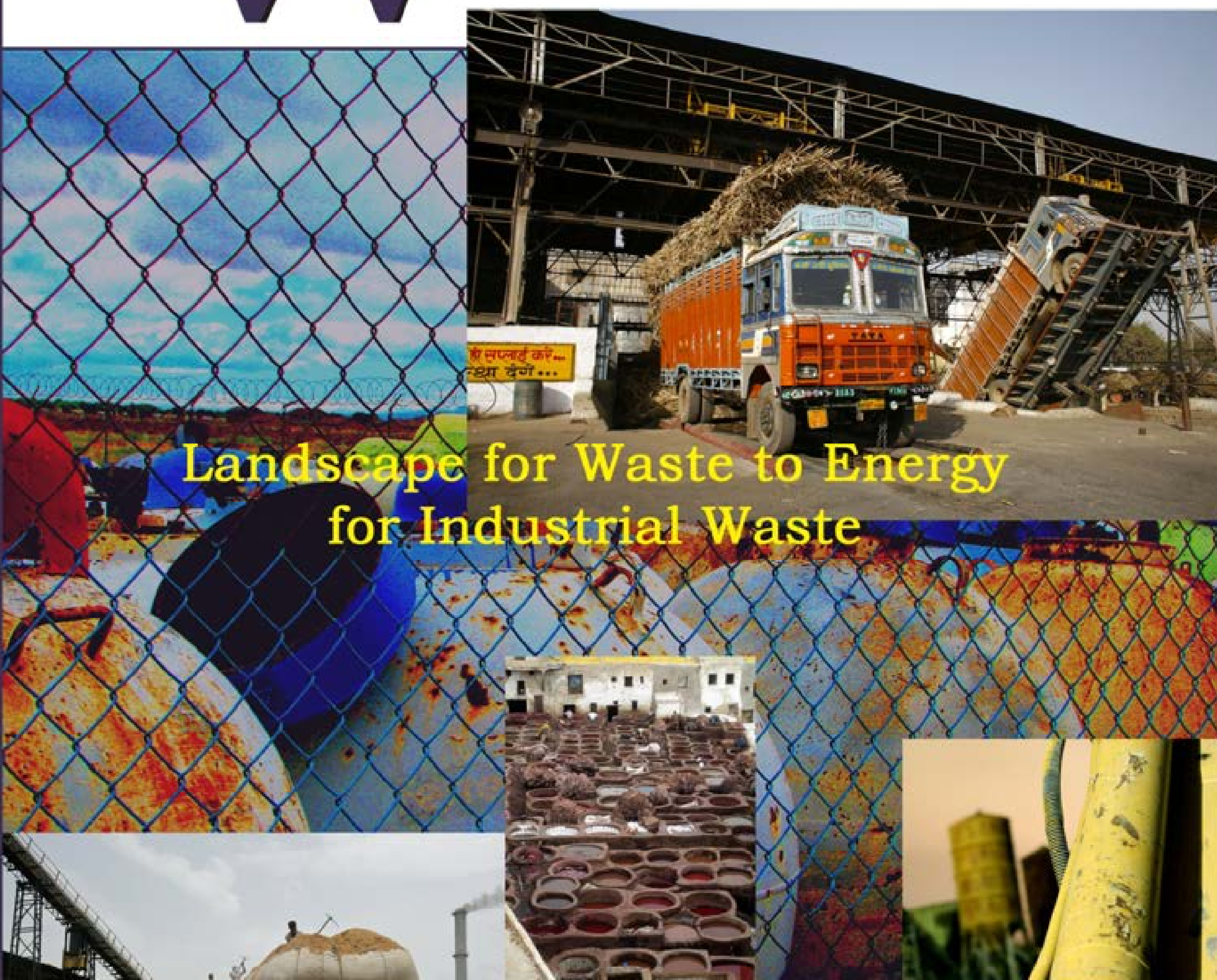
Quality Council of India

Ministry of New and Renewable Energy
Government of India

ASSOCHAM
INDIA

Waste to Wealth



Landscape for Waste to Energy for Industrial Waste

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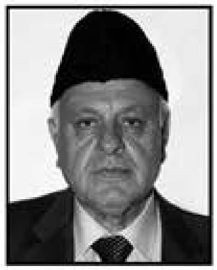
cKinetics is an operational consulting and strategic services firm exclusively focused on shaping scalable sustainability solutions and low carbon growth practices within industry and communities. With operations in India and in the United States, the firm focuses on (a) resource efficiency on the fronts of carbon, energy, water and waste; (b) renewable energy and (c) smart infrastructure.

डा. फारुक अब्दुल्ला
DR. FAROOQ ABDULLAH

सत्यमेव जयते

मंत्री
नवीन और नवीकरणीय ऊर्जा
भारत सरकार
MINISTER
NEW AND RENEWABLE ENERGY
GOVERNMENT OF INDIA

Dated: 11-11-2011



MESSAGE

I am happy to note that ASSOCHAM is organizing a Conference on 'Waste-to-Wealth' in Delhi on November 14, 2011. I understand the focus of the Conference is on recovery for energy from industrial wastes. The Ministry of New and Renewable Energy considers the subject of this Conference extremely relevant as the development of effective waste-to-energy systems in industry not only helps in addressing the challenges of effective waste treatment and disposal but also addresses the concerns about emission of Green House Gases. Waste to Energy projects help industrial units to produce thermal energy and/or power and also help to improve the environment through safe disposal of waste.

It has been estimated that there is a potential for recovery of about 1300 MW of energy from industrial wastes; this is projected to increase to about 2000 MW by 2017. Projects of over 135 MW on energy recovery from industrial wastes have been installed so far in distilleries, pulp and paper mills, food processing and starch industries; however, there is still an immense untapped potential in the country. I do hope that events like this organized by the industry organizations like 'ASSOCHAM' will lead to harnessing the full potential of energy from industrial wastes not only for meeting their captive energy requirements but also for contributing to the climate change initiatives of our country.

I wish the Conference all success.

(Farooq Abdullah)

MESSAGE

The world, presently, is experiencing an unprecedented pressure on limited environmental resources, which is compounded by the impact of increasing environmental pollution through industrialization and consumption. These are the key challenges that solicit an immediate addressal on the global, national and local stage.

As India, an emerging economic superpower, looks to increase and sustaina high economic growth rate, ensuring the unregulated supply of energysources is a key consideration.

In this backdrop, this report intends to highlight the potential of converting Waste to Wealth, with particular consideration of detailing the benefits, technology and pertinence.

I congratulate the effort and extend my best wishes ASSOCHAM conference on 'Waste to Wealth' and look forward to the outcomes of the same.

Dilip Modi
President, ASSOCHAM

PREFACE

Perched on the tipping point of ecological and economic rebalancing, the business and environmental landscape of the world is shifting towards sustainable growth paths. Energy and resource costs are on the upswing due to heavy reliance on non-renewable and hence limited sources of energy and other materials. This is a precursor to the need to: (1) make existing resources last longer and (2) identify new resources that are both renewable and viable.

