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ENERGY FUTURE

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FEATURE

The Potential for Energy from Waste

COVER STORY

Turning Trash to Treasure: Development of Waste-to-Energy Technologies

teri

From the editor's desk...

Waste, rather disposal and management of waste, appears regularly in media nowadays and all for the wrong reasons. And this waste comprises municipal as well as industrial wastes. The disposal and treatment of waste can produce emissions of several greenhouse gases (GHGs) which contribute to global climate change. The most significant GHG gas produced from waste is methane. As per the Intergovernmental Panel on Climate Change (IPCC), a large part of annual global anthropogenic methane produced and released into the atmosphere can be attributed to the anaerobic decomposition of land filled waste. Methane is around 20 times more potent as a GHG than carbon dioxide. Wastewater, both from domestic and industrial waste sources add to this. Countries like India, which are mainly agricultural-based economies, have many industries such as food and fruit processing, sugar industries, cattle and bird farming, agriculture export units, and food parks, etc. These industries produce a substantial amount of waste. However, all of these wastes have a huge potential of resource recovery, including energy, which can then substitute fossil energy. Indeed, waste minimization and thereafter its recycling is necessary to address not only global climate change but also local environmental concerns as well.

Undoubtedly, from a circular economy perspective, there is no term as 'waste' because the so-called waste from a particular process can very well be a valuable 'resource' for another one. And that is the approach being increasingly looked upon as a cost-effective alternative to traditional waste management practices, especially in urban and industrial sectors as well as along the agriculture value chain. The challenge of waste management becomes even more daunting if one takes into account the projections of the United Nations Department of Economic and Social Affairs in its report on *World Urbanization Prospects*. The report, alluding to rapid urbanization, projects that by 2030, there would be 41 megacities—most of them in global South—and by 2050, the world will be two-thirds urban. Waste can become a rich resource for energy, especially if this dichotomy of effective waste management on the one hand and meeting the ever-growing energy needs on the other hand is to be reconciled in a sustainable manner. May be this is how future megacities will meet their energy needs!

Amit Kumar

Amit Kumar
Senior Director, Social Transformation, TERI

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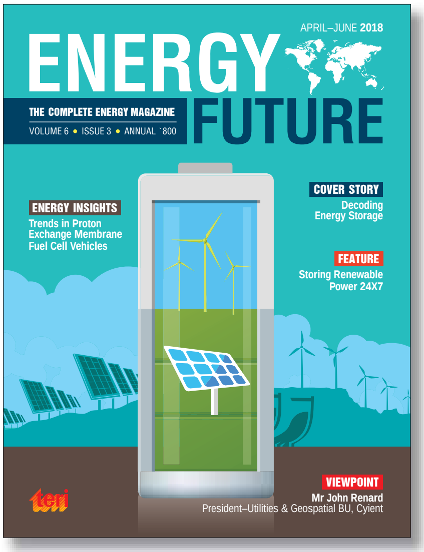

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Letter to the Editor

With reference to the cover story on decoding energy storage published in the latest issue of *Energy Future*, I would like to say that energy storage technologies provide flexibility in the use of electricity, for both centralized and decentralized supply provisions. Conventional use of storage systems by way of batteries (in electronic goods, vehicles) and accumulators (inverters and other electricity backup solutions) have been driven by commercial and technological considerations (and requirements), with little policy directive to incentivize the use of these novel solutions. Although, there are a number of barriers to energy storage market growth that must be overcome, energy storage will play an increasingly important role in the development of many emerging markets in the approaching decade (2020s).

Stuti Ram Menon
Kochi, Kerala

"The article on proton exchange membrane fuel cell vehicles published in the April–June 2018 issue of *Energy Future* is a highly informative and technical article indeed. It helped me in one of the projects at college. I also strongly agree with the authors (Radhey Shyam Meena, et al.) that while India is starting from a relatively weak position in battery manufacturing globally, the scale of its market opportunity is attracting strong interest from leading companies in India and globally as well.

Gaurav Mandhana
Mumbai, Maharashtra"

"The April–June 2018 issue of *Energy Future* with its theme on energy storage is replete with apt articles. Needless to say that nature stores solar energy as hydropower and biomass; our challenge is to concentrate the electrical energy derived from solar and wind energy into both portable and stationary stored energy that is efficiently and rapidly convertible, without air pollution, back into electrical energy. Today's challenge is the design of an electrochemical technology that can perform safely the task of electrical-energy storage and recovery at a rate and cost that are competitive with the performance of the well-established fossil fuel technologies.

Anshuman Biswas
Kanpur, Uttar Pradesh"

"I have been reading TERI's Energy Future magazine since the time I landed in India from the US in 2013. I must say that the magazine publishes exhaustive articles on a chosen energy theme in each quarter. This time also I liked the coverage and the in-depth analysis. The product update (boxofscience.com) is also very interesting. They are doing a stupendous work. The innovative methods of learning/teaching created by them are an ideal combo of theoretical and experimental learning. Kudos!

Joseph Langer
New Delhi"

Thank you very much for your encouragement. The editorial team of Energy Future will ensure that the magazine caters to your information and knowledge needs. We welcome your suggestions and comments to further improve our content and presentation.

Email: teripress@teri.res.in

Editor
Energy Future

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DELHI TO TAP SUN TO RAISE FARMERS' INCOME

The Delhi Cabinet has approved a proposal to increase the income of Delhi farmers by three to four times. The Chief Minister Arvind Kejriwal announced the 'Mukhyanmantri Kisan Aaye Badhotri Solar Yojna' under which the surface area of agriculture land will be used to install solar panels without disturbing the agriculture activities as the height of solar plates will be 3.5 m.

The solar panel will be installed in one-third area of the farm land. The estimated annual income of farmers is `20,000 to ` 30,000 per acre per year and with the introduction of this scheme, their income will increase three to four times per acre.

It would be pertinent to mention here that the scheme will provide a source of additional earning to farmers starting from `1 lakh per acre with an annual increment at 6 per cent; this further means farmers will get `4.04 lakhs per acre of the land in the 25th year.

"This will also provide clean energy to Delhi and help fight the menace of pollution. The solar power generated would be bought by different departments of the Delhi Government at a cheaper rate than on what they buy electricity presently. The Government would also save `300 to `400 crore using the cheap power from farm solar scheme," the Chief Minister added. EF

Source: The Pioneer

KARNATAKA NOW THE LARGEST PRODUCER OF GREEN ENERGY

Karnataka beat Tamil Nadu to emerge as the largest producer of renewable energy in the country. The state had a total of 12.3 gigawatts (GW) of renewable capacity installed as of March, of which 5 GW was added in 2017/18 alone, according to a report by the Institute for Energy Economics and Financial Analysis (IEEFA).

The report noted that due to its push towards renewable energy sources, "Karnataka is set to move from being a net importer of electricity to having a net balance, and it could become a net exporter" by 2028. Renewable energy sources, such as solar and wind energy, now account for 27% of the total power generated in the state. In contrast, coal powered thermal plants generate 49% of the total power. Nuclear and hydro-electric plants contribute 12% each to the total power generation, the report titled *Karnataka's Electricity Sector Transformation* stated. While coal costs swelled, cost of renewables has decreased. The report notes that recent solar tenders in Karnataka—such as the one for Pavagada Solar Park - have seen near record low bids of "`2.82–3.06 per kilowatt-hour (kWh), which was less than the average `3–5/kWh for domestic thermal power tariffs and the `5–6/kWh tariffs required for imported coal fired power". EF

Source: The New Indian Express

RAJASTHAN FIRST STATE TO IMPLEMENT BIOFUEL POLICY

Rajasthan has become the first state in the country to implement the national policy on biofuels unveiled by the Centre in May this year. The desert state will lay emphasis on increasing production of oilseeds and establish a Centre for Excellence in Udaipur to promote research in the fields of alternative fuels and energy resources.

