

CHP FOR RURAL INDIA - A CONCEPT PAPER

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Introduction

India is a predominantly a rural oriented country. Notwithstanding the present growth rates, it would be a long time before the population in the villages exceed the population in the urban areas.

It is also accepted that the urbanisation adds much more pressure and expenses in providing civic amenities, especially the water and sewage facilities.

Enough has been said about the energy demand projection outgrowing the energy generation with respect to electricity.

As India's Energy demand increase, Her contribution to global warming is also likely to increase – Already there is a lot of pressure about India's need to start looking at reduction of greenhouse gases.

Thus, we are having four independent problems, namely,

1. Rural economy improvement
2. “de urbanisation”
3. Electrical energy shortage.

And consequent reduction of greenhouse gases.

The paper proposes to give direction on how the three problems can be tackled by decentralised energy generation.

The hypothesis is that most non-urban energy requirements, also require heating / cooling. Where such apparent need does not exist, processing of agricultural products using heat can either be introduced, or energy generation can become a part of any heating process.

Two real life cases, based on a tea estate, and the other for a hotel in a remote island are discussed, to prove the feasibility of such application, technically. They are also expected to be economically viable, though the details are not discussed.

The available technologies for such a system are discussed, with stress on a long term direction to look at the small turbine based CHP, compared to heat recovery from “diesel” or compression ignition based generation.

Why decentralised generation

The centralised generation in India is dependant of fossil fuels, with only 25% being hydro, and 3% being nuclear on installed capacity. (figures from CEA -2005).

**ALL INDIA INSTALLED CAPACITY (IN MW) OF POWER STATIONS LOCATED
IN THE REGIONS OF MAIN LAND AND ISLANDS AS ON 31.03.2006**

Ownership	Modewise breakup				Thermal Total	RES						Grand Total	
	Hydro	Thermal				Nuclear	SHP	Wind	B.G	BP	U&I		Total
		Coal	Gas	Diesel									
State	25247.62	38305.00	3499.72	604.61	42409.33	0.00	777.48	1790.05	0.00	0.00	0.00	2567.53	70224.48
Private	906.15	4241.38	4771.20	597.14	9609.72	0.00	0.00	2643.85	77.00	867.53	34.95	3623.33	14139.20
Central	6172.00	25972.50	4418.99	0.00	30391.49	3360.00	0.00	0.00	0.00	0.00	0.00	0.00	39923.49
Total	32325.77	68518.88	12689.91	1201.75	82410.54	3360.00	777.48	4433.90	77.00	867.53	34.95	6190.86	124287.

Abbreviation: SHP = Small Hydro Project, B.G= Biomass Gasifier, B.P= Biomass Power, U&I= Urban & Industrial Waste Power, RES= Renewable Energy Sources.

With the present technology, the thermal efficiency of these generating stations are in the range of 25 - 28%. The CHP in centralised generation practised for district heating in the west would not be applicable due to the tropical climate. The centralised air-conditioning, can become a reality in urban building clusters, but are along way as a general requirement.

However, when each rural requirement is considered as a predominantly an agricultural based economy, heat can be used for agricultural processing. The other major rural produce of India is milk. The cooling requirement of milk chilling centres can be met by the heat available during electricity generation. Chilling can also be of big economic advantage where perishables, such as vegetables, flowers, fish etc are produced.

Thus, the thermal efficiency of a decentralised system can go beyond 80% - a big leap from 28% in centralised generation. Further, the available technologies make it possible to use the biowaste as an energy source, making the generation cost very low. The avoidance of transmission cost would further contribute to low cost power for the end user.

The potential power from biowaste is estimated to be 16000 MW, as per the report from MNES.

“The availability of biomass in India is estimated at about 540 million tonnes per year covering residues from agriculture, forestry, and plantations. Principal agricultural residues include rice husk, rice straw, bagasse, sugar cane tops and leaves, trash, groundnut shells, cotton stalks, mustard stalks, etc. It has been estimated that about 70-75% of these wastes are used as fodder, as fuel for domestic cooking and for other economic purposes leaving behind 120-150 millions tonnes of usable agricultural residues per year which could be made available for power generation. By using these surplus agricultural residues, more than 16,000 MW of grid quality power can be generated with presently available technologies. In addition, around 3,500 MW of power can be produced, if all the 500 sugar mills in the country switch over to modern techniques of co-generation. Thus, the country is considered to have a biomass power potential of about 19,500 MW.”

Of the above, hardly 77MW is utilised. (ignoring bagasse Power from sugar mills)

As many states provide free power to agriculturists, low cost generation would mean less cost to the exchequer. The investment for such a venture being comparable to that of centralised generation, the free fuel source would make it economically attractive.

These decentralised generation would also provide rural employment to skilled, semi-skilled and unskilled manpower – without considering the employment generation by processing of agricultural based produce.