Waste and, in particular, the exponentially growing Industrial Waste presents one such invaluable opportunity to generate energy from waste; thereby incorporating a natural by-product of industrial production into meeting the industrial energy demand.

The Government of India has, through policies and directives, laid significant emphasis on the need and the pathways to exploit the waste to energy potential in India. Various programs are providing assistance to industrial units to set up plants to convert waste to energy.

In addition, the economic viability of Industrial Waste as a substantial, easily available and renewable source of energy is a key catalyst to drive industrial uptake of 'Waste to Energy' programs.

To accelerate the adoption of Waste to Energy programs, it is imperative to understand and mitigate roadblocks for all stakeholders. The ASSOCHAM initiatives on Waste to Wealth, supported by this report detailing the operative landscape, would create the ideal forum to initiate and incubate the dialogue that enables the road to generate Wealth from Waste.

Upendra Bhatt
Managing Director
cKinetics

FOREWORD

Today, India stands on the threshold of being the third largest economy in the world with a double digit growth rate, driven by domestic and global investments. Thus, it becomes imperative that Indian Industries continue to deliver rapid growth through increased efficiencies and innovation.

As a nation, the key challenges we face to propel this growth, include securing a stable supply of energy to close the gap between demand and supply and managing the negative effects of rapid industrialization; i.e. drain on resources and high quantities of waste generation.

Conversion of 'Waste to Wealth' is an imminent and pertinent topic, which requires the collaborative effort of industrial representatives and policy makers to find sustainable and economically viable solutions.

The Government of India has made concentrated efforts to create and achieve the potential of converting 'Waste to Energy', through the 'National Programme on Energy Recovery from Urban and Industrial Wastes'.

This report intents to builds the background for discussions regarding efficient management of Industrial Waste for energy and resource recovery, and provide a framework to the conversations during the ASSOCHAM Conference on 'Waste to Wealth.

I support this endeavor to build and define a platform to understand the needs and challenges faced by all stakeholders and pave the way for mutually beneficial solutions, which would contribute to the development, we all seek to achieve.

D. S. Rawat
Secretary General,
ASSOCHAM


TATA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NATIONAL PERMIT
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TATA

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Executive Summary

Waste: Challenges and Opportunities

The world in general, and a developing economy like India, has experienced rapid changes in the past few decades; technical and industrial evolution, medical evolution, and globalization have increased both the length and the impact of human activity on each other as well on the environment.

This growth has resulted in increased consumerism and urbanization leading to increased waste generation; both due to the scale of lifestyle as well inefficient use of resources. Residues from industrial activities in the form of waste often end up in landfills or water bodies. Such untreated waste leads to environmental and health problems. Thus efficient cost-effective industrial Waste Management is an absolute necessity going forward. Already several regulatory requirements exist and implementation is increasingly becoming stringent.

A key component of efficiently managing such waste, in a world dealing with rapidly depleting non-renewable resources, is to recycle waste; i.e. derive economic and environmental benefits of turning waste by-products to create raw materials for productive use.

Waste can broadly be classified into Municipal Waste, Electronic Waste, Biomedical Waste and Industrial Waste.

An integrated and efficient waste management system would encompass all these waste types to deliver a framework to reduce, reuse and recycle or dispose waste.

In this Knowledge Paper, we focus on the challenges and opportunities presented by Industrial Waste management, specifically:

(a) Opportunity and potential of reusing Waste to generate Energy and as potential input materials for other products
(b) Identify priority areas in the industrial sectors and the technological options for Waste Conversion particularly Waste to Energy Technologies
(c) Operating Environment and the gaps that need to be addressed for large scale uptake
(d) Insight into the Road Ahead

Waste to Wealth

As the term suggests, Waste to Wealth is about creating economic benefits out of what was traditionally regarded as waste. Generation of wastes is inevitable in all industrial processes. Each industry is unique in its waste generation spectrum. In the background of rising energy costs, scarcity of resources, and deterioration of ecological systems, innovative mechanisms to shape waste into useful ingredients (energy and/or other useful by-products) represents an appealing solution to several pressing problems.

Waste generated from manufacturing and agri-industries presents a formidable opportunity to create energy in an economically viable fashion. The Global waste to energy market has grown from $4.83 billion in 2006 to $7.08 billion in 2010[1].

A report by SBI energy[2] predicts estimates that with the global drivers such as growth in Asia, and the maturing of EU waste regulations and U.S. climate mitigation strategies, the market will exceed $27 billion by 2021; and cater to 10% of the total energy needs.

The Global waste to energy market has grown from $4.83 billion in 2006 to $7.08 billion in 2010

In the Indian context, Ministry of New and Renewable Energy (MNRE) has identified a few key sectors generating industrial wastes as those with high energy potential. The table below summarizes the sectors, the key raw materials and the major waste streams.

Table ES 1: Industrial Wastes with Energy Potential

Sectors	Raw Materials	Major Waste Stream		Power generation potential (in MW)	
		Liquid	Solid	2012	2017
Distillery	Mollases	Spent Wash		628	785
Dairy	Milk, Cheese	Washings, Whey		77	96
Pulp & Paper	Bagasse / Straw	Black Liquor	Pith	72	90
Poultry	Chicken	-	Litter	81	102
Tanneries	Raw Hide	Toxic (complex)	Flesh / Hair	8	10
Slaughterhouse	Animals	Blood	Flesh / Bone	117	146
Cattle farm Waste	Cattle		Farm Waste		
Sugar	Sugar cane	Waste water	Pressmud	453	567
Maize Starch	Maize	Steep Liquor	Pith	132	164
Tapioca Starch	Tapioca	Waste water	Pith, Peelings	30	37

Additionally waste materials in certain sectors can also be used as inputs for other sectors, e.g. fly ash from thermal power plants are usable as inputs for the construction sector. A snapshot of similar opportunities is presented in the table ES 2 on the next page.

Various countries, particularly those in Western Europe, are already in the process of using a significant proportion of their waste to produce energy as also for recovering waste material for reuse in other industrial sectors. Technologies have been developed and are further being improved upon to provide the necessary fillip for large scale uptake of these initiatives.

Waste to Energy Technologies and Pathways

The most significant waste-to-energy technologies are based on biological or thermal methods. Biological method involves bio-methanation producing methane enriched bio-gas, which can be used as fuel whereas thermal method (incineration) involves combustion of organic wastes as fuel with the evolution of heat energy for recovery.

Advanced thermal conversion involves destructive heating of organic materials with a limited supply of oxygen (gasification) or without any oxygen (pyrolysis) to produce a combustible gaseous product consisting of simple hydrocarbons and hydrogen.