The policy on biofuels seeks to help farmers dispose of their surplus stock in an economic manner and reduce the country's oil import dependence. It has expanded the scope of raw material for ethanol production by allowing use of sugarcane juice, sugar containing materials, starch containing materials and damaged foodgrains, such as wheat, broken rice, and rotten potatoes for ethanol production.

Rural Development and Panchayati Raj Minister Rajendra Rathore said here on Tuesday that a biodiesel plant of the capacity of 8 tonnes a day had already been installed in the state with the financial assistance of the Indian Railways. The state government would promote marketing of biofuels and generate awareness about them, he said.

While approving the policy on biofuels for implementation in the State at a meeting of the high-power Biofuel Authority, Mr Rathore said the Biofuel Rules, 2018, would shortly be brought into effect.

The Minister said the State Rural Livelihood Development Council would also encourage women's self help groups to explore the scope for additional income through the supply of biodiesel. EF

Source: The Hindu

CIAL WINS UN'S HIGHEST ENVIRONMENTAL HONOUR

The Cochin International Airport Ltd (CIAL) has been selected for the Champion of Earth Prize 2018, the highest environmental honour instituted by the United Nations. CIAL is honoured for its successful switch to solar power for all its energy requirements. The Cochin airport is the first such facility in the world to run fully on solar electricity.

A communiqué signed by Erik Solheim, Global Chief of Environment and Executive Director, United Nations Environment Programme (UNEP), sent to V J Kurian, Managing Director, CIAL, said: "This is the United Nation's highest environmental accolade and reflects your leadership in the use of sustainable energy".

It further said: "Previous champion laureates range from world leaders to inspiring scientists — all visionaries who drive the world closer to its aspiration of environmental sustainability and a life of dignity for all. As the world's first fully solar powered airport, you set an ambitious example that we hope many others will follow."

The award will be presented at a gala ceremony on the sidelines of the General Assembly in New York on September 26, according to a communication from CIAL.

The UN established Champion of Earth award in 2005 to recognise outstanding environmental leaders from the public and private sectors, and from civil society. There are four categories, wherein the CIAL was chosen for 'Action and Inspiration' which recognizes individuals or organizations that have taken bold environmental action, and, in doing so, inspired others to follow in their footsteps. EF

Source: The Hindu

INDIA'S ENERGY DEFICIT DOWN TO 1% IN FOUR YEARS: NITI AAYOG

The installed power generation capacity in India has risen to 344 gigaWatts (GW) and its energy deficit, which stood at over 4% per cent in 2014, has shrunk to less than 1% in 2018, according to an official release. "In course of the presentation made by CEO NITI Aayog, it was noted that the installed power generation capacity in India has risen to 344 GW. India's energy deficit, which stood at over 4 per cent in 2014, has shrunk to less than 1 per cent in 2018.

The release said that India now ranks 26th in the World Bank's "Ease of Getting Electricity" Index, up from 99th in 2014. EF

Source: The Economic Times

DELHI GETS SOLAR TREE, FREE WI-FI UNDER SMART CITY PROJECT BY NDMC

Parts of the national capital will now enjoy free Wi-Fi and high-speed broadband as Union Home Minister Rajnath Singh launched a slew of "smart city" projects. During the inauguration at the Charkha Park in Connaught Place, Singh said that the New Delhi Municipal Corporation (NDMC), by successfully launching the smart city initiative, has set an example before other aspiring smart cities in the country to follow.

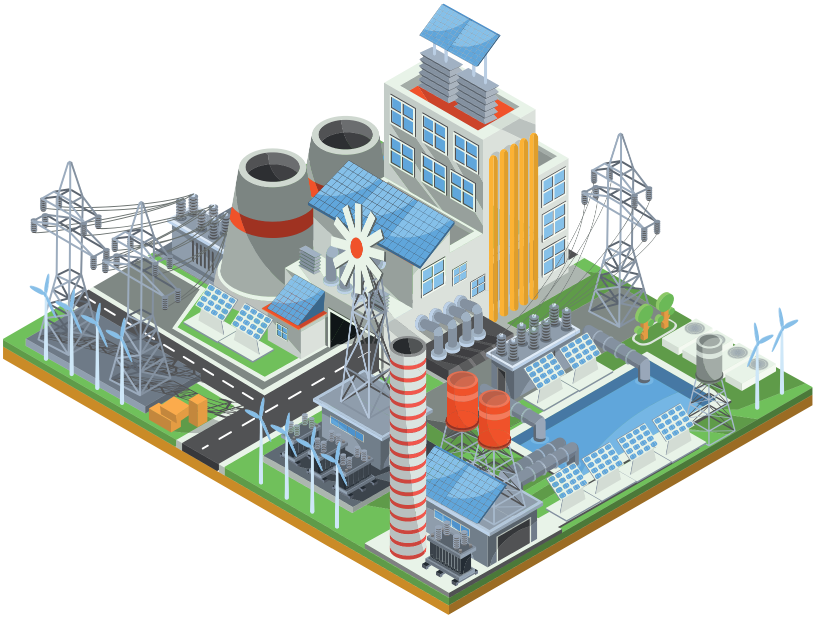
Other initiatives which were inaugurated by the BJP leader include smart poles, solar tree, ideation centre, 50 LED interactive screens, Ambedkar Vatika, two hi-tech nurseries, four mechanical road sweepers, two litter picking machines and 10 auto tippers. EF

Source: The Economic Times

INDIA'S FIRST THERMAL BATTERY PLANT UNVEILED IN ANDHRA PRADESH

India's first thermal battery plant was unveiled at Andhra Pradesh's capital Amaravati on 6 August by Chief Minister N Chandrababu Naidu. The plant will manufacture an energy storage device which will store renewable energy for various purposes and thereby reduce carbon emissions. The plant is expected to commence commercial operations by May 2019. Manufactured by Bharat Energy Storage Technology (BEST) Pvt Ltd, this device will help store energy for commercial vehicles and highway recharge points and is expected to be of great help in hilly and remote areas. The device, known as High Energy Density Storage (HEDS), is a technology that was invented and patented by Dr Patrick Glenn in 2016. These devices cost the same as the erstwhile lithium-based batteries, which have a limited life. EF