Thus, both from the economic and environment point of view, the decentralised generation has a big attraction.

Energy security and energy independence

India imported 99.4 million tonnes of crude oil for \$38.77 billion and 11.67 million tonnes of petroleum products for \$5.86 billion, and 11-12 Million tons of coal (for power production) in 2005-06. Though India has coal reserves to last for the next 200 years, the coal is of low grade and the extraction and beneficiation costs makes it less attractive.

India is looking at first establishing that her economy is not affected by not getting the required quantity of energy source, in the form it is required. Obviously, it requires lot of trade-off and a considerable price to achieve this energy security.

Achieving energy independence seems to be a more difficult goal to achieve.

Let us consider the energy security and energy independence at the village level. Many villages in India are supposed to be provided with free/heavily subsidised electricity. There are 25.6 % villages which have not been provided with any electricity.

The 2006 CEA report states

“During 2005-06, 2191 number of inhabited villages have been electrified and 357993 Pumpsets have been energised. Cumulatively, 441991inhabited villages constituting 74.4 % have been electrified out of a total of 593732 inhabited villages as per 2001 census and 14803007 pumpsets have been energised in the country.”

Even where the electricity connection is available, electricity availability is uncertain – resulting in direct monetary loss both in terms of poor yield and equipment failures.

And, the other energy needs such as cooking and processing fuels depend either on depleting traditional fuels such as fire wood, or charcoal.

While this is going on, tons of biowaste, such as stems of plants like pulses, sugar cane leaves and prune litter etc., are either burnt or allowed to decompose. When burnt, the CO₂ is produced along with particulate pollution, and when allowed to decompose methane is produced – both being green house gases, and the energy is allowed to dissipate into the atmosphere.

Thus, finding a way to convert this into useful fuel as methane through biomethanisation, or gasification, these can be used to run conventional diesel engines / micro turbines. Large systems of 4 MW and above can also be done on steam generation – power from steam route.

The waste heat from micro turbine exhaust or diesel engine (both exhaust and jacket cooling) can be converted into heat and used as heat for agro-processing, centralised cooking, or for chilling (through pollution free, maintenance free, adsorption chilling)

The combined effect of high thermal efficiency, distributed generation and low cost fuel enables the electricity to be provided at affordable rate – or would cause drastic reduction in the subsidy.

Rural employment / Improvements

Rs.14000 Crores of the budget has been allocated to the rural - Rural self sufficiency in energy will help in this in the following ways. Rs 16000 Crores has been allocated for rural electrification in 11th plan. Obviously such large expenditure should be made with maximum returns – both financially and socially.

1. The energy generation, distribution, agro-processing, fuel collection, fuel processing etc., will provide direct employment
2. Availability of energy as required would improve village prosperity, and provide secondary employment

3. By providing urban comforts in rural area, (Our Hon. president Dr Kalam's PURA) the educated would have an incentive to stay in rural areas, and create role models for the village population
4. India's competitiveness would improve in the international market.
5. More industries requiring thermal energy / cooling would migrate to rural areas, and reverse the urbanisation trend.

Thus, it makes sense to seriously work on demonstration projects and invest on research to reduce the costs / improve the reliability.

Many technologies are available, and are at various stages of commercialisation. The market in US on bio-gasification is expected to be in projected by one of the start-up firms. Different technologies would be discussed, with emphasis on the status of the micro-turbine (below 300 kWe).

Major technologies available

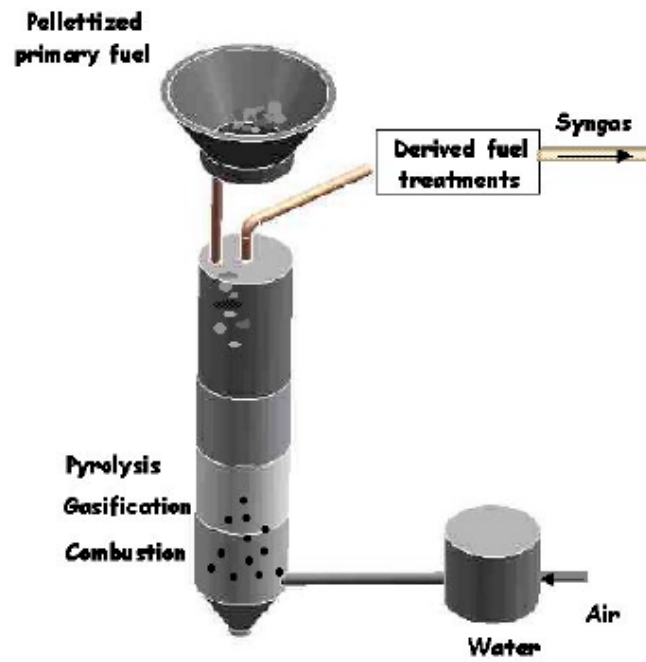
The micro CHP technologies can be grouped two major categories, external combustion route and internal combustion route