Table ES 2: Areas of reuse of industrial waste

Industry	Waste	Areas of Use
Thermal Power Plants	Fly ash	1. Feedstock in the cement industry 2. Making of Bricks 3. Structural fill for roads, construction sites, land reclamation 4. Stablilisation of soil
Iron and Steel	Blast Furnace Slags	Structural fill for roads, construction sites
Paper and Pulp, Sugar	Lime Sludge	1. As a sweetener for lime in cement manufacture 2. Manufacture of lime pozzolana bricks/ binders 3. For recycling in parent industry 4. Manufacture of building lime 5. Manufacture of masonry cement
Aluminium Smelter	Red Mud	1. As a corrective material 2. As a binder 4. Making construction blocks 5. As a cellular concrete additive 6. Coloured composition for concrete 7. Making heavy clay products and red mud bricks 8. In the formation of aggregate 9. In making floor and all tiles 10. Red mud polymer door
	Spent Pot Lining	1. Energy savings in the brick and cement industries; 2. Beneficial fluxing properties in the brick, cement and steel industries; 3. Enhances strength development from cement. 4. Recycle into cathodes, and anodes for use in the aluminium ramming paste industry; 5. Fluorides recovery (cryolite).
Cement	Kiln Dust (Particulate Matter), Waste Heat	1. Feedstock in the cement industry 2. As a soil stabiliser, to create raw materials for road constructions 3. Treatment of other waste such ad flue gas and sewage sludge

Various technologies as relevant for different kind of industrial waste materials are listed below:

- Bio-methanation: Relevant for Liquids and Semi-solid waste
- Gasification /Pyrolysis: Relevant for Solids and Semi-solid waste
- Incineration / Combustion: Relevant for Solids and Semi-solids

An analysis of the above WTE process options[3] based on technology systems, environmental aspects, resources recovery and commercial aspects presents the following insight:

- Bio-methanation has emerged as a favoured technology for industrial waste
- Gasification/pyrolysis have a distinct promise, and although further technology maturity is desired
- Incineration is a mature technology for energy recovery from industrial wastes and has been successfully commercialized in the developed countries. However it represents an increasingly expensive option due to rigorous environmental compliance requirements

The desirable range of important waste parameters for technical viability of Energy recovery waste for the above processes is presented in Table 2.1 in Chapter 'Waste to Energy Technologies and Pathways'.

Operating Environment and the Road Ahead

As the Indian industrial sector continues on its growth path, the India Waste to Energy market promises huge potential for wealth generation and energy 'savings'. In India, the industrial waste-to-energy projects have been successfully implemented independently in industrial sectors like distilleries, pulp and paper, dairy etc.

The Ministry of New & Renewable Energy, under its Biomass led power generation programme, has been instrumental in catalyzing projects in the following areas:

- Industrial bio-methanation for power and thermal applications
- Biomass gasifier based captive power and thermal applications in industries
- Biomass power based on agro / forestry residues through combustion technology
- Bagasse based co-generation in sugar mills
- Non-bagasse based co-generation in other industries

Under the ministry's 'Accelerated Programme on Recovery of Energy/ Power Generation from Industrial and Commercial Wastes and Effluents', the Government has provided considerable support for up-gradation of various conversion technologies. The ministry is attempting to significantly upscale the activities on this front to shape a conducive environment for the development of the sector in the country with a view to harness the available potential by the end of the 12th Five year plan.

Investments to generate energy from industrial wastes are generally cost effective and offer attractive rates of returns in addition to enabling the statutory regulatory compliance the industry should adhere to. The IRR of bio-methanation plant generating only biogas is in excess of 30 % (without downstream aerobic treatment) and about 20 % when the downstream aerobic treatment cost is taken into account.

In addition to the support from the central government for Waste to Energy (WTE) projects, project developers also have access to concessional loans and lines of credit set-up to support such projects. Amongst the institutions that support these projects are: IREDA, NABARD, SIDBI, state financial corporations and even some commercial banks.

Despite a sufficient policy framework to drive, direct, assist and govern the market for Waste to Energy projects in India, the potential has not been fully tapped into. The National Conference on Waste to Wealth organized by ASSOCHAM aims to foster the dialogue amongst diverse stakeholders to highlight the progress made on the technology front and reflect on the gaps and the efforts required expedite larger adoption and truly unlock the huge potential of the Waste to Energy market in the country to create wealth generation and critical energy 'savings'.

Introduction into Waste – Challenges and Opportunity

The world has experienced rapid changes in the past century; technical and industrial evolution, medical evolution, and globalization have increased both the length and the impact of human activity on each other as well on the environment.

Increased consumerism and urbanization has resulted in increased waste generation; both due to the scale of lifestyle as well inefficient use of resources.

Industrial Waste can broadly be classified as Bio-degradable waste, Non bio degradable waste and Hazardous waste. Furthermore, by formation, the waste is generated in all three forms of Solid Waste, Semi-solid Waste and Liquid Waste.

With rising energy costs, scarcity of resources, and deterioration of ecological systems, innovative mechanisms to shape waste into useful ingredients (energy and/or other useful by-products) represents an appealing solution.

Industrial Waste Generation – Problems

Solid waste, often un-segregated, is typically dumped in landfills. The waste lying in these landfills leads to generation of Greenhouse Gases such as methane and carbon dioxide. This not only contributes to climate change but can also cause fires/ explosions and collapses at landfills, as methane is highly flammable.

Unprecedented growth of urban areas has created an acute shortage of land available for landfills and cities are under the pressure of managing both the municipal solid waste and industrial waste.

Untreated liquid, solid and gaseous waste can seep into Air, Water, and Soil to cause a plethora of ecological and health problems. Particulate matters in the air, polluted water with chemical effluents, hazardous waste etc are increasing the urban pollution levels. This problem is worsened in Industrial areas, many of which are critically polluted.

The environmental impacts of certain elements of the waste streams (such as plastics, metals and glass, etc.) as well as certain waste streams themselves (such as e-waste) stem not only from the waste treatment and disposal itself but also from the indirect impacts due to the loss of resources from the supply chain. In other words, such resources must be produced again from virgin materials (often non-renewable), thus contributing to the overall depletion of valuable natural resources. The resultant ever-increasing demand of resources makes waste management a global issue.

Already several regulatory requirements exist mandating specific ways for management / treatment of Industrial waste. These typically entail additional expenses and in certain cases, even significant capital expenditure on part of the industry. At the same time, in a resource constrained world, energy prices and raw material prices continue to be on the rise thus creating additional burden on the industrial sector.

In the background of rising energy costs, scarcity of resources, and deterioration of ecological systems, innovative mechanisms to shape waste into useful ingredients (energy and/or other useful by-products) represents an appealing solution to several pressing problems.