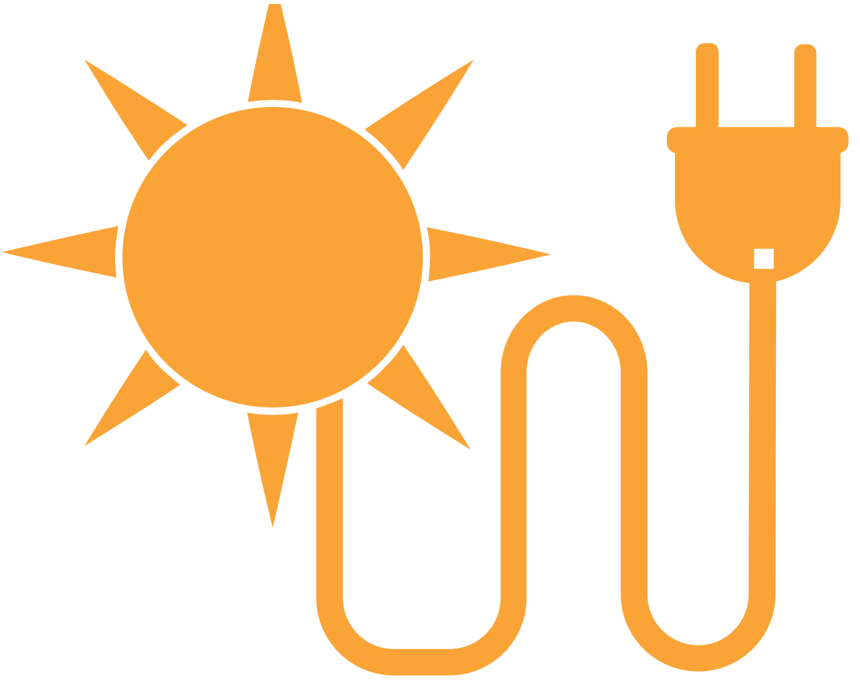
Source: The Tribune



DELHI UNIVERSITY COLLEGE GOES THE GREEN WAY, GETS 77KW SOLAR PLANT

Delhi University's Lakshmibai College has gone solar by installing a rooftop solar project on its campus. Taking a major step towards becoming an environment- friendly campus, the college has installed solar panels which would provide 77 kilowatts of electricity. The project is expected to reduce the electricity bill by 40% to 50% with savings of over ` 5 lakh per annum for the next 25 years. The initiative was undertaken with the help of a private entity and the Delhi government's power generation arm, Indraprastha Power Generation. The expected reduction in CO_2 emission is 88.7 tonnes in a year for the next 25 years. The college has partnered with CleanMax Solar, which has provided solar power based on the "pay as you go" or commonly known as "OPEX" model, at a tariff, 50% cheaper than the prevailing grid electricity tariffs. EF

Source: The Asian Age



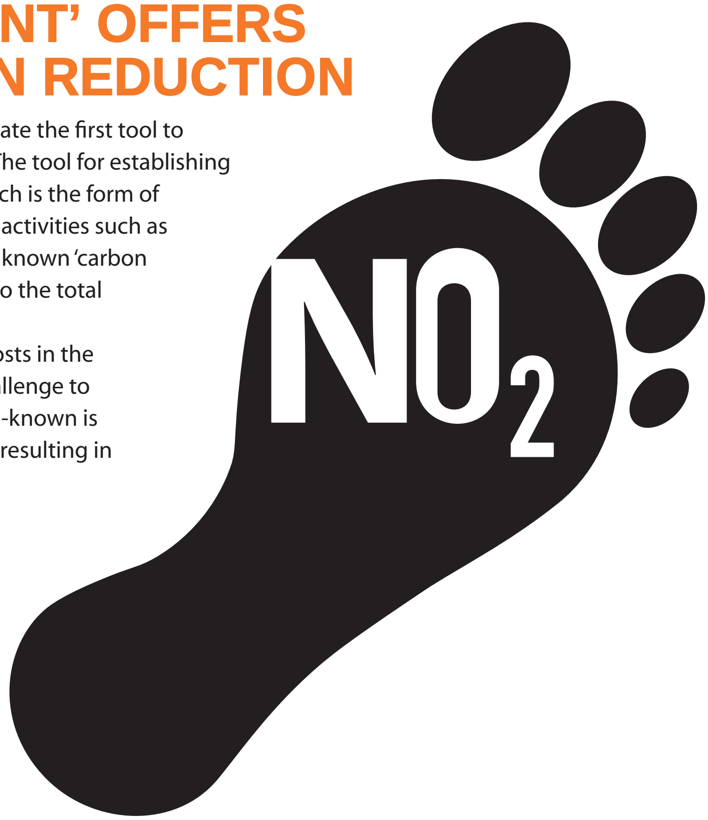
AFRICA: ETHIOPIA INAUGURATES AFRICA'S FIRST WASTE-TO-ENERGY PROJECT

Ethiopia's first waste-to-energy facility, the Reppie waste-to-energy facility, fully financed by the Ethiopian government, expected to process 1,400 tonnes of solid waste daily, was inaugurated in the presence of high-level Ethiopian and foreign dignitaries. The project, located in Addis Ababa, was constructed by China National Electrical Engineering Company (CNEEC). Speaking at the inauguration event, Ethiopian President Mulatu Teshome said investment in energy projects are crucial if Ethiopia is to achieve its aim of becoming an environmentally friendly industrialized middle-income economy by 2025.

"Sustainable development and environmental protection are major components of China–Africa cooperation. China supports Africa's endeavour towards green, low carbon and sustainable development," according to Chinese Ambassador to Ethiopia Tan Jian. "We actively participate in projects on clean energy, wildlife protection, environmentally friendly agriculture and smart cities." EF

Source: The New Times (Kigali)

NEW TOOL TO CALCULATE 'NITROGEN FOOTPRINT' OFFERS GUIDE TO POLLUTION REDUCTION



University of Melbourne researchers have helped create the first tool to calculate the 'nitrogen footprint' of an organization. The tool for establishing a nitrogen footprint calculates reactive nitrogen, which is the form of nitrogen released to the environment from our daily activities such as food consumption, travel and energy. Like the better known 'carbon footprint', it is a sum of individual activities that add to the total nitrogen output.

Nitrogen has human and environmental health costs in the hundreds of billions of dollars and is a significant challenge to the sustainability of our society. One of the most well-known is the nitrogen run-off from agriculture in Queensland, resulting in damage to the Great Barrier Reef.

The authors note that nitrogen pollution is often disguised as other global change issues, such as climate change, which nitrous oxides and nitrogen oxides contribute to, or harmful particulate matter 2.5, which ammonia gas contributes to. They found that the University of Melbourne has a nitrogen footprint of 139 tonnes of nitrogen, with three factors playing dominant roles: food (37%), energy use (32%), and transport (28%). EF

Source: Science Daily

SOLAR ROOFTOP PANELS TO SAVE ENERGY IN DUBAI

Following the successful retrofitting of 640 villas in Hatta with solar rooftop panels, Dubai is now extending the innovative approach across additional buildings and villas. The Safaqat programme will support the implementation of solar rooftop panels on buildings across the UAE, with demand coming from Hatta and residential villas in Dubai. Safaqat is the solar revolution enabler for the UAE and falls under the Shams Dubai initiative which aligns with Dubai's integrated energy strategy (DIES) 2030, the UAE National Energy Strategy 2050 and UAE Vision 2021. The solar rooftop panels are photovoltaic (PV) panels, which generate electrical power by using solar cells to convert energy from the sun into a flow of electrons. Safaqat, Arabic for transaction, is the green deal platform for the UAE, leveraging the power of crowdsourcing to provide economically viable low carbon solutions. Safaqat offers energy and resource efficient smart products, which will enable buyers to 'pay with their savings' whilst decreasing their environmental footprint. EF

Source: Gulf News

CHINA DOMINATES EUROPE'S WIND ENERGY MARKET: IEEFA

China's investment in foreign wind-powered electricity markets has surpassed $12 billion in Europe and Australia alone as private and state-owned Chinese companies move aggressively to capitalise on fast-growing renewable energy markets, as per the Institute for Energy Economics and Financial Analysis (IEEFA).