Group	description	Mechanical / electricity	Thermal power	remarks
External combustion	Stream boiler and turbine	Steam turbine	steam	Most conventional and used in industries. Number of micro turbines are available in the market
	Sterling engine	Sterling engine	Any desired form, using the heat after sterling engines	Mechanical construction problems are restriction the popular use of this technology
	Fuel cells	Fuel cells	Any desired form, after electricity production in high temperature fuel cells.	Technical viability is established – commercial viability is being improved by research. Requires hydrogen or hydrogen rich fuels.
Internal combustion	Bio gas – IC engines	IC engines	Exhaust of IC engines and engine cooling	A mix of medium and low temperature sources. Gas has to be cooled and treated
	Gasification of biomass – IC engines			
	Bio gas – micro-turbine	From exhaust	Higher temperature single source for heat enables more flexibility. Technically, higher temperature gas can be used in turbine, enabling even more thermal recovery	
	Gasification of biomass – micro turbine			

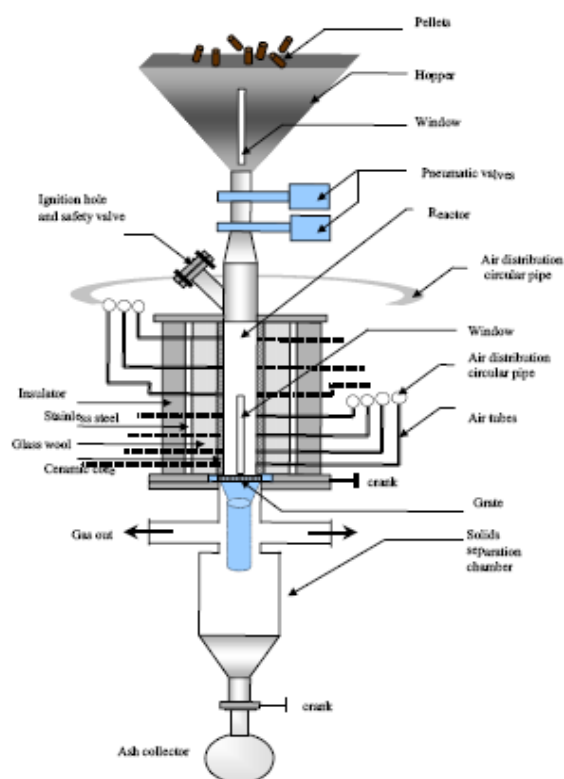
For chilling, absorption refrigeration has been more popular, but the use of lithium bromide, a possible pollutant encourages use of ammonia where higher temperature heat is available.

Adsorption refrigeration has no polluting component, and can be used with very low temperature heat source, say even at 50 Deg C.

Typical “up-draft” gasifier



Typical down-draft gasifier



Present micro CHP status in India

Two major designs are commercialised for biomass gasification and IC engine applications.

Downdraft technology by IISc Bangalore, and their licensees and similar technology by Ankur energy systems of Vadodara have many Biomass gasification – IC engine systems from 5 Kw to 200 KW – higher capacity systems are in the process.

The MNES program for co-generation states

“BIOMASS POWER / CO-GENERATION PROGRAMME

The Biomass Power/Co-generation Programme is being implemented with the following objectives:

- To promote co-generation, biomass combustion, megawatt scale gasification, and industrial co-generation.
- To develop Biomass Resource Atlas based on biomass resource assessment studies in different regions of the country.
- To support R&D for development of technologies including Advanced Biomass Gasification and 100% producer gas engines, as well as applications research for enhancement of potential in identified areas of thrust.
- To support and thus enlarge activities through awareness creation, publicity measures, seminars/workshops/business meets etc.”

The use of biogas for electricity generation in India is rare and has only a few application, with the 1 MW plant in punjab (details in the annexure 1) being one of the few.

A list of few industry based electricity generation through biogas are given in annexure 2

But there is hardly any application of CHP in these small application.

It is the application of CHP technique which will make the biogas / gasification much more attractive, and can be tried without looking at large industries.

One rare example of cooling in rural area is remaining as technology demonstration project.

“Biomass Based Cold Storage Systems for Rural Area Applications” - Anna University, Chennai

A Biomass Gasifier based direct fired vapour absorption cold storage system for rural areas has been designed and 60-75% diesel saving has been achieved. It has been found that real co-efficient of performance of the system is between 0.4 – 0.2. The cost of such a system is expected to be lower than the presently available conventional compression based units. The system will make it possible to store fruits and vegetables up to 10 MT capacity at 2-4o C.

Case studies for CHP are rarer to find.