Potential areas for reuse: Waste to Wealth

The major indicator of potential usefulness of waste is the proportion of organic and inorganic matter, which correlates well with the energy potential in terms of the calorific value. A waste with good proportion of organic matter can be a good substrate for recovery of bio-energy potential (from biodegradable fraction of the organics) or for the recovery of thermal energy potential (equivalent to calorific value observed).

Waste to Energy – Potential end-fuels

As a result of the conversion process, different kind of fuel products can be generated. The same are listed as follows

Waste to Solid Fuels	Waste to Liquid Fuels	Waste to Gaseous fuels
• Briquettes • Pellets • Charcoal • Bio-char	• Bio-diesel • Bio-ethanol • Bio Oil	• Biogas • Syngas

Several proprietary anaerobic processes have been developed for energy recovery as biogas from various liquid and solid wastes of industrial processes. Anaerobic technology has emerged as a mature technology for industrial applications since the nineties.

The type of technology process enabling conversion of waste in different state is summarized:

Liquids	• Bio-methanation
Solids	• Gasification / Pyrolysis, Incineration / Combustion
Semi-Solids	• Biomethanation, Gasification / Pyrolysis, Incineration / Combustion

Re-use of waste as input material

Waste materials in certain sectors can also be used as inputs for other sectors, e.g. fly ash from thermal power plants are usable as inputs for the construction sector. A snapshot of such opportunities has been presented in the table ES 2 earlier in this paper.

Waste to Energy Technologies and Pathways

Waste-to-energy (WTE) is the process of creating energy in the form of electricity or heat from the incineration of waste source. WTE is a form of energy recovery. The most significant waste- to-energy technologies are based on the biological or thermal methods.

The table below presents an insight into the types of conversion process and the associated end-products.

Technology Type	Process	End Products
Thermo-chemical Conversion	Combustion	Electricity & heat
	Gassification	Methanol,Hydrogen, Gasoline
	Pyrolysis	Methanol,Hydrogen, Gasoline, Naptha, Bio-diesel
	Liquefaction	Methanol,Hydrogen, Gasoline
Bio-Chemical Conversion	Anaerobic Digestion	Biogas
	Fermentation	Bio Ethanol, Hydrogen
Chemical Conversion	Trans-esterification	Bio-diesel

Thermo-chemical conversion

Combustion

Combustion produces flue gas from waste, at high temperatures. The higher the temperature, higher is the electricity output. However extreme temperatures in the boilers will cause corrosion.

The following are the key combustion processes:

- Co-combustion of coal and waste
- Dedicated residual derived fuel (RDF) plant
- Incineration

Advantages	Disadvantages
1. Combustion leads to a reduction in the volume of the waste that ultimately needs to be disposed off by up to 90%. This significantly lowers the pressure on limited land resources. 2. Waste disposed in landfills emits Green House Gases, in particular Methane. By offsetting this emission, combustion leads to carbon savings. 3. The initial investment cost of Combustion plants are lower than other technologies for Waste to Energy	1. The combustion/ incineration plants require strict emission control, as they release tars, dioxins, furans and char into the atmosphere. However, the ash released, if captured, can be used in building roads. 2. Only organic matter can be combusted, while the inorganic matter is released as ash, which needs landfill disposal.

Gasification

Gasification is the process of converting a carbon-based material (Industrial, Agricultural or Municipal waste) into a combustible gaseous product (combustible gas) by the supply of a small amount of gasification agent (typically oxygen).

Pyrolysis

Pyrolisis is the process of converting the carbon based to gas, in the absence of any oxygen (or any other agent). The combustible gas produced is called Syngas and contains Hydrogen, Carbon Monoxide and Carbon dioxide. It can be used for running internal combustion engines, substitute furnace oil as also to produce methanol, which is useful both as fuel for heat engines as well as chemical feedstock for industries.

These technologies can be applied to most sectors, including Dairy, Poultry, Paper and Pulp, Slaughterhouse, Sugar and Distillery; as all of these sectors produce waste with a high Biological Oxygen Demand (BOD).

Advantages	Disadvantages
1. As gasification occurs at high temperatures, as compared to combustion, the residual effluents such as chloride and potassium are refined and rendered chemically stable. Thus Gas is produced with relatively low emissions. 2. The feedstock used in gasification is relatively flexible; it can contain wood, plastics, aluminum, agricultural and industrial wastes, sewage sludge etc. 3. The processes are typically seen as producing a more useful product than standard incineration – gases, oils and solid char can be used as a fuel, or purified and used as a feedstock for petro-chemicals and other applications. The syngas may be used to generate energy more efficiently, if a gas engine (and potentially a fuel cell) is used, whilst incineration can only generate energy less efficiently via steam turbines.	1. The initial investment required for Gasification plants is high and thus larger scale is required to bring economic sustainability. 2. Waste processing in gasification plants consumes high amounts of power and pure oxygen, which offsets the efficiency of the energy it produces (electricity) 3. Studies have demonstrated that it may not be possible to maximize recycling prior to treatment by gasification and pyrolysis, due to the requirement for a fairly specific composition of waste, including combustibles, in order for the process to work effectively.[4]

Liquefaction

Liquefaction is the process of converting biomass and organic materials into hydrocarbon oils and byproducts using high pressure (generally up to 200 atm) and temperature (generally up to 350 °C). The resulting intermediates are convertible to hydrocarbon fuels and commodity chemicals to generate end-products similar to those produced from petroleum. The difference between Gasification / Pyrolisis and Liquefaction is in the state of the output (i.e. liquid fuel instead of gaseous). Advantages and disadvantages of this process are the same as that of Gasification/Pyrolysis.

Bio-Chemical conversion

The bio-chemical conversion of biomass occurs when different microorganisms convert biomass into gases or liquids typically under anaerobic conditions and by addition of heat.

Anaerobic Digestion or Bio-methanation

Anaerobic digestion is the naturally occurring process of breakdown of organic material by micro-organisms in the absence of oxygen. This is believed to be the oldest technique for waste management and/or treatment. This process can be replicated and accelerated under artificial conditions leading to the generation of Biogas, consisting of methane and carbon dioxide, which in turn can be used as a fuel for power and heat.

Advantages	Disadvantages
1. As compared to Incineration technologies, Anaerobic Digestion does not release any gases into the atmosphere and is a 'net', 100% renewable source of energy.	1. The initial investment required for anaerobic digestion is high and thus scale is required to achieve commercial viability. Additionally, the maintenance cost is also high, owing to the involvement of bacteria. 2. Only organic matter is treated in this process, and thus the waste water produced could contain metals and other materials.

This process can easily be introduced into Sugar, Slaughterhouse and Distilleries industries for waste to energy projects.

Fermentation

Organic wastes can be converted to ethanol, the alcohol found in beverages, through bacterial fermentation (enzymes may be used to speed up the process), which converts carbohydrates in the feedstock to ethanol. Feedstock for this process includes forestry and agricultural wastes, such as molasses or waste starch.

The applicability, advantages and disadvantages are similar to Anaerobic Digestion.