IEEFA's research brief says China's foreign renewable energy investments have increased as a result of the country's pan-Asian Belt and Road Initiative (BRI), but the majority of these investments are not in BRI countries. Interestingly, in BRI countries and in non-BRI developing countries, China continues to build coal-fired power projects as opportunities for domestic coal projects dry up. That report put China's 2017 investment in new energy technology and resources at $44 billion, up from $32 billion in 2016. The US-based IEEFA conducts global research and analyses on financial and economic issues related to energy and the environment. EF

Source: The Economic Times

RENEWABLE RESORT: GREEK ISLAND TO RUN ON WIND, SOLAR POWER

When the blades of its 800-kilowatt wind turbine start turning, the small Greek island of Tilos will become the first in the Mediterranean to run exclusively on wind and solar power. The sea horse-shaped Greek island between Rhodes and Kos has a winter population of 400. But that swells to as many as 3,000 people in the summer, putting an impossible strain on its dilapidated power supply. This summer, technicians are conducting the final tests on a renewable replacement system that will be fully rolled out later this year. It will allow Tilos to run exclusively on high-tech batteries recharged by a wind turbine and a solar park. The EU has largely funded the project. Named TILOS — Technology Innovation for the Local Scale Optimum Integration of Battery Energy Storage — the project uses a prototype battery system that improves storage of the excess energy generated until it's needed.

Source: www.cbc.ca

FIRST PLANT-BASED LINE OF LEGO GOES ON SALE

As the plastics debate continues to gather pace, companies have moved to include bio-based plastics in their products and packaging in recent times in a bid to decrease their reliance on fossil fuel-based raw materials. The latest news comes from toymaker Lego which began selling its first range of pieces made from plant-based plastic sourced from sugar cane. The new-style Lego elements are made from bio-polyethylene–a soft, durable, and flexible plastic that is made with ethanol extracted from sugar cane material.

Lego claims that the new pieces, which have been developed to look like plants, are just as durable as conventional plastic, but are able to be recycled more times. The caveat is that the material is unlikely to be 100% biodegradable. "At Lego, we want to make a positive impact on the world around us, and are working hard to make great play products for children using sustainable materials," said the Lego group's vice-president of environmental responsibility Tim Brooks.

Source: www.edie.net

THE WORLD'S LARGEST SOLAR FARM RISES IN THE REMOTE EGYPTIAN DESERT

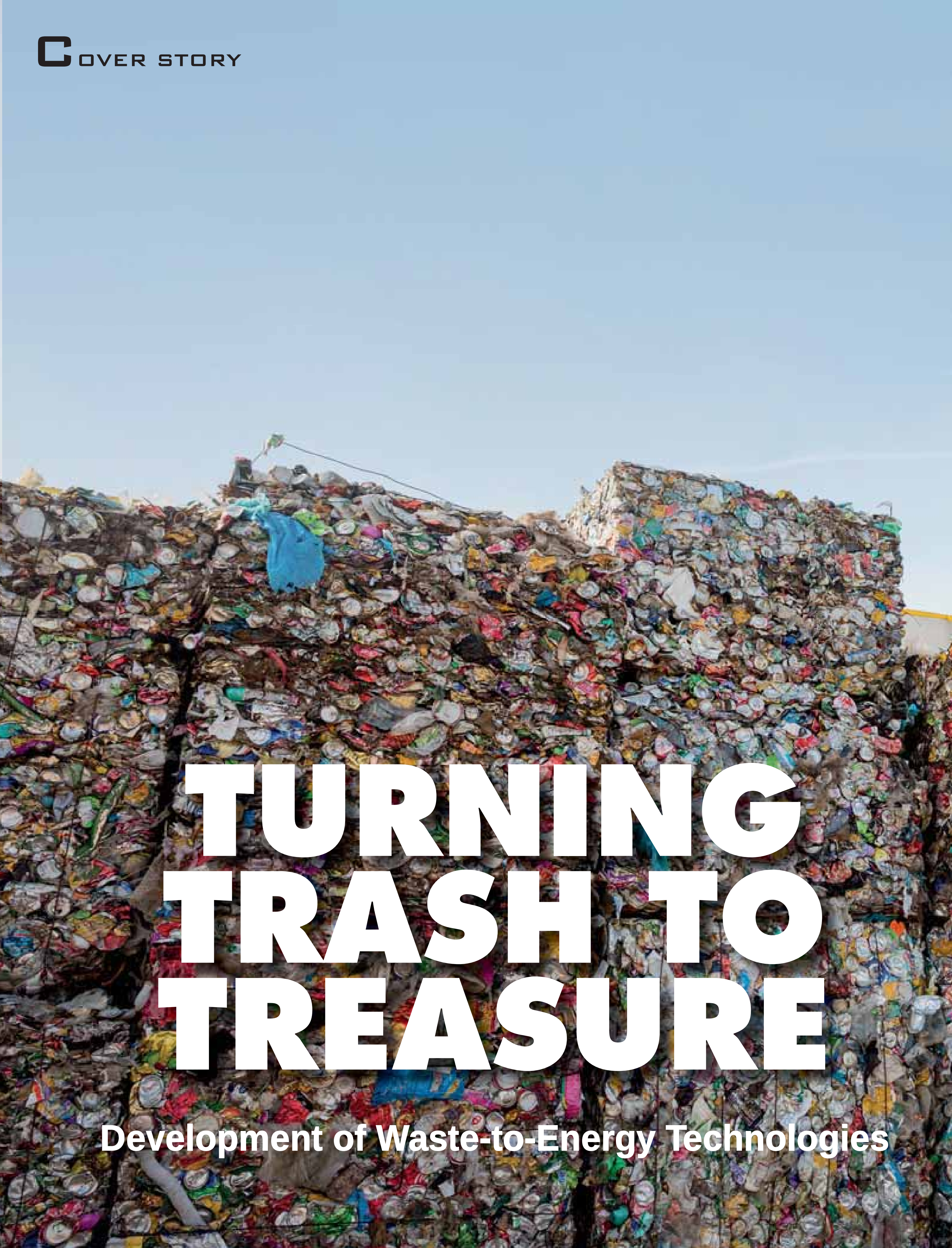
In 1913 on the outskirts of Cairo, an inventor from Philadelphia named Frank Shuman built the world's first solar thermal power station, using the abundant Egyptian sunshine to pump 6,000 gallons of water a minute from the Nile to irrigate a nearby cotton field. More than a century later, that vision has been resurrected. The world's largest solar park, the $2.8-billion Benban complex, is set to open next year 400 miles south of Cairo in Egypt's Western Desert. It will single-handedly put Egypt on the clean energy map. The Benban complex, which will be operated by major energy companies from around the world, is expected to generate as much as 1.8 gigawatts of electricity, or enough to power hundreds of thousands of homes and businesses. It will consist of 30 separate solar plants, the first of which began running in December, and employ 4,000 workers. EF

Source: LA Times

NZ CREATES WORLD'S FIRST DIGITAL TEACHER

New Zealand has created its very own digital teacher and has become the first country in the world to do so. The virtual teacher named Will has been made with artificial intelligence and is teaching primary school pupils around the country about renewable energy from inside an internet browser. Soul Machines Chief Executive Greg Cross shared how the same brain functions as real people. "Will is based on the likeness of a real person in then we build out using different aspects of artificial intelligence, including its outward personality." EF

Source: Newstalk ZB



TURNING TRASH TO TREASURE

Development of Waste-to-Energy Technologies

Waste-to-energy refers to a family of technologies that treat waste to recover energy in the form of heat, electricity or alternative fuels such as biogas. The scope of the term 'waste-to-energy' is very wide, encompassing a range of technologies of different scales and complexity. These can include the production of cooking gas in household digesters from organic waste, collection of methane gas from landfills, thermal treatment of waste in utility size incineration plants, and co-processing of Refuse Derived Fuel (RDF) in cement plants or gasification. **Dr Suneel Pandey**, through this article, explains the concept, need, available options, challenges, and the way forward for waste-to-energy technologies.