MICRO TURBINE status in India

IISC Bangalore in collaboration with IIT-Chennai, BHEL , IICT are in the process of developing a micro turbine to use the gas produced from their down-draft gasifiers.

The MNES report quotes

“ A multi-institutional co-ordinated project on “Advanced Biomass Gasification” (ABG) is also being implemented at IISc, which aims at the development of a high pressure gasifier coupled with gas turbine engines for generation of power. The work on the high pressure gasifier for gas turbine application has progressed with contributions from three other participating institutions, namely, Indian Institute of Technology (IIT), Chennai; Indian Institute of Chemical Technology (IICT), Hyderabad; and Bharat Heavy Electrical Ltd. (BHEL), Tiruchirapalli. The high-pressure gasifier has been tested using woody biomass and briquettes of coffee husk with bagasse and pure sawdust. The gas turbine has been operated using the modified combustor with producer gas fuel at close to possible outputs of the system. Various parameters related to these tests namely the gas composition, pressure, temperatures and biomass consumption have been recorded and analysed. Similarly the gas quality in terms of tar and particulate matter has been examined. The control system for governing of gas turbine operations has been built and initial tests carried out.”

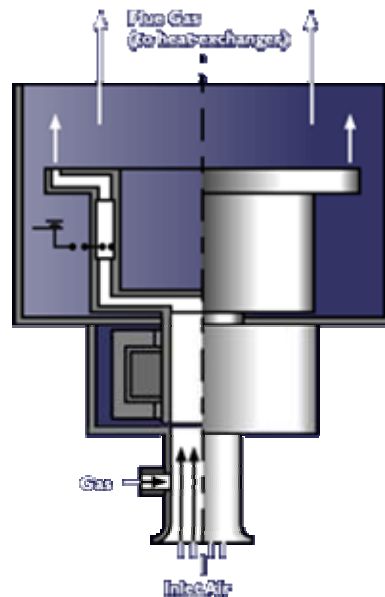
MICRO TURBINE STATUS in the world

Both in United States and Europe, the micro turbine of <300 kW are commercialised and are freely available for CHP. As a thumb rule, the micro-turbine would cost about 800 US\$, or less than Rs 4000/kWe.

The thermal efficiency is about 27-28%, and the balance is available as heat. Thus, the micro turbine becomes an ideal choice for CHP applications. The heat recovery need not become complicated with

An ad for secondhand micro turbine is given in the annexure 3

A commercial model from Europe



A typical commercial Specification from US of A

Renewable CR65 & CR65-ICHP

MicroTurbine Performance Specifications(1)

Electrical Performance

Electrical Power Output 65 kW

Voltage 400 to 480 VAC

Electrical Service 3-Phase

Frequency 50/60 Hz

Maximum Output Current 100A, Grid Connect Operation

Electrical Efficiency LHV 29%

Fuel/Engine Characteristics

CR65 MicroTurbine Type Landfill Gas Digester Gas

Raw Natural Gas HHV 350 to 600 BTU/scf 550 to 875 BTU/scf

H₂S Content < 400 ppmv

Inlet Pressure 75 psig (5.2 barg)

Fuel Flow LHV 765,000 BTU/hr (807,000 kJ/hr)

Generator Heat Rate LHV 11,000 BTU/kWh (11,600 kJ/kWh)

Exhaust Characteristics

Exhaust Gas Flow 1.08 lb/sec (0.49 kg/s)

Exhaust Gas Temperature 588°F (309°C)

CR65-ICHP Heat Recovery(2)

Integrated Heat Recovery Module Type Stainless Steel Core

Hot Water Heat Recovery 251,000 BTU/hr (74 kW)

Total System Efficiency LHV 62%

Dimensions & Weight CR65 CR65-ICHP

Width x Depth x Height 30 x 77 x 83 inches 30 x 77 x 94 inches

Weight 1,671 lbs (758 kg) 2,200 lbs (1,000 kg)

Certifications

Classified UL 2200 and UL 1741 for raw natural gas and biogas operation (UL file AU5040)

Meets statewide utility interconnection requirements for California Rule 21 and the New York State Public Service Commission

Materials Equipment Acceptance (MEA) approval for New York City

Models available with optional equipment for CE Marking

Abstract of field experiment in Europe

OPERATIONEL EXPERIENCES FROM MICRO-TURBINE ENERGY SYSTEMS – "THE OMES PROJECT"

AKSEL HAUGE PEDERSEN - DONG A/S, DENMARK

Abstract

The experiences gathered in this paper covers 18 micro turbines of 100 kW. The project has been running from September 2001 through April 2004, and conclusions will be presented in this paper. The scope for the project was primarily to validate data on performance, energy efficiency, availability, economy and emission for micro turbines at different applications and fuels. The installations covered are industrial, commercial as well as domestic. **All based upon a 100 kW micro-turbine manufactured by Turbec, Sweden.** The different applications were:

- ☐ Flexible steam generation
- ☐ CO₂ fertilization in greenhouses
- ☐ Cooling
- ☐ Traditional CHP (Schools, Business Centres, etc.)
- ☐ Cluster installation of microturbine CHP units

The general criteria of success for the developed and tested OMES microturbine based CHP units were:

- ☐ Power Efficiency > 30 % during full load operation (ref. LCV)
- ☐ Overall efficiency > 80 % (ref. LCV)
- ☐ Availability > 90 %
- ☐ O/M Costs < 10 Euro/MWh e.
- ☐ Unit Cost < 800 Euro/kWe
- ☐ Emission levels < 15 ppm NO_x, @: 15% O₂

Experiences gathered are based upon more than 100.000 operating hours for the 18 involved demo plants. These experiences tells about a very power efficient unit, which in some cases have a power efficiency exceeding 30% (net). The unit price (excl installation) was in line with the target of 800 €/kW, but a realised price level for O/M costs of 12 - 15€/MWh slightly exceeding the target of 10 €/MWh. The goals for availability have been meet, still the overall efficiency is very dependent of the actual installation and the goal of 80% was not achieved. The measured numbers for NO_x are in line with the success criteria for the project of 15 ppm NO_x, @: 15% O₂.

Application 1 – Tea estate

This is a real tea estate in the plains of Assam. Since the proposal has not been implemented due to risk perception, the name of the estate is not disclosed.

Description	Information	Remarks
General Information		
Location of the estate	North Assam plains	
Area of the estate	About 500 hectares	
Annual production	0.7 Million Kgs of tea	The production is expected to increase with improved crop management
Daily tea leaves production (peak)	5000 – 6000 Kgs	
Average	2500 - 3000	
No of yield days/ year	250	No tea production during winter
Leaf / bio waste collected per year (wet basis)	2500 tons	
Cow dung purchased per year	500 tons	
Proposed increase of manure production	100%	
Annual prune litter production	150 – 200 tons	During three months of winter
Firewood (internal and bought)	200 tons per year	@ 1 ton / employee/per year, for domestic use
Energy Information		
Electrical energy requirements		
Peak demand (before study)	250 kW	
Units consumed per year	4.5 lakhs per year	
Peak demand projected	170 kW	
Units projected	3.8 lakh units per year	

Description	Information	Remarks
Thermal energy before study		
Coal	80 tons per year	
Furnace oil	90 KI per year	
'000 Kcals per year	1184000 per year	
Total energy bill per year	Rs 75 lakhs	
Potential energy available		
Solid content in cow dung	25%	
Solid content on leaves	20%	
Total solids	625 tons per year	
Total solids with increase manure production	1250	
Bio gas potential	0.4 to 0.5 Nm ³ per dry weight	
Total potential (min)	500,000 Nm ³ per annum	
Expected calorific value of biogas	3500 kCals/ Nm ³	
Expected units per Nm ³	1.1	
Total unit possible	5.5 lakh units per year	This exceed the projected demand , and leaves excess electricity for distribution amongst workers
Thermal energy requirement		
As per the coal and fuel oil usage	1.2 Billion kCals per year	
Thermal energy available from biogas, after generation (70%)	1.22 billion Kcals	
Possible recovery , say @80%	0.98 Billion kcals	
Short fall	0.22 Billion kcals	
prune litter required to make up the short fall	62 tons per year	Excess prune litter can be pelletised and distributed to the workers. Firewood consumption can be reduced at worker's quarters with high efficiency "choolas"

Thus, it is clear, right sized biogas generator, storage facility to take care of the demand variation, supplement by biomass gasification, for better reliability etc., can make this CHP application totally self sufficient, with very attractive financial terms. This process would also increase the manure quality and help reduce greenhouse gases, by reducing the methane to atmosphere. (CO₂ can be reabsorbed by the plants)

Application 2 – Hotel in an island

This case is for a hotel, which was to be located in island at sea, without any access to grid due to the huge expense of laying undersea cables.

The hotel was expected to be the only building in the island, which has lush vegetation, and lot of coconut trees. It was also meant to be essentially a convention centre with about a dozen rooms for the organisers, and limited accommodation for hotel staff.

Coconut pith was available in large quantities – which was allowed to decompose into natural manure.

The hotel's air-conditioning requirement is 200 TR (peak) and lighting load was 50KW, AC circulation load and AHU/FCU load was 40 KW and other loads 10 KW.