Chemical Conversion

Trans-esterification

Trans-esterification is a process that uses an alcohol (like methanol) and reacts it with the triglyceride oils contained in vegetable oils, animal fats, or recycled greases, forming fatty acid alkyl esters (biodiesel) and glycerin. This is a useful technology for converting waste to energy. Depending on the fatty acids' content of feedstock, some pre-treatment of feedstocks may be required before the transesterification process. Feedstocks with less than 4% free fatty acids, which include vegetable oils and some food-grade animal fats, do not require pretreatment. Feedstocks with more than 4% free fatty acids, which include inedible animal fats and recycled greases, must be pretreated in an acid esterification process.

Advantages	Disadvantages
1. Output from this process, Bio-diesel, is more combustible than diesel, and hence a more efficient fuel. 2. The process does not have any harmful emissions	1. The process, if used on fresh edible oil, may contribute to supply changes and re-pricing / increased plantation and resultantly more deforestation. 2. The process may change depending on feedstock content; hence it is important to ensure that the feedstock is of the required constitution.

Establishing technical viability of waste to energy recovery process

The desirable range of important waste parameters for ensuring technical viability of Energy recovery waste for the above discussed processed are captured in Table 2.1 below.

Table 2.1: Desirable range of important waste parameters for technical viability of Energy Recovery Waste Treatment

Waste Treatment Method	Basic Principle	Important Waste Parameters	Desirable Range*
Thermo-chemical conversion - Incineration - Pyrolysis - Gasification	Description of organic matter by action of heat	Moisture content	< 45%
		Organic / Volatile matter	> 50%
		Fixed Carbon	< 16%
		Total Inert	< 36%
		Calorific Value (NCV)	> 1200 kcal. /kg
Bio-chemical conversion - Anaerobic digestion / Bio-methanation	Decomposition of organic matter by microbial action	Moisture Content	> 60%
		Organic Volatile Matter	> 40%
		C / N Ratio	25 - 30

* Indicated values pertain to segregated / processed / mixed waste and do not necessarily correspond to wastes as received of the treatment facility

Current Landscape in India

Industrial Sectors with high waste to energy potential

Post liberalization, Indian Industries have undergone a major transformation, with the emergence of new industries, influx of new technologies, and increased competiveness. This has resulted in increased quantities of waste, produced through the manufacturing process of products as well as operational inefficiencies, leading to ecological, environmental and economic damage.

Under the National Master Plan for Conversion of Waste to Energy, the ministry of new and renewable energy (MNRE) has identified the following industries in the country, which offer a high potential for conversion of waste to energy:

- Sugar industry
- Distillery sector
- Dairy sector
- Pulp & paper industry
- Poultry sector
- Tanneries
- Slaughter houses
- Cattle Farms
- Maize starch waste
- Tapioca starch waste

The tables below indicate key characteristics of the waste materials from these sectors and their energy potential.

Table 3.1: Key Characteristics of Indian Industrial Liquid Waste

Sector	Waste Generated (m3/Tonne)	BOD (mg /L)	COD (mg / L)	Total Dissolved Solids (mg/L)	Indicative Biochemical Energy Potential (N m3 of biogas/m3)
Distillery	25	45000 - 50000	90000-100000	70000-90000	25
Paper	15-30	4000-9000	12000-25000	10000-15000	5
Dairy	4 - 4.5	1000-1200	1800-2500	600-900	0.8
Abattoir	40-50	3500 - 4000	6000 - 8000	2500-3000	0.25
Maize	15	12000-12650	10000-20000	4000-6000	6
Tapioca	30	4600-5200	5600-6400	3500-4000	2.5
Tannery	30-40	1200-2500	3000-6000	14000-20000	1
Sugar	0.3-0.5	1250-2000	2000-3000	1000-1200	1

Table 3.2: Key Characteristics of Indian Industrial Solid Waste

Waste Sector	Moisture (%)	Total Solids (%)	Inerts (%)	Organics (Volatile) % TS	Thermal Energy Potential * Kcal / kg (Dry basis)
Poultry	75-80	20-25	25	75	1000-1400
Cattle Farm	80-90	20-Oct	20	80 - 85	3700
Bagasse	50	50	5 – 8	80-90	4000
Pressmud	75-80	20 – 25	10-20	75-80	4000
Abattoir	75 -80	20 – 25	NA	75 - 85	NA
Tannery Fleshings	75 - 80	20 -25	NA	75 - 85	NA
Corn cobs	10 - 15	85 – 90	< 5	95	3500
Tapioca peelings	10 - 15	85 – 90	5 - 10	85 - 90	3000
Tapioca Tippi	80 - 90	10 – 20	2 – 5	90	3000
Rice Husk	5-8	70-78	20-25	75-80	3000
Coal++	8 -10	90	25-30	70-75	4500

* Adopted from indiasolar.com; ++ - Value for Coal is indicated only for comparison purpose

A snapshot of the waste materials in these sectors and their respective energy generation potential at the end of 11th and 12th five year plans[5] is presented in the Table 3.3 and 3.4.

Table 3.3: Industrial Wastes with Energy Potential: Key raw materials and major waste streams

Sectors	Raw Materials	Major Waste Stream	
		Liquid	Solid
Distillery	Molasses	Spent Wash	
Dairy	Milk, Cheese	Washings, Whey	
Pulp & Paper	Bagasse / Straw	Black Liquor	Pith
Poultry	Chicken	-	Litter
Tanneries	Raw Hide	Toxic (complex)	Flesh / Hair
Slaughterhouse	Animals	Blood	Flesh / Bone
Cattle farm Waste	Cattle		Farm Waste
Sugar	Sugar cane	Waste water	Pressmud
Maize Starch	Maize	Steep Liquor	Pith
Tapioca Starch	Tapioca	Waste water	Pith, Peelings

Under the National mission plan for Waste to Energy (WTE) projects, these sectors have been prioritized based on the sector potential (in MW), waste availability/ collection, emerging clean technology and technology status.

Priority A: Distillery, Paper, Sugar (Pressmud), Maize Starch.

Priority B: Dairy, Sugar (Liquid), Poultry Farms, Slaughter House, Tapioca Starch

Priority C: Tannery

For sectors where individual units do not have a potential for energy generation (e.g. Poultry, Cattle farms etc.) energy potential needs to be harnessed based on clusters of units.