The Concept and the Technologies

The development of waste-to-energy market emerged as the perfect solution to the sustainable management of large quantities of waste, creating opportunities through several different drivers. These included the growing use of renewable energy resources, increasing amounts of waste generation globally, waste management regulations, taxes and subsidies, climate change policies to curb greenhouse gas (GHG) emissions, technological advancements, new financing opportunities, environmental degradation due to poor waste management practices, circular economy, green business models, industrial symbiosis (companies that work in partnerships to share resources), and the improved public perception of waste to energy.

Figure 1 summarizes the list of waste-to-energy technologies which have worked elsewhere and have the potential to work in the Indian context. The waste to energy option in the context of managing Municipal Solid Waste (MSW) in the developing countries is to process non-recyclable but biodegradable waste to produce biogas and use it for thermal or electrical application. A recent development is also to enrich biogas to produce compressed natural gas equivalent and use it as fuel for industrial or transport applications. The added by-product of process is stabilized waste which can be either used as soil conditioner or manure.

Thermochemical Conversion

As far as the thermal route of waste processing is concerned, the aim is to process non-biodegradable, non-recyclable organic waste by combustion to produce heat and power. Though generally there is significant reduction in waste volume, leading to diversion of waste from the landfills, the residue generated in the process may often contain toxic constituents and has to be managed accordingly.

Incineration

Municipal solid waste incineration is the burning of waste in a controlled process within a specific facility that has been built for this purpose. The primary goal of this option is to reduce MSW volume and mass and also make it chemically inert in a combustion process without the need of additional fuel.

As a side product it also enables recovery of energy, minerals, and metals from the waste stream. The reaction temperature is between 850 ºC and 1450 ºC, and the combustion process takes place in the gas and solid phase, simultaneously releasing heat energy.

During incineration, exhaust gases are created which after cleaning, exit into the atmosphere via a pipe or channel known as flue gas. These flue gases contain the majority of the available fuel energy as heat, as well as dust and gaseous air pollutants which must be removed via a flue gas purification process. Excess heat from combustion can be used to make steam for electricity generation and carry out district heating/cooling or steam supply for the nearby process industry.

There are always about 25% residues from incineration in the form of slag (bottom ash) and fly ash. Bottom ash is

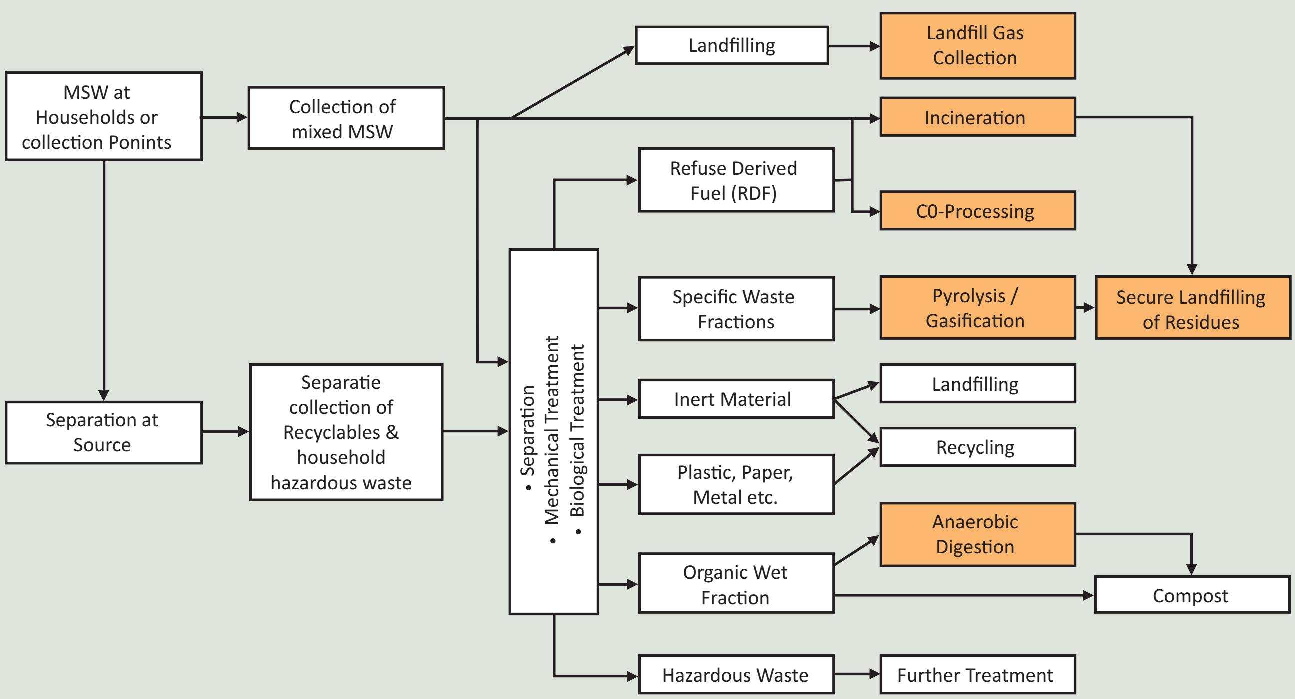


Figure 1: Suggested waste flows and applicable waste-to-energy options

Source: GIZ

made up of fine particulates that fall to the bottom of the incinerator during combustion whilst fly ash refers to fine particulates in exhaust gases which must be removed in flue gas treatment. These residues need further attention and in the case of the hazardous fly ash, a secure place for final disposal.

Co-Processing

As an alternative to conventional incineration with energy and/or heat recovery, the non-recyclable, non-degradable organic waste can be pre-processed to be used as alternative fuel in cement kilns. The process for firing alternative fuel in cement kilns is referred to as co-processing. It is the use of waste derived materials to replace natural mineral resources (material recycling) and/or traditional fossil fuels, such as coal, fuel oil, and natural gas (energy recovery) in industrial processes. Co-processing is applied worldwide mainly in the cement industry and in thermal power plants; in a few cases it is also applied in the steel and lime industry. In thermal plants where only energy recovery takes place, this is referred to as co-incineration. In the European cement industry, the thermal substitution rate of traditional fuels by waste can reach up to 80% in certain facilities (averaged over the year), while the average substitution rate across the European Union (EU) amounts to about 39%. Co-processing in cement plants has also become a widespread part of waste management systems in a number of developing and emerging countries. Nevertheless, the share of municipal solid waste (MSW) used in co-processing is still low compared to special waste streams, such as used tires, hazardous industrial waste, contaminated soil, biomass residues or sludge from wastewater treatment plants.

Co-processing in cement kilns has the advantage that the clinker reactions at 1450 °C allow a complete incorporation of ashes and in particular, the chemical binding of metals into the clinker material. Toxic organic compounds are completely destroyed in the flame at higher temperatures of >2000 °C.

