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Power Generation From Municipal Solid Waste- A Case Study

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ABSTRACT

In the modern world, the quantity of Municipal Solid Waste (MSW) is increasing rapidly as a result of increase in population, industrialization and urbanization. The municipal authorities and government agencies are planning to reduce landfill waste and promote renewable energy. In this paper the case study of 6.6MW MSW power plant run by SELCO international Ltd., Shadnagar near Hyderabad in the state of Andhra Pradesh, India is presented. The MSW collected from Hyderabad city is a composite mixture. It is collected separately as bio-degradable and non-biodegradable waste. The MSW processing plant is working since year 1999 at GandhamGuda, Hyderabad and is generating 700 tons per day of processed MSW. The processed waste is transported to power generation plant. The 6.6MW MSW power plant generates electricity since 2003. The processed municipal solid waste is mixed with rice husk in the ratio 80:20. The MSW power plant produces many useful byproducts such as agricultural manure, fly ash, waste heat etc., which can be used fertilizer, fly ash bricks & tiles etc. This technology mainly reduces environmental pollution and landfills, thus improving the health standards of urban people.

Keywords:*Municipal Solid Waste (MSW), environmental pollution, landfills, renewable energy, green technology, fly- ash bricks.*

1. INTRODUCTION

The renewable energy is fast emerging globally from and alternate source of energy to a main stream energy option as per renewable energy global status report 2007[1].The total global power capacity of 4300GW, the renewable energy (without hydro) now provides about 240 GW clean power , avoiding 5 gage ton per year of carbon emissions. Wind power contributes 90GW and solar photo voltaic to 8GW. Solar hot water systems now provide hot water to more than 50 million rural households worldwide and about 25 million rural household benefit than bio-gas , small wind power, household and solar power and other technology.

Over the past two decades renewable energy technologies are identified as a potential, sustainable and environmentally friendly alternative energy source. The UN Kyoto protocol on climate change [2] considered MSW as a ‘green technology’ when burned and thus this type of waste-to-energy (WTE) conversion is becoming popular in ASIA as an environmentally friendly technology. It is also realized that WTE [3] contributes to a positive cash flow from cogeneration.

In INDIA, the state governments of Delhi, Tamil Nadu, Madhya Pradesh, Uttar Pradesh, Maharashtra, Andhra Pradesh etc., started paying a great attention to MSW conversion technologies. This paper discusses the case study of 6.6MW plant of SELCO INTERNATIONAL and MSW processing plant at GandhamGuda , Hyderabad processing 700 tons per day. In order to help the investors and government, a thorough study has been conducted both inside and outside India and was presented [5] based upon this study. This paper also presents the comparison between MSW power generation and wind farm.

GLOBAL ENERGY ISSUES: Energy is the backbone of economic growth. The world consumption of energy in 1970 is 4800 million metric ton of oil equivalent (MTOE) in 1970 to about 8477 MTOE in 1999. The world had oil resources of a little over 1055 million barrels (140,900 MMT) while that of gas, a little less than 140 trillion metric meters. At the current rate of production, oil reserves are likely to last for about 40 years and natural gas resources for about 65-80 years. The reserves are unevenly distributed with the Middle East countries together holding 65% of oil and 84% of the gas reserves. Oil and gas contributes about 61.1% of energy usage despite of the reserves depleting very fast and now the world is keeping its eye on renewable energy sources and doing lot on R&D to tap urge potential through new renewable energy technologies like solar photo voltaic, solar thermal, wind turbines, bio gasifier etc.

A study of UK department of energy technical support (ETSV) at Hartwell revealed that from about 60 million was equivalent of energy, 18% of total energy consumption was thrown away every year as waste. According to technology information forecasting & assessment (TIFEC), Delhi, Mumbai and Kolkata would be generating 5000 tons of garbage everyday in about a decade whose disposal would be very difficult. As per the global status report, renewable energy in 2005 is 1,82,000MW. Investment in 2006 itself was around $ 38 billion and in 2005 was $30 billion. The following tables (1-3) presents the percentage of world’s renewable energy shared by various sources of renewable energy, their cost and estimated potential in India.