Table 3.4: Power Generation Potential in identified Industrial sectors (in MW)

Sectors	2012	2017
Dairy (Liquid Waste)	77	96
Distillery (Liquid waste)	628	785
Maize Starch	132	164
Liquid Waste	*30*	*37*
Solid Waste	*102*	*127*
Tapioca Starch	30	37
Liquid Waste	*22*	*27*
Solid Waste	*8*	*10*
Poultry (solid waste)	81	102
Paper (Liquid Waste)	72	90
Slaughterhouse (solid waste)	117	146
Sugar	453	567
Liquid Waste	*73*	*92*
Solid Waste	*380*	*475*
Tanneries (Liquid waste)	8	10
Total	**1598**	**1997**

Technology suitability for Indian conditions

The MNRE, under the Waste to Energy master plan, recommends the following technologies: Bio-methanation, incineration, gasification. An analysis of the above WTE technology options[6] based on technology systems, environmental aspects, resources recovery and commercial aspects reveals the following:

Bio-methanation	Gasification	Incineration
1. Offers the benefit of high commercial uptake internationally; hence implementation expertise is available. 2. Lesser impact on the environment due to low or no emissions. 3. The payback period of bio-methanation project is normally under 5 years.	1. It offers higher energy recovery potential and reduced environmental impacts (as compared to incineration). 2. With an increasing number of installations worldwide, gasification has started emerging as a mature technology.	1. Incineration is losing appeal with the emergence and adoption of Bio-methanation and gasification. 2. Incineration still has emissions which contribute to climate change. Developed countries are looking to prevent its use.

Indicative Case Studies[7]

Company Name	Context to WTE project	Waste Material used	Outcome
Kanoria Chemicals	Use of anaerobic digesters for bio-methanation of effluent producing biogas to be utilized for generating electricity	Spent Wash	At an initial outlay of under Rs. 9 crores, a 2 MW plant has been put up producing a little over 1 million units of electricity each month and generating a saving of Rs 40 lakhs /month. Payback period works to be about 3 years.
Agarwal Duplex Ltd.	Replacement of the existing boiler with a new fluidised bed boiler. The new boiler used bagasse as a fuel in place of coal under high pressure. The steam from this boiler was used to power extraction cum condensing turbine to produce electricity.	Bagasse	At an initial outlay of $2 million, the project resulted in annual savings of $1.5 million for the company. Reduction in GHG emissions by 37.4 tons per year.
M/s Alkabeer Exports Ltd.	Biogas plants were installed for treating both solid and liquid wastes generated from slaughterhouse. The sludge from the anaerobic digester is dried and is being marketed as a nutrient rich soil conditioner	Slaughterhouse waste	The biogas plants have resulted in a total saving of Rs 6.00 lakh per month; Adoption of biomethanation technology has resulted in saving of furnace oil as well as chemicals used for treatment of wastewater.
Vasundhara Dairy	UASB technology used for converting Waste to Energy with Biogas; Produced biogas is flared into the atmosphere	Dairy waste	40 cubic meter of Biogas produced; Plant investment - Rs 45 Lakhs
Varalakshmi Company	UASB technology used for conversion of Waste to Energy project using DFG engine	Sago Waste	Power generation plant of 0.2 MW - run using a 40 TPD sago effluent plant; Capital Investment of Rs 3.6 crores leading to production of almost 1.2 lakhs of electricity units (in KWh) per month.
Universal Starch	UASB technology used for conversion of Waste to Energy project; Produced biogas is fed to the boiler to save boiler fuel consumption.	Maize starch waste	Project cost of Rs 2 crores - 10,000 cubic metres of biogas produced each day
Vensa Biotek	UASB technology for biomethanation of effluent producing biogas to be utilized as fuel in the boiler. Produced biogas is used directly as fuel for generating steam in the boiler.	Starch and glucose manufacturing waste	Project cost of Rs. 1.8 crores for 8,000 cubic meter per day biogas production; Payback period of 4 years

Key drivers for Waste to Energy Projects for Indian Industries

Globally, advancement in technology and evolving environmental regulations has resulted in a growing demand and need for Waste to Energy Projects. Waste to Energy projects help address the key concerns of the prevalent global economic environment:

(a) Need to address Environmental Pollution

(b) Need for Renewable Energy

There are several drivers for the adoption of waste to energy projects by Indian Industries; these include the benefits of these projects as well as the enabling conditions created by the policy framework.

- The Indian Economy ranks amongst the largest and fastest growing economies in the world and the 12th Five Year Plan (2012-2017) targets for average growth of 9.5%-10%.
    - Resources and Energy, which are a key consideration for achieving this target, are limited in supply and subject to inflationary pressures.
    - Thus it becomes imperative that energy capacity be augmented by renewable sources (including solar, wind, nuclear, and waste) and resources utilization be optimized; both of which can be partially addressed through efficient waste management.
- Though the application of waste to create energy (or other products) is relatively nascent in India, it presents a tremendous and unique opportunity for a significant and strategic return on investments, as demonstrated by success of such interventions in several developed markets.

What drives Indian Industries towards 'Waste to Energy'

Financial Incentives

- Various schemes such as capital and interest subsidies, 100% accelerated depreciation, and exemption from sales and excise taxes, are offered by State and Central Government. Other incentives include funds for feasibility studies and detailed project reports.

Cogeneration of Electricity

- There is widening gap between demand and supply of energy, which would have a direct bearing on industrial operations. Waste to Energy projects offer industrial units and cluster a source of cheap and renewable energy.

Policy Compliance

- Government of India, through central and state agencies, has established a regulatory framefork for minimising and treatment of waste and control of pollution. Waste to energy projects would aid the adherence to these rules.

Other Economic Benefits

- In addtion to financial aid from government and lower energy costs, companies implementing waste to energy projects also register the same as CDM's and gain Carbon Emission Reductions, which can be traded.

Attract International Stakeholders

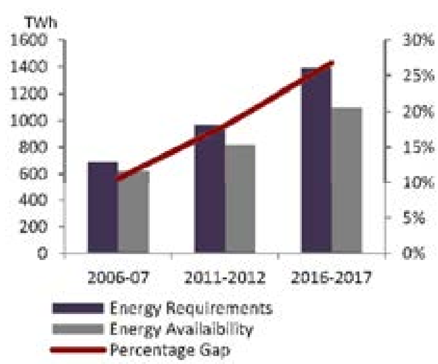
- Large scale industries and industrial sectors form a part of a global market place. Thus international customer and investor interest drives many industries to voluntary create positive environmental impact through waste to energy projects.

Energy Availability: Demand vs. Supply Pressures

Energy, in the form of heat or power, is a fundamental requirement for any industry unit.

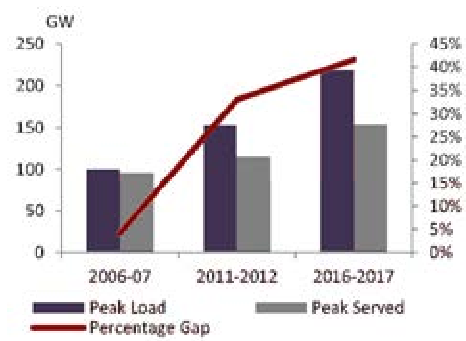
- The gap between the demand and supply of power in India is widening; which is impacting the growth potential. The Fig 4.1 depicts the projected demand and supply of power.
- There is rise in the gap between demand and supply from 2006 to 2017. This gap is amplified during the peak period, as seen in Fig 4.2.
- Fig 4.3 depicts the industrial demand for different fuels; the reliance on coal will continue to rise; exponentially increasing the emission of GHGs.
- Waste to Energy Projects will help reduce the gap and limit the reliance of units on grid based power supply or fossil fuel powered generators.