Biochemical Conversion

Existing large waste disposal sites with depth or height of more than 5 m and having history of organic waste being disposed, can also be source of energy in terms of tapping landfill gas (LFG) for thermal or electrical applications. The methane in LFG is formed by the anaerobic digestion of organic matter in the landfill body which can be seen as an over-dimensioned bioreactor. In order to reduce GHG emissions from landfill sites into the atmosphere the capturing of methane gas is essential. This is possible through LFG capture however, significant losses occur in the start-up phase of a landfill site, before the methane capturing system is installed and in operation. When in operation it is still not possible to capture all of the gas emitted by the landfill. Over 200 LFG collection projects

were successfully realized under the Clean Development Mechanism of the Kyoto Protocol for mitigation of climate gas emissions. For sufficiently large projects, the LFG can also be purified and used as a transport fuel.

Yes another biochemical option for processing waste-to-energy is anaerobic digestion (AD). It is referred to as decomposition of organic matter through microorganisms in the absence of free oxygen. Suitable waste streams for AD are biodegradable food waste, vegetable market waste, slaughter house waste, flower market waste, etc., which are easily biodegradable. AD occurs naturally under oxygen deprived conditions, such as some lake sediments and can be used under controlled conditions to produce biogas. For this purpose a gas-tight reactor, a so-called anaerobic digester, is used to provide favourable conditions for microorganisms to turn organic matter, the input feedstock, into biogas and a solid-liquid residue called digestate. The digestate can be used as organic fertiliser when the feedstock is source separated and non-contaminated organic waste. Biogas is a mixture of different gases which can be converted into thermal and/or electrical energy. The flammable gas methane (CH_4) is the main energy carrier in biogas and its content ranges between 50%–75% depending on feedstock and operational conditions. Due to its lower methane content, the heating value of biogas is about two-thirds that of natural gas (5.5 to 7.5 kWh/m^3).

There are two promising alternative technology options—gasification and pyrolysis—which have been used successfully at times for specific waste streams, such as wood chips, agricultural residues, tyre chips, plastics, etc., at the decentralized levels. Their commercial success, however, is yet to be proven for MSW. Also, the environmental standards need to be evolved in India with respect to adoption of these technologies.

Evolution of waste-to-energy

The evolution of the waste-to-energy concept initiated with commissioning of waste incinerators to essentially combust the waste to reduce the volume and the toxicity. The first incinerator in the USA was built in 1885 on Governors Island in New York. By the mid-twentieth century, hundreds of incinerators were in operation in the USA but little was known about the environmental impacts of the water discharges and air emissions from these incinerators until the 1960s. When the Clean Air Act (CAA) came into effect in 1970, existing incineration facilities faced new standards that banned the uncontrolled burning of MSW and placed restrictions on particulate emissions. The facilities that did not install the technology required to meet the CAA requirements were closed.

On the European side, in the United Kingdom, both the Horsefall Destructor Company of Leeds and Heenan and Froude of Worcester were active in incineration in the latter half of the nineteenth century, with their cell-type furnace systems. By the beginning of the twentieth century, electricity was being generated in plants by recovering the energy released from the incineration of refuse. The first electrical waste to energy plant in the UK appears to have been built in Oldham in 1895 whilst Zurich operated a facility in 1904.

Early plants in this time scale were all known as batch facilities. Many such incinerators were built throughout Europe and the USA of which a surprising number had energy recovery.

The major advance in waste incineration during the twentieth century was the development of moving grates, which allow refuse to be fed continuously into a furnace, initially either by gravity or mechanical means. Once again, this technique may have been a British invention although this is open to contention. For example, the Heenan and Froude Company were building moving-grate continuous 'mass-burn' incinerators in the early 1920s.

The moving-grate system was then, and is today, the heart of the so called mass-burn system, where waste is processed at the plant 'as received'. In modern waste management, this is post-source separation for the recovery of recyclable materials before the recovery of energy from the residual waste stream. Such systems, particularly incorporating integrated grate and furnace systems, have now been developed to a high degree of sophistication, providing very high levels of reliability, efficiency, and consistent release of energy.

In India, on other hand, MSW was traditionally disposed on open, often low-lying areas, with a sole purpose of reclaiming land for urban development activities. The first MSW-based incineration plant was set up at Timarpur (Delhi) in 1987 using Danish technology, with a capacity to process 300 tonnes per day (TPD), to produce 3.75 MW power. However, the plant was unable to sustain combustion with the low calorific value and high content of moisture and inert material in the input garbage. So, the plant had to be closed down and now it is being dismantled. As of now, there are three combustion-based plants

in operation for processing MSW—of these, two are in Delhi and one is in Jabalpur at various levels of maturity. Anaerobic digestion-based MSW to energy projects got commissioned by utilizing the incentive schemes of the Ministry of Non-Conventional Energy Sources (now Ministry of New and Renewable Energy), Government of India. A number of efforts were made to install facilities for AD of municipal garbage. Two attempts were made on a large scale—first at Nagpur followed by the second in Lucknow for generating electrical power from municipal garbage. The project at Nagpur was abandoned at an early stage of construction by the entrepreneur. The project at Lucknow was commissioned successfully but its actual operation got embroiled in controversy about the quality of garbage being supplied by the municipal corporation, almost from the beginning. Also, the project cost was about `16 crore per MW and there was no cushion for lesser than calculated production due to quality mismatch of the input garbage.

These were followed by two small-scale attempts, which were perhaps more successful. At Vijaywada, an AD facility, followed by power generation, was installed which is designed for 20 TPD—about 16 TPD of segregated municipal garbage and 4 TPD of slaughterhouse waste. Another AD plant has been installed at Koyambedu flower market with a designed capacity of 30 TPD. This was followed by series of decentralized AD plants utilizing food waste from hotels and restaurants in Pune and as on date, there are around 20 such plants functioning in the city in the range of 1–10 TPD capacity. The biogas generated is processed into power which is used for street lighting.

The work on processing waste to generate Refuse Derived Fuel (RDF) and then use it for thermal or power applications began in England as construction began at Byker, New Castle and Doncaster, South Yorkshire in 1976 (Warmer Bulletin, No. 39, 1993, Kent, UK). Two plants were built in Italy in 1978, one in Germany in 1981, Laval (France), Chatel St. Denis (Switzerland), five plants in Sweden, and one 800 TPD capacity plant at Edin Prairie, Minnesota, USA. The RDF was used for generating power or used in cement plants.

The Department of Science and Technology, Government of India, had installed a refuse derived fuel (RDF) plant at Deonar in Mumbai in 1994; the plant had a capacity to process 80 TPD garbage. Almost at the same time, a 5 TPD capacity plant was installed in Bengaluru by a private company. The plant in Mumbai had initial difficulty in acquiring good calorific value. Both the plants were subsequently closed but the DST technology was further developed and marketed by the Technology Information Forecasting and Assessment Council (TIFAC). Two plants were set up—one in Hyderabad (200 TPD in 1999, later expanded to 700 TPD with generation of 6.6 MW power in 2003) and one in Vijayawada (600 TPD with a capacity to generate 6 MW from 600 TPD waste available from Vijayawada and Guntur set up in 2003).

Current Status

As per the Task Force Report submitted to Lok Sabha on waste to energy, there are 2,200 waste-to-energy plants around the world. They have a disposal capacity of about 255 million tonnes of waste per year. By 2017, another 180 plants with a capacity of 52 million tonnes shall have been added. Modern waste-to-energy technologies have been commercially deployed, especially in Europe, Japan, Australia, China, and the USA. In the USA, there are 86 WtE plants—about 12% of waste is combusted for energy recovery—mostly 'mass burn'. The number of plants built during 2008–11 all over the worldis shown in Figure 2. No new plants have been built in the US since 1995.