Table 1: The World renewable energy percentage in 2005

S. No	Type of renewable energy	Percentage (%)
1.	Large Hydro	58.23%
2.	Small Hydro	5.12%
3.	Wind power	4.85%

4.	Biomass etc.	3.42
5.	Photovoltaic	0.42
6.	Biomass heat	3.42%
7.	Solar heat	6.83%
8.	Geatwal Heart	2.17%
9.	Bio-diesel food	1.21%
10.	Bio-ethanol food	0.16%
11.	Other elect.	0.05

Table 2: World's 2001 and future estimated per unit costs*

Type of energy	2001 cost in $ /KWH	Future cost in $ /KWH
Wind	4-8	3-10
Sl2pu	25-160	5-25
Solar thermal	12-24	4-20
Large Hydro	2-10	2-10
Small Hydro	2-12	2-10
Geothermal	2-10	1-8
Bio-mass	3-12	4-10
Coal comparison	4	-

*Source: World Energy Assessment, 2006

Table 3: Estimated renewable potential in India**

Type of energy	Potential(MW)
Wind power	45,195 MW
Small Hydro	15,000 MW
Waste to energy	2,200 MW
Bio-power	16,880 MW

** Source: Vol. 48, No. 2, Feb 08, Electrical India.

Bio-Mass and energy: Bio-mass can be obtained by nature in many ways. Plants, trees, grass (sugarcane), oil plants (Soya been, sunflower etc.), energy trees Algae, municipal solid and liquid waste, wood waste, agricultural waste, industrial waste, bio-fuels. From all the above we can get energy by different methods. Mainly burning the biomass heat can be generated, the heat can be used for cooking, and industrial heating or produce electricity.

Bio-mass mix with coal in power plants is a process known as co-fixing. The US Department of energy and Alliant Energy Group in 2000 at Allicats, Ottumwa power generating Station in Iowa, subsequently received permission to build Biomass processing facility at the plant (in 2005) co-fixing up to 5% of its energy with "SWITCH GRASS".

Different numbers of non-combustion methods are also available to convert Biomass into variety of gaseous, liquid or solid fuels and different chemicals. Also bio-chemicals from bacteria, enzymes etc. can be used. Biomass oils from soybean, Canola oil can be converted into liquid fuel called bio diesel. The bio-mass conversion also gives environmental benefits like reduction in air, water and soil pollution, increase soil quality reduces erosion and improve wild life habitat and increase in job availabilities.

Management of MSW across the world: According to the US Environmental Protection Agency (EPA), the MSW generation in US and per capita MSW is shown in figures 1 and 2 below respectively. The US Environmental Protection Agency estimates that in 1998 17% of the MSW was burnt to generate electricity (Ex.14% Pennsylvania, 2% New Jersey 2%, California) 55% was disposed in land fills and 28% was recovered for reuse. In US there are two WTE methods in use.

1. **Mass burn:** MSW is combusted directly similar to the fossil fuels. MSW is used to convert water to stream to drive the turbine to generate electricity.

2. **Refuse Derived Fuel (RDF):** MSW is processed and made for use as a coal equivalent.

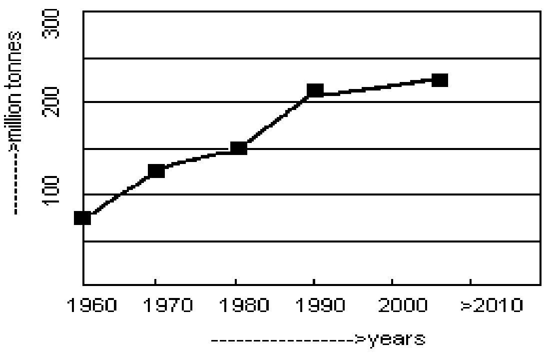

Fig 1 MSW generation over years in US

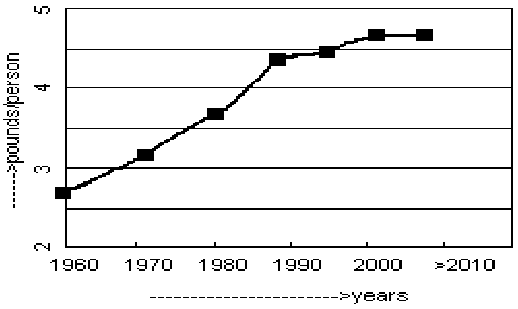

Fig. 2 MSW per capita in US

As per the US EPA, Table 4 gives the US MSW management [4].