Fig 4.1 Projected Demand and Supply of Power



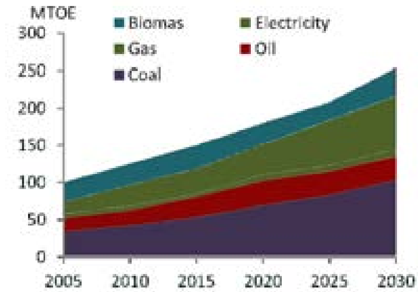
Source: India Energy Handbook 2011

Fig 4.2 Peak Demand and Supply of Power



Source: India Energy Handbook 2011

Fig 4.3 Industrial Energy Demand by Fuel



Source: IEA World Energy Outlook (2007)

Policy Compliance

In a bid to control Industrial and resultant urban pollution the state and government agencies have introduced many regulations. They include industry wide pollution control norms; implemented by the central and state pollution control boards.

The increasing concern regarding climate change and India's participation in global dialogues and conventions, such as the UNFCCC, has brought focus to the increase in carbon emissions experienced and projected for India.

This broadly defines the different environment with regards to policy, which Industries will have to adhere to. Waste to Energy helps in pollution control and facilitates policy compliance. These policies are detailed in a subsequent section.

Financial Incentives

Waste to Energy projects are capital-intensive in nature; they can be designed, executed and operated by a private entrepreneur/organization, the industrial unit or the urban local body or by waste management service provider either on supply and commission basis or on BOOT basis.

Financial incentives such as subsidies on interest rates and capital costs for demonstration projects, 100% accelerated depreciation, and exemption from sales and excise taxes, are offered. There are many agencies in India, providing financial assistance to waste-to-energy projects. These include ministries like MNRE and MoEF and financial institutions like IREDA, NABARD, state financial corporations and commercial banks. These programs and incentives are detailed out in a subsequent section.

Multilateral agencies such as the World Bank, GEF, IFC , KFW and ADB also have facilities for funding of waste-to-energy projects.

Other Economic Benefits

Opportunity in the CDM space - Industrial Waste to Energy conversion lends a large potential for development of Clean Development Mechanism (CDM) projects, which can lead to higher return on investment and lower payback period.

Analysis and Evaluation of CDM Potential of Bio-methanation sector in India, carried out in 2006, depicted that in 3 out of 4 Industrial Sectors, the registration of Bio-methanation Plants as CDM Projects led to positive returns (i.e. Distilleries, Pulp and Paper and Starch / Food Processing).[8]

Emerge as thought leaders and attract International Stakeholders - International investors/ customers are increasingly looking at the environmental performance of a company which forms a part of their portfolio or supply chain. Environmentally responsible companies, who emerge as leaders, would benefit from early mover advantages

Operating Environment

Policy

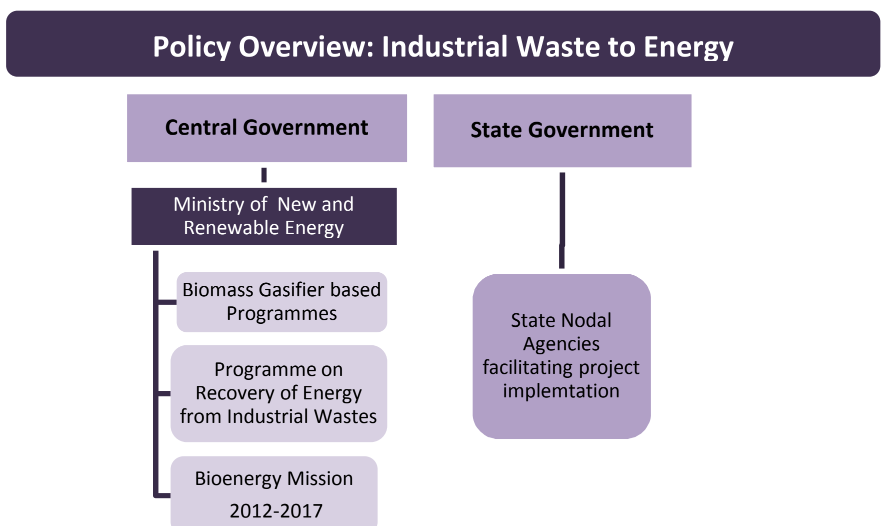
Management of Industrial Waste including waste to energy projects in India is broadly governed by different acts; policies and regulations. These exist along the continuum of the hierarchy of waste management to minimize environmental impact- i.e. Reduce, Reuse, and Recycle.

The Ministry of New & Renewable Energy (MNRE) along with the Ministry of Environment and Forests (MoEF) are the 2 nodal central ministries influencing the Waste to Energy programme legislation and incentives. MNRE, under its Biomass led power generation programme, has been instrumental in catalyzing projects in the following areas:

- Industrial bio-methanation for power and thermal applications
- Biomass gasifier based captive power and thermal applications in industries
- Biomass power based on agro / forestry residues through combustion technology
- Bagasse based co-generation in sugar mills
- Non-bagasse based co-generation in other industries

MNRE supports the waste to energy projects under 2 flagship programmes:

- Programme on Recovery of Energy from Industrial Wastes
- Biomass gasifier based programmes



Programme on Recovery of Energy from Industrial Wastes

The Program on Recovery of Energy Waste is a part of the National Master Plan for Development of Waste-to-Energy in India. According to the program notice, the objective of the program is to

1. To accelerate the installation of energy recovery projects from industrial wastes with a view to harness the available potential by 2017
2. To assess and upgrade various conversion technologies; and
3. To create a conducive environment for the development of the sector in the country

The ministry is attempting to significantly upscale the activities on this front to shape a conducive environment for the development of the sector in the country with a view to harness the available potential by the end of the 12th Five year plan.

The scheme provides for Central Financial Assistance[9] in the form of Capital subsidy and Grant-in-aid in respect of the following activities:

- Industrial waste to biogas
- Power generation from biogas
- Power generation from solid industrial waste
- Promotional activities
- R &D, resource assessment, technology upgradation and performance evaluation, etc.