In India, as of now, two waste-to-energy plants are functional in Delhi, one based on mass burn option operating at rated capacity, another one based on RDF processing is yet to operate commercially, There is another plant commissioned at Jabalpur which is yet to attain commercial level. More RDF plants are on the anvil, boosted by the demand from cement plants aiming at fuel substitution to achieve desired thermal substitution rates.

It is also estimated by Ministry of New Renewable Energy, Government of India, in its deposition to Task Force at Lok Sabha that Indian cities currently have potential to produce around 500 MW of power through waste to energy route. The breakup of the potential is provided in Table 1.

As far as the waste to energy market is concerned, the global market was valued at US$25.32 billion in 2013, recording a growth of 5.5% on the previous year. Waste to energy technologies, based on thermal energy conversion, led the market and

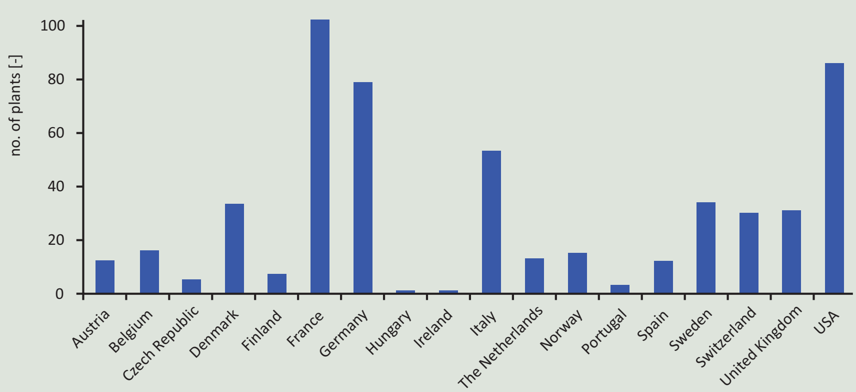


Figure 2: Waste to energy plants in Europe and US

Table 1: State-wise potential for power generation from waste to energy in India

S. No.	State	Power equivalent (MW)
1	Andaman and Nicobar	1
2	Andhra Pradesh	43
3	Arunachal Pradesh	1
4	Assam	2
5	Bihar	6
6	Chandigarh	1
7	Chhattisgarh	7
8	Daman & Diu and Dadra	1
9	Delhi NCT	28
10	Goa	1
11	Gujarat	31
12	Haryana	13
13	Himachal Pradesh	6
14	Jammu and Kashmir	7
15	Jharkhand	17
16	Karnataka	35
18	Kerala	6
19	Madhya Pradesh	19
20	Maharashtra	62
21	Manipur	1
22	Meghalaya	1
23	Mizoram	2
24	Nagaland	1
25	Odisha	9
26	Puducherry	2
27	Punjab	15
28	Rajasthan	19
29	Sikkim	0
30	Tamil Nadu	53
31	Tripura	1
32	Uttar Pradesh	72
33	Uttarakhand	5
34	West Bengal	32
	Total	500

Source: Lok Sabha Report on Waste to Energy

accounted for 88.2% of total market revenue in 2013.

Europe is the largest and most sophisticated market for waste-to-energy technologies, accounting for 47.6% of total market revenue in 2013. Increasing industrial waste, coupled with stringent EU-wide waste legislation, have been the major drivers for the European market. Switzerland, Germany, Sweden, Austria, and the Netherlands lead installation capacity within Europe. The Asia-Pacific market is dominated by Japan which uses up to 60% of its solid waste for incineration. However, the fastest market growth has been witnessed in China which has more than doubled its waste-to-energy capacity in the period 2011–2015.

On the other hand, market growth in the developing economies of Sub-Saharan Africa has been largely inhibited by the large upfront costs for waste to energy as well as a general lack of awareness of the benefits of waste to energy implementation. Low-cost landfilling remains the preferred option for the processing of waste in these parts of the world.

Challenges in implementing waste to energy projects

The calorific value of MSW is contributed by the biodegradable content of the waste, such as food waste and non-biodegradable content, such as paper waste, plastics, rags, leather, etc. The characteristics and variability of MSW as a fuel has a significant impact on its behaviour as a fuel in combustion and other thermal processing systems. In the context of MSW, there are challenges, enumerated as follows, in terms of waste processing and feeding of waste to energy systems.

- The composition of MSW continues to vary on daily basis which is further a problem in absence of source segregation. In addition to the variability in composition, MSW is notoriously difficult to handle and to feed in a controlled manner to incineration and other equipments. This is reflected in the design of MSW handling and feeding systems and has a significant knock-on effect on the difficulties encountered in the control of the combustion conditions in a conventional incineration plant.
- MSW is also a high slagging and fouling fuel, that is, it has a high propensity to form fused ash deposits on the internal surface of furnace and high temperature reactor, and to form bonded fouling deposits on heat exchanger surfaces.
- Arranging for higher costs for implementation of waste to energy project is another challenge for India. In most cases the cost of energy from waste is more expensive compared to that from fossil fuel. The thermal processes of energy recovery from

wastes are especially expensive due to high cost incurred in gas cleaning in order to comply with stringent air emission standards.

- Regarding social aspects, the main challenge is the lack of public acceptance which is based on negative perceptions of impact of these operations on health and the environment. There is a lack of public acceptance to specific processes, such as waste incineration.
- General opposition to the population residing in the vicinity of such projects is a result of often poor visual aesthetics of the project site. This is due to poor construction practices for the project site to keep the cost low, poorly maintained waste storage areas at the site, and the foul smell emanating from waste piles in unfavourable wind conditions.

The Road Ahead

Waste to energy projects whether decentralized (in case of AD) or centralized (RDF, incineration, co-processing, recovery of LFG) would be key strategies for diverting waste from landfills. Most of the cities are now facing problem of siting and developing landfill sites due not only to paucity of land but also opposition of neighbourhood population. It is therefore desirable to look at the following aspects to make waste to energy projects viable for India.

1. As the waste quantities would be heterogeneous on the daily basis, there is a need to add biomass or any other supplementary fuel to make it uniform for the purpose of firing it into the boilers.
2. To address the funding issue in order to make waste to energy plants viable, as suggested by Parliamentary Committee, the principle of "Polluters Pay, along with common but differentiated responsibility" should be adopted, that is, the increased cost should not be borne by all customers equally instead of the one who produces more solid waste (such as restaurants, hotels, marriage halls, other commercial establishments, etc.) should be made to pay more through a tax/cess/ fine.
3. The size of the project for different option would also be a crucial aspect. For example, as a general rule, incineration should only be considered if the incoming waste stream has an average net calorific value of at least 7 MJ/kg (that is, combustion process is self-sustaining). In addition, for optimal operation of the plant, the supply of combustible MSW should at least amount to 100,000 tonnes / year.
4. Seasonal changes in waste quality, such as during holidays and festivals and local traditions which may impact the nature of waste must also be taken into consideration. Where waste has significant water content and the organic fraction of the waste is relatively high, and sophisticated waste collection and transportation structures are not in place, biochemical methods of energy conversion should be the preferred option.