Thus, other than chiller load, the electrical demand was 100 KW. The non convention days the lighting load

was expected to be 15 KW and the air conditioning load was expected to be 15TR (peak)

To make the project economical, it was recommended that

1. The complete energy needs are met from coconut coir pith
2. Generator of 1 x 30 KVA and 2 x 65 KVA , but modified to use 90% gas from gasification of coir pith
3. The gas from coir pith to have excess capacity for adsorption refrigeration, over and above available from engines
4. Heat is recovered from turbine as pressurised hot water for use in adsorption chillers
5. Excess heat requirement of the adsorption refrigeration system to be met by gas fired hot water heater
6. Due to non acidic exhaust, the heat recovery to be more than conventionally possible , with target exhaust temperature very close to ambient.
7. Adsorption refrigeration system can be of 1x 100 tons and 2 x 50 tons capacity

The complete electricity would be met by coir pith based gas.

CHP considerations

Assumptions:

Convention days	200
Hours of usage	8 am to 8 pm
Night usage for convention dinners	50 days
Demand with season	Assumed constant
Demand variation within the day	Lighting is constant 100 kW for 12 hours, AC variation with peak 160 tons for 3 hours, 100 tons for 5 hours and 70 tons for 4 hours
Night demand on convention dinners 8pm -12 pm	70 tons and lighting 100 kW
Night time lighting load	15 KW
Night AC load	15 TR
Total AC load on convention days	1440 TR
Total AC load on non-convention days (60%) for 100 days (guests staying for organising / other reasons)	216 TR
No or limited guests – for 65 days – 20% AC load	72
Total tonnage of chiller load per year	280680
Units required for non chiller loads (convention days)	1380
Units required for chiller @ 0.7 KW per ton (convention days) and 0.9kw for 15 ton air-conditioning	162
Total units for convention days	1542
Convention nights consumption per year (= 70*0.9* 50)	3150
Total chiller units per year	196476
Total non chiller loads per year	388700
Total units per year	585176
@ 3 units per lit , litres of diesel (kL)	195.06
@ Rs 35/ litre cost of diesel (Rs lakhs)	68.27
If pith cost is neglected, investment on 3 year payback	204.81
Gas calorific value per kg of pith (80% efficiency 3500 kCals per kg))	2400
pith required for generator with average Electricity generation efficiency @28% (tons)	497.67
Heat available from generator (Mcals)	773983.88

Heat required for chiller @ COP of 0.9	848776.32
Shortfall of heat per year	74792.44
Pith required for covering the shortfall (tons)	31.16
Total pith required (tons)	528.84
Capacity of the gasifier (Kgs per hour)	297.85

This amount can easily meet the cost of gasifier and the adsorption chiller, and the heat recovery system – The cost of microturbine / diesel generator remaining same or less, with CHP, when compare to conventional method.

Additional savings in reduced transport of diesel, savings in cooking gas etc., would more than cover the cost of pith collection. Carbon credit, though eligible, would be too small for isolated application.

Due to very high variation in demand, thermal storage in terms of ice making can be considered by installing separate compression refrigeration chiller. Any attempt of using adsorption/ absorption refrigeration for ice making would reduce the COP below economic levels.

Comparison

Description	Conventional	CHP
Generator	300 KVA	160 KVA*
Compression refrigeration	200 TR	30 TR
Adsorption chiller	-	150 TR
Diesel	216 KL	-
Cost of diesel(Rs lakhs)	75	-
Pith requirement (Tons)	nil	528.84
Cost of pith @ Rs 250/ton for collection / transportation (Rs lakhs)	-	1.32
Carbon credit (70% C in diesel -54 kgs of CO2 per kg of C) tons	nil	289.17
Carbon credit Rs @ Rs 400/ton (Rs lakhs)		1.16

*Derated for use with gasified biomass

Application 3 - A village with 1000 households

Electrical Demand calculations	
Average demand to peak demand ratio	1.5
Unit per person per day (without heating/cooling)	0.5
Persons per household	5
No of households	1000
Energy requirement	2500
No of pump sets per household	0.25
Average rating of the pump	3.00
No of pumps	250
No of hours of operation (average)/ day	4
Energy requirements for the pump	3000
Total daily energy	5500
Average energy	229.17
Peak energy	343.75

Thermal efficiency	28%
Heat available	0.72
Recovery efficiency	80%
Heat available (average) Mcals /hr	405.62
COP of the adsorption chiller	0.7
Heat which can be removed /hr	283.93
Heat removal possible per day	6814.37
Possible milk production at 10 litres per household per day	10000
Heat to be removed for cooling the milk from 35 deg to 4 deg (delta T =31) Mcals	310
For a cold storage of 10 m x 10 m x 3 m , exposed area in sqM	220
For average heat gain of 0.3 kW /sqM per day, heat gain per day (kW)	66
Heat gain in Mcals	56.79
Additional heat removal possible	6447.58
Heat removal required per ton of vegetable and air change etc (Mcals)	400
Quantity of vegetables which can be cooled Tons	16.12

Similar application is possible for flowers, fishes etc., Additionally, if such cooling requirement is not required in the specific rural area, then food processing such as squash/jam preparation, papad dough making/ drying, agricultural product drying, sago and other food processing etc., as per the local availability of the agricultural product / energy source availability can be considered.