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Table 4: US Solid Waste Management (1960 to 2005 million tons)

Year	1980	1990	1995	2000	2005
Generation	151.6	205.2	213.7	232.0	245.8
Recycling	14.5	29.0	46.2	51.2	58.4
Compost	-	4.2	9.6	16.5	20.6
Landfill	123.4	140.7	122.4	130.6	133.3

MSW management in UK: A WTE plant has been commissioned in London, which processes 4, 20,000 tons of MSW/year. The incineration plant generates 32MW of electricity to power 30,000 homes. Tyseley plant set up in 1996, uses mass-burn energy from MSW for combustion of 3, 500, 00 tons / year which provides 25MW of electricity.

MSW Management in Germany: The national management act of Germany is recycling waste under ecological and technical aspects. It is done by paralysis or gasification. Around 5, 00,000 tons of MSW is processed through these methods every year and is used for various uses.

MSW Management in China: The details of MSW management in china are as follows. The Municipal solid waste (MSW) generated is 136.5 million tons (MT) per year and industrial Solid Waste and hazardous waste generated are 945 MT, 10 MT respectively. Out of the 74.04 MT quantity disposed, 89.03% was land filled, 3.72% incinerated and 6.98% was composted. There are 651 disposal facilities for MSW in China. The china's government is also focusing on an effective management of MSW.

MSW Management in ASIA: Asian cities are populated more than one billion today. By 2025, Asia will be inhabited by more than four billion, with half of them in cities and will produce more than 180 million tons of MSW per day. Table 5 shows MSW management in Asian cities.

Table 5: Management of MSW in Asian cities

S. No.	Various cities	Less developed cities	Rapidly developed cities	Developed cities
1.	Cities	Dhaka, Karachi, Katmandu.	Beijing, Bangkok, Shanghai, Manila, KaulaLampur	Tokyo, Seoul, Singapore, Hong Kong,
2.	MSW generated / day /kg/ person	0.3 – 0.7	.5 to 1-5	> more than 1.0
3.	MSW collection rate%	Less than 70%	80 to 95%	95 to 100%
4.	Amount spent in total budget	15 – 40%	5-25%	1-5%
5.	Recycling	Informal	Found+ informal	Formal

Despite large waste volumes, waste management is efficient in developing countries. With the collection rate reaching 100%, most waste is incinerated and used.

Waste management in India:

Presently in India about 960 MT of solid waste is being generated as a bi-product, of this 350 MT is organic waste from agricultural norms, 250 MT of organic waste from Industry & mining, 4.5MT of hazardous waste [6]. The per capita MSW generated in India is shown in fig.3 shown below.

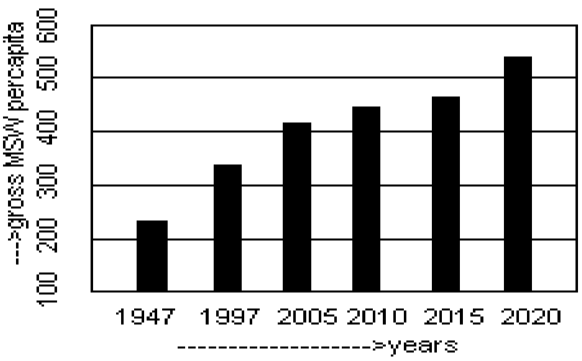

Fig.3 MSW generated per capita

The characteristics of MSW collected in India are as follows. Its moisture content is 50%, gross calorific rate is 800 kcal/kg. The cost of MSW collection is 65%, transportation is 30% and disposal is 5%. Waste disposal practices are adopted in many places in India. Nearly 30,000 hectares are used for land fills till date. As per the NEERI survey 2004-05 the solid waste production of the same Indian cities is as under in tons per day, Delhi – 5922, Kolkata – 2653, Chennai - 3036, Mumbai – 5320, Bangalore – 1669, Hyderabad – 2187, Ahmedabad – 1302, Pune – 1175, Kanpur 1100, Surat – 1000, Jaipur – 904, Nagpur – 504, Bhopal – 574, Agra – 654, Visakhapatnam – 584, Vijayawada – 374, Srinagar – 428, Varanasi – 425, Allahabad – 509, Coimbatore – 5309, Chandigarh – 326, Amritsar – 438.