The key characteristics of the programme and the available incentives are summarized below:

Eligibility Criteria	Project support defined on the basis of Type of Waste and Technology Used. There is no limit on the project capacity that can be supported under the programme. *Waste:* • Projects based on any bio-waste from industrial/agro –industrial sector (excluding risk husk and bagasse) that requires pre-processing before utilization for energy recovery. (Excluding distillery effluents, wastes from fossil fuels and waste heat (flue gases). • Projects for co-generation /power generation from biogas • Mixing of other wastes of renewable nature, including risk husk, bagasse, sewage, cow dung, other biomass and industrial effluents, including distillery effluents, upto a maximum of 25% is permissible • Projects based on distillery effluents for generation of biogas, wastes from fossil fuels and waste heat (flue gases) are not supported under the scheme *Technology* • Bio-methanation or combustion or combination thereof • Projects should either on 100% biogas or engines or steam turbines with a minimum steam pressure of 42 bar
Assistance Offered	• Capital subsidy offered to the Promoters on the basis of technology and capacity a. Waste to Biogas • Biomethanation of low energy density wastes –INR 0.5 - 1 crore/MWeq (depending upon the kind of industrial waste) b. Biogas to Power • Boiler + Steam Turbine – INR0.20 crore/MW • Biogas Engine / Turbine– INR 1 crore/MW c. Power Generation from Solid Industrial Waste (Boiler + Steam Turbine)- Rs. 0.20 crore/MW d. Total capital subsidy is limited to INR 5 crore per project or 20% of the project cost. e. 50% of the cost of DPR preparation, subject to a max. of Rs 1 Lakh per project • Incentives to State Nodal Agencies State Nodal Agencies are given 1% of the subsidy restricted to INR 5 lakh per project, in order to facilitate development of projects and their monitoring during implementation / post commissioning.

Biomass gasifier programme for Industry

The program on "Biomass Co-generation (non-bagasse) in Industry"[10] has a total outlay of INR 12 crores in the current year to:

a) encourage the deployment of biomass cogeneration systems in industry for meeting their captive thermal and electrical energy requirements with supply of surplus power to the grid
b) conserve the use of fossil fuels for captive requirements in industry and bring about reduction in greenhouse gas emissions in industry
c) create awareness about the potential and benefits of alternative modes of energy generation in industry.

Under the Biomass gasifier programme, MNRE aims to catalyze the adoption of Biomass Gassifiers to harness the potential of Biomass Energy. According to the program notification, the purpose of the program is to focus on:

1. Distributed / Off-grid power program for Rural Areas
2. Biomass Gasifier based Grid Connected Power Programme
3. Biomass gasifier based programmes in Rice Mills

The key characteristics of the programme and the available incentives are summarized below:

Eligibility Criterion	Off-grid power programme • Plants with maximum installed capacity of 250 kW, to be set up in areas / cluster of areas, which have surplus biomass resources and unmet demand of electricity. Grid Connected Power Programme • Biomass gasifier based power plants with 100% producer gas engines or Boiler-Turbine-Generator (BTG) projects, having a decentralized distribution component would also be supported. • The maximum installed capacity of each such project should be 2 MW.
Assistance Offered	• 100% biomass based off grid (in rural areas) and grid connected power projects - INR15,000 per KW • 100% biomass based captive power projects (captive power less than 50%) – INR 10,000 per KW • Projects involving installation of 100% gas engines with an existing gasifier – INR 10 lakh per 100 KW • Off-grid projects for Rural Areas and grid connected power projects for ensuring regular availability of biomass, provision of collection, processing and storage and operation & maintenance – INR 1.50 lakh per 50 KW • Other incentives are available for activities such as support towards lighting devices and distribution network, towards project formulation, preparation of Detailed Project Report (DPRs) for centralized distributed / grid connected / captive power generation project, training etc.

Financing of Waste to Energy Projects

In India, the industrial waste-to-energy projects have been successfully implemented independently in industrial sectors like distilleries, pulp and paper, dairy etc. The Waste to Energy projects based on Industrial waste in these sectors have typically proven to be cost effective and have generated attractive rates of returns. The IRR of bio-methanation plant generating only biogas is in excess of 30 % (without downstream aerobic treatment) and about 20 % when the downstream aerobic treatment cost is taken into account.

Such attractive returns and a growing track record of successful projects has bolstered the confidence amongst the financiers to back such projects and many new projects have been able to successfully source funding from commercial sources.

In addition to the support from the Central Government for Waste to Energy projects, project developers also have access to concessional loans and lines of credit setup to support such projects by IREDA, NABARD, SIDBI, state financial corporations and even certain progressive, commercial banks. International agencies supporting funding of waste-to-energy projects include USAID, kfW, JBIC, World Bank, GEF, IFC, ADB and the US EXIM Bank.

Harnessing the Potential: Addressing the Gaps

Waste to Energy conversion is a keenly pursued subject in India by policy makers and industry stakeholders, driven by international and domestic needs. It has been observed that there exists a sufficient policy framework to drive, direct, assist and govern the market for Waste to Energy. However, this has not translated into quantifiable outcomes at the level permitted and desired by the said policies. In order to harness the potential and expedite larger adoption, it is critical to reflect on the gaps and the efforts required for mitigating the same.

Gap Analysis

Policy

There are many stakeholders incentivizing / influencing the Waste to Energy market in India. Although the central government sets the overall policies, local authorities are expected to be involved in implementation as well as formulating supplementing policies. These local authorities are typically ill-equipped to determine specific technologies that are better suited for their areas and the type of waste generated. It is thus important to rationalize the approval process and engagement with the government machinery so that appropriate inputs guide the process.

Structured data to ascertain feasibility

A lot of the industries, such as slaughterhouses, poultry farms, etc operate largely as unorganized sector. Thus, data on waste generation and characteristics of the solid and liquid waste by the processing units is not available and hence feasibility studies are difficult, in absence of pilot projects. Structured database of waste generation and the potential it offers would be a helpful tool to attract investments and drive uptake of waste to energy projects by companies.

Industry structure

For small and medium scale enterprise, in certain sectors, the quantum of waste may not sufficient to make waste to energy installations feasible. Cluster formation and collective project implementation may be the solution to this problem; groups of producers can share investments outlays and benefit from the same.

Need for Increased Stakeholder Engagement

Mitigating Climate Change, a study carried out by ASSOCHAM, has reported that India has the potential to generate in excess of 1,000 MW from industrial wastes over the next couple of years, which can augment the traditional energy sources and lower the inflationary pressures.

In the sugar sector alone, it is estimated that a potential of almost 5000 MW of power exists that can be generated through bagasse based cogeneration in the country's existing 550 sugar mills.

To achieve this, however, it is important that the stakeholder engagement is structured. To achieve this, it is imperative to create a platform for stakeholder discussions whereby inputs of representative of stakeholder groups are assimilated and issues and concerns are alleviated.

As the goals become shared across the platform, participation from key catalyst groups would ensure that the goals are met. ASSOCHAM's Waste to Wealth conference aims to support and facilitate the requisite collaboration amongst diverse stakeholders to highlight the progress made in this sector over the last few years and motivate larger adoption of these initiatives by the industry. The Waste to Energy market offers a 'win-win' to enable wealth generation as also facilitate critical energy 'savings'.

End Notes

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