Summary

It is clear that the rural India has sufficient biomass, Current technology is economically viable when considered as CHP, and the social benefits are as attractive as economic benefits. Thus, sufficient investment has to be made by the government in “demonstration Units” as development, while research funding should match the commercial requirement. Any investment without field application would remain as a technology demonstration and would be difficult to replicate.

Thus, it is essential to shift focus from generation only to CHP and tap the 16000 + MW available for the asking.

The table below gives the gap in cost realisation of electricity cost. The application of CHP in rural areas would bridge this gap.

Average Cost of Supply and Average Realisation of Electricity from all Sectors (including Agriculture)

Year	Average Cost of Supply	Average Realisation (including Agriculture)	Gap
1980-81	41.90	32.30	9.60
1984-85	65.07	49.39	15.68
1989-90	105.68	78.58	27.10
1990-91	112.32	86.84	25.48
1991-92	120.23	95.32	24.91
1992-93	139.02	112.28	26.74
1993-94	154.78	125.27	29.51
1994-95	156.00	134.23	21.77
1995-96	179.38	151.28	28.10
1996-97	205.35	176.13	29.22

Year	Average Cost of Supply	Average Realisation (including Agriculture)	Gap
1997-98	228.16	192.79	35.37
1998-99	246.98	198.91	48.07
1999-00*	296.19	225.66	70.53
2000-01*	314.62	249.24	65.38
2001-02\$	348.33	266.99	81.34
2002-03@	335.49	287.44	48.05
2003-04**	239.00	202.00	37.00
2004-05**	250.00	208.00	42.00

* For 14 SEBs \$ For 8 SEBs @ For 9 SEBs **Source PFC data & Gap is without subsidy SEBs
(The data upto 2002-03 above, is based on the Annual Accounts of the SEBs)
(in Paise/Unit)

Annexure – 1

Details of the GE biogas based plant in Punjab

Jenbacher Biogas Engines Power Methane-to-Energy Plant in India

New Delhi, India [RenewableEnergyAccess.com]

A GE Energy Jenbacher biogas engine is powering a demonstration cattle manure-methane cogeneration plant at a dairy complex in Punjab, India, helping to address the region's mounting energy and environmental needs.

"Expanding the recycling of cow manure for energy and fertilizer, while simultaneously improving our air and water quality, is clearly within our mission to promote a sustainable energy future. We are increasingly looking for possibilities of establishing more such plants in the state of Punjab."

The Punjab Energy Development Agency (PEDA) installed and commissioned this demonstration power generation facility based on the biomethanation process of cow manure in an effort to reduce the facility's greenhouse gas emissions (methane has 21 times the greenhouse warming potential as carbon dioxide) and to prevent the improper disposal of the animal wastes.

Since late 2004, GE's 1-MW Jenbacher biogas cogeneration system has supported the model waste-to-energy conversion plant at the Haebowal dairy complex in the city of Ludhiana. The 50-acre complex, one of two centralized cattle facilities in Ludhiana, serves 1,490 dairy operations that own 150,000 head of cattle, generating 2,500 tons of manure daily. GE's Jenbacher demonstration project uses the biogas with high methane content created during the anaerobic digestion of 235 tons of cow manure per day to generate electricity and thermal power (hot water).

Surplus energy after meeting the plant auxiliary requirements from the engine is sold to the local grid of Punjab State Electricity Board (PSEB), while water heated by the engine is used to assist the fermentation process in the digester. In addition to the energy and thermal output of the plant, remnants from the digester process are used as fertilizer by local farmers.

"Expanding the recycling of cow manure for energy and fertilizer, while simultaneously improving our air and water quality," said Shri M.P. Singh, Senior Project Manager of PEDA, "is clearly within our mission to promote a sustainable energy future. We are increasingly looking for possibilities of establishing more such plants in the state of Punjab."

A few Success Stories from Waste-to-Energy :-

1. Biogas from Wastewater at Starch and Glucose Manufacturing Unit

M/s Vensa Biotek Ltd., Samalkot in A.P. produces starch and liquid glucose from about 40,000 metric tonnes of maize and about 25,000 metric tonnes of Tapioca Tuber, per annum. The process also generates about 1600 cum. per day liquid waste. A Biomethanation plant based on Upflow Anaerobic Sludge Blanket (UASB) technology along with aerobic system for secondary treatment has been installed for treating the waste water. The Biomethanation plant has been generating about 8000 cum. biogas everyday for the last one year. The biogas is not only leading to substantial savings in cost of fuel in the boiler but also results in large savings on cost of chemicals, which were required for wastewater treatment prior to installation of this project. The payback period of this project works out to about four years.

8000 cum. biogas per day Biomethanation plant at M/s Vensa Biotek Ltd., Samalkot, A.P.