SELCO International MSW Processing Plant: The SELCO plant is located at GandhamGuda (Village), Vikarabad-Tandur road. It is having a capacity of 700 TPD. The 10 acres of land is taken from GHMC (Greater Hyderabad Municipal Corporation) for lease for 30 years. The Financial support is extended by NEDCAP, MNRE, IRDA, and UNDP. This plant is working since the year 1999.

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MSW Composition: Hyderabad MSW in collected and transported free of cost to SELCO by GHMC. The typical Indian MSW composition is shown in table 6 .

Table 6: Typical MSW composition of India (As per NECR findings)

Material	(%)
Paper / Cardboard	5 to 25
Plastic	0.6 to 9
Glass ,ceramics, stone	0.1 to 7
Sand / line earth	30 to 40
Metal	6 to 1
Compost able matter	30 to 45%

SELCO plant has 3 units of 200 to 250 tons of MSW processing capacity per day. The plant is having 75 staff with a turnover of 100 million / year.

PROCESS DESCRIPTION: The raw MSW cannot be used for power generation. The process treatment mainly has five steps. The plant is under operation for 24 hours except in rainy season.

1. Segregation and pretreatment.
2. Anaerobic digestion
3. Recovery of organic residue
4. Effluent treatment/ pelletization/ RDF pellets
5. Power generation

Segregation& Pretreatment: The MSW collected from various parts of the city, kept in the storage area is conveyed through refuse conveyers. Large pieces of wood, stones, plastics, rags etc., are segregated by hand picking. This refuse is taken to the rotating drum sieve, which is rotated by an electric motor. Due to the rotating action of the drum the lumps if present are broken into smaller particles. The particles longer than 40mm are rejected and it is conveyed through another conveyor system, where the plastic material is also removed. Thus the material which is smaller than 40mm is sent along with spray water to the anaerobic digester.

Anaerobic Digestion: Anaerobic digester design is based on floating layer reactor technology which has four zones i.e., completely mixed zone, floating layer zone, methane zone, and gas zone. In the completely mixed zone the readily digested fraction is converted partly to fatty acids which are transported by recirculation flow to methane zone to be converted to biogas and partly directly to CH_4. In the floating year, the slowly degrading material is degraded partly to fatty acids which are transported to methane zone by percolating effluents from the methane zone through the floating layers where a stable environment for degradation of cellulose components from waste is created. There is no continuous turbulent mixing and the PH and fatty acids concentration are controlled by percolation to methane zone. In this methane zone, the volatile fatty acids and other dissolved hydrolysis layer zone are converted to biogas. This methane zone is mixed intermittently by biogas recycle.

Recovery of Organic residue: The residue from the reactor is subjected to dewatering by a screw process to facilitate the handling and its ultimate disposal. The floating layer is removed with the help of dunkers and open and screw and is further screw pressed for dewatering. The dewatering liquor flows back into the reactor and the dewatered floating layer solids are removed from screw press. These solids will have about 40% to 60% moisture. The solids are discharged from the centrifuge containing stabilized organic matter along with biomass. The moisture content in the cake discharged from the centrifuge is about 20% to 30%. The settled mass in the settling compartment of the reactor is removed and taken out on conveyor belt which are disposed off along with the rejects from the drum sieve.

Effluent treatment / pelletization / RDF pellets: The effluent generated in the process is subjected to aeration employing activated sludge process. The pelletization process prepares pellets in different sizes 25-30mm, 50-90mm diameter and 5-8mm long. The pellets of 25-30mm are mostly used as an alternative for coal whose calorific value in 3000-3600 kcal/kg. The pellets of 50-90mm diameter are called RDF Briquettes. Out of the waste which collected from GHMC, 70% is useful as RDF and 30% is used as manure.

Power Generation at SELCO power plant: The capacity of SELCO power plant is 6.6 MW. The figure 5, shows the layout of the SELCO Plant. The SELCO power plant connected with the APSTRANSCO grid since November 2003 in the first plant of its kind in India. Since then many changes have been made in the boiler to customize it to suit burning of RDF. Apart from RDF firing, another special feature of the power plant is the provision of air cooled condenser in place of conventional water-cooler condenser. It does a lot of water saving of approximately 30,000 liters per hour. The details of the equipment used in the plant are as follows.

