*53,276*	*93,216*	*158,260*	*113,841*
Nett Present Value of Project Savings	*$37,666*	*($81,495)*	*$78,368*	*$128,457*	*$68,556*
Nett Present Value of Tariff	*$102,768*	*$234,130*	*$198,077*	*$334,281*	*$259,717*
Debt Ratio	*75.0%*	*70.0%*	*70.0%*	*70.0%*	*70.0%*
Weighted Average Interest Rate of Borrowing	*11.1%*	*11.8%*	*11.8%*	*11.8%*	*11.8%*
Equity Investment	*$13,040*	*$15,983*	*$27,965*	*$47,478*	*$34,152*
Ratio of Project savings NPV to Equity investment	2.9	-5.1	2.8	2.7	2.0
5 year Cumulative savings	*$45,278*	*($68,920)*	*$96,229*	*$158,865*	*$90,877*
10 year Cumulative savings	*$92,063*	*($128,517)*	*$208,770*	*$345,426*	*$201,675*
Internal Rate of Return	*86%*	*Negative returns*	*67%*	*65%*	*52%*
Payback period (years)	**9.6**	*Negative returns*	***4.8***	***5.0***	***6.3***
Normalized savings ($/kWh) nett of taxes	0.028	*(0.063)*	*0.029*	0.029	0.022
Rs./kWh	*1.34*	*(3.07)*	*1.43*	*1.40*	*1.07*
Normalized tariff ($/kWh)	*0.075*	*0.181*	*0.074*	*0.075*	0.083
Rs./kWh	*3.66*	*8.81*	*3.60*	*3.65*	*4.05*
Percentage Savings nett of taxes	*37%*	*-35%*	*40%*	*38%*	*26%*
Cost of Electricity ($/kWh) by NPV*	**0.048**	**0.244**	**0.045**	**0.046**	**0.061**
Cost of Electricity (Rs./kWh) by NPV*	**2.32**	**11.88**	**2.18**	**2.25**	**2.98**