2. Power from biogas at Distillery (1)

About 12000 cum. biogas per day being produced from Biomethanation plants installed for treating distillery wastewater (Spent wash) at M/s K M Sugar Mills (Distillery) Faizabad, U.P. is being utilized for generating power through the steam-turbine route for meeting the total electricity requirement of their distillery as well as that of their residential colony. The project has been performing satisfactorily for last four years and has been generating an average of about 4 lakh units of electricity every month. The payback period for such a project works out to be about 3-4 years.

1 MW biogas based power project at M/s K M Sugar Mills Ltd., (Distillery) Faizabad, U.P.

3. Power from biogas (2)

About 21000 cum. biogas per day being produced from Biomethanation Plants treating distillery wastewater (Spent wash) at M/s. Kanoria Chemicals and Industries Ltd., Ankleshwar, Gujarat is being utilized for generation of power required for their captive use. The project is based on two internal combustion engines fuelled by only biogas, each of 1.003 MW capacity. The waste heat of the flue gases of the engines, which is at a temperature of more than 500^oC, is also being utilized for generation of about 1.5 tonne per hour steam at about 130^oC. The steam is used for meeting process heat requirements. A H₂S removal plant based on a bio-chemical technology has also been installed to avoid the corrosion of biogas engines. The project has been performing satisfactorily for the last three years and generating about 10 lakh units of electricity every month. The payback period of this project works out to be about 3 years.

2 MW biogas based power project at M/s Kanoria Chemicals and Industries, Ankleshwar, Gujarat

4. Biogas from Slaughterhouse Wastes

M/s Alkabeer Exports Ltd. (AKEL) have an integrated meat processing unit at Rudraram Village (35 km from Hyderabad) in Medak Distt. of Andhra Pradesh. Solid and liquid waste being generated during slaughtering and processing of meat is being treated through biomethanation plants. While about 2000 cubic metre biogas is being generated from liquid wastes thus reducing the COD content by 75-80% and BOD₅ content by 85-90%, about 2500 cubic metre biogas is being generated from solid wastes. Adoption of biomethanation technology has resulted in saving of furnace oil as well as chemicals used for treatment of wastewater. The sludge from the anaerobic digester is dried and is being marketed as a nutrient rich soil conditioner.

Biomethanation of slaughterhouse waste at Al Kabeer, Medak, A.P.

5. Biogas from Tannery Wastes

In India has about 1600 tanneries with total processing capacity of 0.7 million tonnes of raw hides and skins. Fleshing and sludge are the two wastes emanating from tannery and treatment of tannery wastewater. A project for demonstration of application of biomethanation technology for treatment of tannery fleshing and sludge from tannery effluent treatment plants has been set up at Visharam Tanners Enviro Control Systems (VISTECS), Melvisharam, Tamil Nadu. The plant has been designed to handle about 3 tonnes of tannery fleshing and 2 tonnes of primary sludge from ETP. The generated biogas is then used for generation of

electricity in a dual fuel engine



Biomethanation of Tannery Fleshings and Sludge at Melvisharam, Tamilnadu

6. Biogas from Pulp and Paper Mill (Black Liquor)

Pulp and Paper Industry is considered to be one of the highly polluting industries and consumes large amount of energy and water in various unit operations. The wastewater discharged by this industry is highly heterogeneous as it contains compounds from wood or other raw materials, processed chemicals as well as compound formed during processing. A biomethanation plant for treatment of black liquor has been set up at M/s Satia Paper Mills Ltd., Muktsar, Punjab. The biomethanation system is based on Up flow Anaerobic Sludge Blanket (UASB) Technology and consists of two reactors having a total volume of about 52,000 cum for treating about 4000 cum. black liquor per day. About 10,000 cum biogas being produced by this biomethanation system is being used as fuel in the boiler, saving about 20 – 22 tonnes of rice husk, which was being used as fuel in the boiler, which is equivalent to about 15 – 20% of the total energy requirement of the mill. This plant also leads to other indirect benefits like savings in electricity and chemical consumption required to achieve same level of COD and BOD reductions by activated sludge process.



Biomethanation of paper mill black liquor at M/s Satia paper Mills, Muktsar

Annexure 3

A commercial advertisement for used micro-turbine

MICRO - TURBINE ELECTRIC GENERATOR SYSTEM: Here is your chance to procure a 95% complete 100KW prototype Micro-Turbine system for pennies on the dollar. No, we do not have the blueprints, but we can direct you to the visionary engineers who created it. You can buy it for the intellectual property it contains. The cost to build this system exceeded \$1,000,000 dollars. It was begun in 1999-2000. The company ran out of money in 2001. The most advanced R&D (cost-no-object) effort in trendy Alameda, California (close to UC Berkley) resulted in this "Crown Jewel" of a working unit.