Boiler: Stroke fired, panel monitored, bottom supported water tube boiler of capacity 32 TPH. The processed MSW is used as fuel. The temperature of economizer is, in 105oC and out 175^0 C.

Steam Turbine: Bleed cum condensing turbine with an input steam cap of 42 kg/ sq. cm. And output of 0.72 kg / sq. cm. Its speed is 8280 rpm / 1500 rpm.

Alternator: Synchronous, three phase star connected, 50 Hz alternator with ratings 8250 KVA, 6600 KW, 1500rpm, 11KV, 433A, 0.8 lag and is having class F insulation. The power is connected to the grid via 11 KV underground cables. An air coded condenser is used, which saves 3000 It’s of water / hour approx. Rice husk is mixed as an auxiliary fuel with RDF before feeding to the boiler for an efficient burning in a proportion of 1:4. Out of the generated electricity 90% is evacuated to the Shadnagar substation and 10% is used for the plant’s maintenance.

RESULTS AND DISCUSSIONS:

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The MSW power Plant performance is evaluated for three shifts of a day has been presented below. The energy production, import, export and plant load factor in three shifts on Dt. 04-01-08, three years energy production has been presented in Table (7-8) and Table 9 respectively.

Table 7 Power generation, import and export as on 04.01.2008

Date	Generated units	Support	Import	Aux	P.L.F
4 -01-2008	1,55,440	1,39,750	-	15,650	98.10
23-01-2007 to 03-01-2008	18,26,800	16,33,510	960	-	91.19

Table 8: Power Produced in Shift basis

Shift period.	Generation	Export	Import	P.L.F.
A: 46200	45400	40830	-	98.26
B: 54800	51700	46190	-	96.96
C: 59400	58800	52730	-	98.98

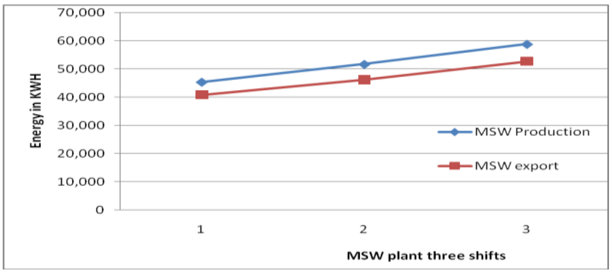

Fig. 4: MSW prod. & export curves

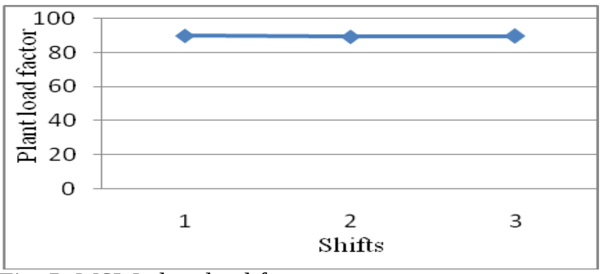

Fig. 5: MSW plant load factor curve

The MSW energy production in KWH & the export energy in KWH and plant load factor for three shifts on Dt.04-01-2008 are presented in Fig. 4 to Fig. 5 respectively.

Table9: Three years energy production of MSW Plant

Year	2004	2005	2006
working hours	5,694	4,709	1,389
MSW in tons	1,49,916	1,42,210	1,14,701
RDF in tons	56,230	53,160	28,502
Auxiliary consumption	28,98,582	27,04,941	3,35,603
Energy prod. In KWH	2,80,79,303	2,47,36,401	59,05,502
Energy Export in KWH	2,41,46,900	2,14,15,000	50,39,900
Ash	11,650	10,700	7,491

The MSW Power Plant working years versus the three years Power plant working hours, RDF in tons, energy production & export energy and ash production curves are presented in Fig. 7 to Fig. 9 respectively.

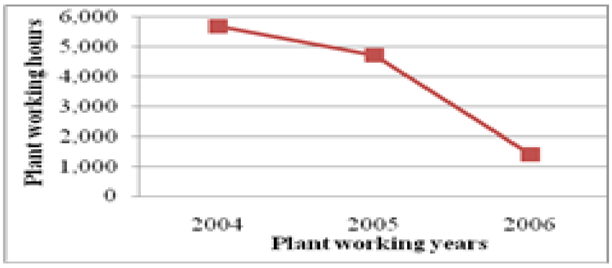

Fig. 6: MSW plant working hours curve

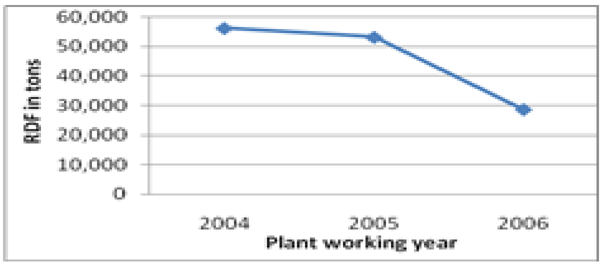

Fig. 7: MSW plant RDF in tons curve

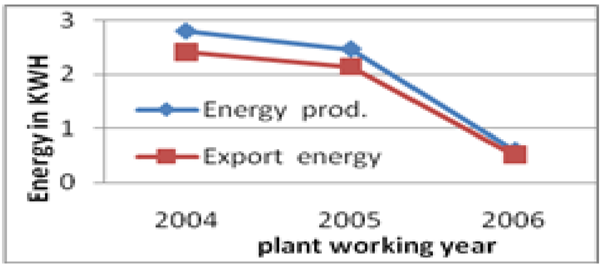

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Fig. 8: MSW plants prod. & export curve

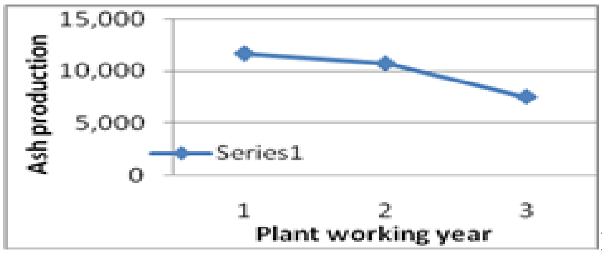

Fig. 9: MSW plant Ash production curve

Comparison between MSW Plant and wind-farm: The various economic constraints of MSW power plant are compared with a fully matured renewable energy wind farm below.

Table 10 MSW comparison with Wind farm [4]

Description	MSW	Wind farm
Capital Investment (x10^6 US$)	15.5900	9.7750
Annual maintenance cost (x10^6 US$)	2.7957	0.3757
Annual revenue (x10^6 US$)	6.6650	1.6800
Operational Profit (x10^6 US$)	3.8693	1.3043
Payback period	5years	7 years months
Lifetime	20 years	20 years

It is evident from the above table that the capital cost as well as the operation and maintenance cost of MSW plant are higher than the wind form project of the same capacity. However the net operational profit per annum from the MSW plant is much greater than the wind farm project. Even the payback period of the MSW plant is attractive compared to the wind farm.

Considering the environmental comparison, wind technology does not generate emissions whereas MSW combustors serve as an alternative to landfills. While wind can cause visual and noise pollution and is subject of studies on avian mortality and adverse impacts on micro eco systems, MSW emits toxins. Thus these impacts must be weighted and balanced against energy alternatives.

Apart from the generation of electricity as the main commodity, the MSW project offers many byproducts of great commercial value whereas wind from project does not yield any such byproducts except the possibility of growing low-level crops. The various useful byproducts are methanol; mixed alcohol, acetic acid, single cell protein, photosynthesis plant fertilizer, after conversion, waste heat etc. It also reduces environmental pollution thus reducing the diseases like cancer, bronchitis, anaemia and various skin ailments.

Apart from the above, MSW power plant has various other benefits over wind farm like loading suitability, higher capacity factor and availability, economical grid connection, less space requirement, recycling opportunities , less payback period compared to wind farm etc.

CONCLUSIONS: This paper has been presented the market situation, process, manufacture, benefits of MSW power plant along with the comparison with a wind farm. It also presents a case study of the SELCO International Limited situated in Hyderabad, (A.P), India, which is working satisfactorily. The MSW plant cost would decrease when India practices the environmentally friendly technology at a large scale with its indigenous machineries and equipment. It is hoped that the information provided would be helpful to the investors (private / public) of the energy sector. There is also scope for further research for improvement of power plant performance. Based on this study one can plan bigger or smaller power plants to suit their requirement. It is concluded today thatsolid waste is made a solid opportunity for power generation.

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