The next step should be to strengthen segregation of the non-recyclable dry combustible MSW at secondary storage depots/transfer stations and optimally utilize this material in the form of RDF which can be fed to waste to energy power plants and as an auxiliary fuel in the cement and metallurgical industries. Setting up of small to large plastic waste to liquid fuel plants, thereby utilizing the plastic which is not picked up by kabadiwalas and rag pickers also needs to be encouraged.

It is pertinent to ensure the development and implementation of waste-to-energy (WtE) technologies while following sustainability principles in order to ensure a correct waste treatment strategy and environment-friendly energy production; in addition to resolving challenges in both the waste management and energy sectors. EF

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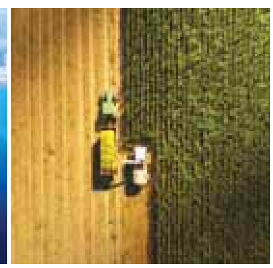

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#ACT4EARTH

THE POTENTIAL FOR ENERGY FROM WASTE

In the present-day global scenario when there is a clear energy crisis, it is imperative to search for new and alternative resources in place of the conventional ones. Further, for the sake of a clean environment, management of waste is also a problem. Recent years have however been witness to novel and feasible researches for conversion of waste to energy, particularly at a large scale. Significantly, energy from waste is a source (of energy) by means of which the waste is converted to some useful form of energy that may include electricity, heat or fuel for transportation. In this article, **Dr Richa Kothari** and **Rifat Azam** explain and evaluate the potential of waste as a source of energy.

Introduction

The term 'energy from waste' is best used to define a number of treatment processes and technologies which are used to produce some valuable form of energy. Among various technical processes, the biological, physical, and chemical treatment technologies in integration with combustion and incineration are used to describe all energy from waste and pre-treatment of waste. Similarly, the type of waste and its composition is also a part of the study if we move towards its utilization considering energy as an end product. Municipal solid waste (MSW) has been regarded as a nuisance and burden in several countries. Insufficient management of solid waste increases health and environmental issues and severely harms the environment due to garbage in public places. In recent times, waste to energy technologies are being viewed as a solution to the problem of sustainable waste management in developing countries, leading to an increase in the quantity of waste energy demand. Waste is a valuable energy resource which recovers two problems by treating non-recyclable and non-reusable amounts of waste that generate a large quantity of energy and which can also be involved in the energy production mix in order to satisfy the demands of consumers. The factors responsible for the relationship between the key to waste management and energy creation technologies, includes waste reduction, collection, recycling, etc. Presently, most of the developing as well as developed countries select/adapt the policies framed in an integrated way with social, economic, and environmental components. These results can have an effect on energy safety, energy equity, and sustainability of the environment, regarded as the future of the energy sector. For the management of waste in energy sector, certain tools are used for the production of energy which comes from waste. However, waste to energy alone cannot resolve the problem; it also requires an integrated solid waste management system tailored to the specific local conditions with regard to waste composition, collection, recycling, informal sector, environmental tasks, financing sector, price of resources, and other aspects as well.

Solid Waste and its Sources

Solid waste based on its physical, chemical, and biological characterization can be divided into various types, such as garbage waste, ash and residue waste, combustible and non-combustible waste, bulky and street waste, and biodegradable and non-biodegradable waste (Table 1). Garbage waste comes from animals and vegetables and result through the management of storage, cooked food, and some are obtained from the serving of food as well. These types of waste require special attention for storage, handling, and disposal. For the purpose of heating and cooking in institutions and residential areas, combustible materials, such as wood, are used for the burning process leading to ash as the residue. Ash, made up of fine particles, is perhaps more valuable for the process of landfilling. The waste which is generated from households, commercial activities, excluding food materials, is known as combustible waste. Household waste, such as refrigerators, old washing machines, equipments, and old van tyres, cannot be accommodated for the storage of normal containers and therefore,

Table 1: Sources of Solid Waste

S. No.	Sources	Typical waste generators	Composition
1.	Residential	Single and multi-family flats	Waste from food, ruff paper, cardboard, plastics, textiles and leather waste, metals, ash, hazardous domestic waste
2.	Commercial and institutional	Hotels, restaurants, markets, offices buildings, hospitals, schools, prisons, and government centers	Rough paper, old cardboard, wood, food waste, glass, and metals
3.	Construction and demolition	Renovation sites, new construction sites, road repairs, and demolition of buildings	Wood, steel, soil, bricks and tiles during construction, glass, plastics and insulation
4.	Municipal services	Parks, beaches, street cleanings, other recreational areas and water and waste water treatment plants	Street sweepings, recreational area waste
5.	Process waste	Chemical and power plants, extraction of minerals, heavy and light manufacturing refineries	Scrap materials, tailings, upper surface soil, waste rock, wastewater, and chemicals
6.	Medicinal waste	Hospitals, dispensaries, health centers and nursing homes	Infectious wastes, hazardous wastes, radioactive wastes, and pharmaceutical wastes
7.	Agricultural waste	Feedlots, farms, crops, orchards, vineyards and dairies	Waste food, rice husks waste cotton stalks, coconut shells, pesticides and animal waste
8.	Industrial waste	Fabrication, waste from construction, power and chemical plants	Waste from houses, waste from packed items, wood, steel, concrete, bricks, ashes

require distinctive mechanisms for the collection of these materials, better known as non-combustible materials. The waste which is collected from streets, empty plots and parks, along with scattering of waste in public places is a severe problem in several countries, including India. Organic matter, such as unwanted food, vegetables, fruit peels, unwanted paper and wood produced from various homes and industrial activities is known as biodegradable waste. Waste is degraded with the help of microorganisms from complex to simple form. The plastic, glass, cans, and metals are categorized as inorganic and recyclable materials which may not be degraded on their own and are referred to as non-biodegradable waste whereas old battery and medical waste is included as hazardous waste. Waste from construction and renovation sites is known as construction waste.

Key Components of Solid Waste Management

Solid waste management refers to the process by which the generated waste is controlled through collection, storage, transfer and transportation, and handling and disposal in a suitable way. Solid waste management is a major problem in day-to-day life due to increased urbanization, industrialization, and economic growth and increase in municipal solid waste management generation. Items that may be rendered useless by someone, such as tins and cans, may be sought by others for certain other purposes. Storage is a system prior to collection and final disposal for retaining materials after they have been discarded. Onsite disposal process is applied for discarding of waste material into pits. In an emergency, especially in the initial stages, the affected people will discard the home waste in poorly distinct loads near to dwelling places; there is a need of improved storage facilities that may include, shallow pits, small containers, large containers, and communal depots. Collection mainly refers to how waste is collected for transportation to the disposal site. Collection must be in a planned manner to ensure the delivery of the solid waste at an appropriate place and that must not be overloaded. Transportation refers to the means by help of which the solid waste collected is transported to the final disposal sites for further use or disposed of entirely. The type of transportation may vary from one region to another and is contingent on the types of transportation facilities for solid waste management at a specific place. Generally it can be divided into three main types: human powered, animal powered, and motorized. Disposal remains the most important phase where we have to minimize the risks associated with it as it remains the last stage of the solid waste management disposal. The more reliable methods for safe disposal are land filling or burial, composting, burning or incineration, and recycling (resource recovery).

Conversion technologies

Energy conversion from waste is involved in thermochemical and biochemical processes. Thermochemical processes are used for reduction of volume and destruction of pollutants. It can be mostly used in incineration and newer technologies, such as pyrolysis and gasification, which are more proficient and produce fewer amounts of greenhouse gases. Gases from landfills, anaerobic digestion, and anaerobic composting are recovered through the biochemical process.

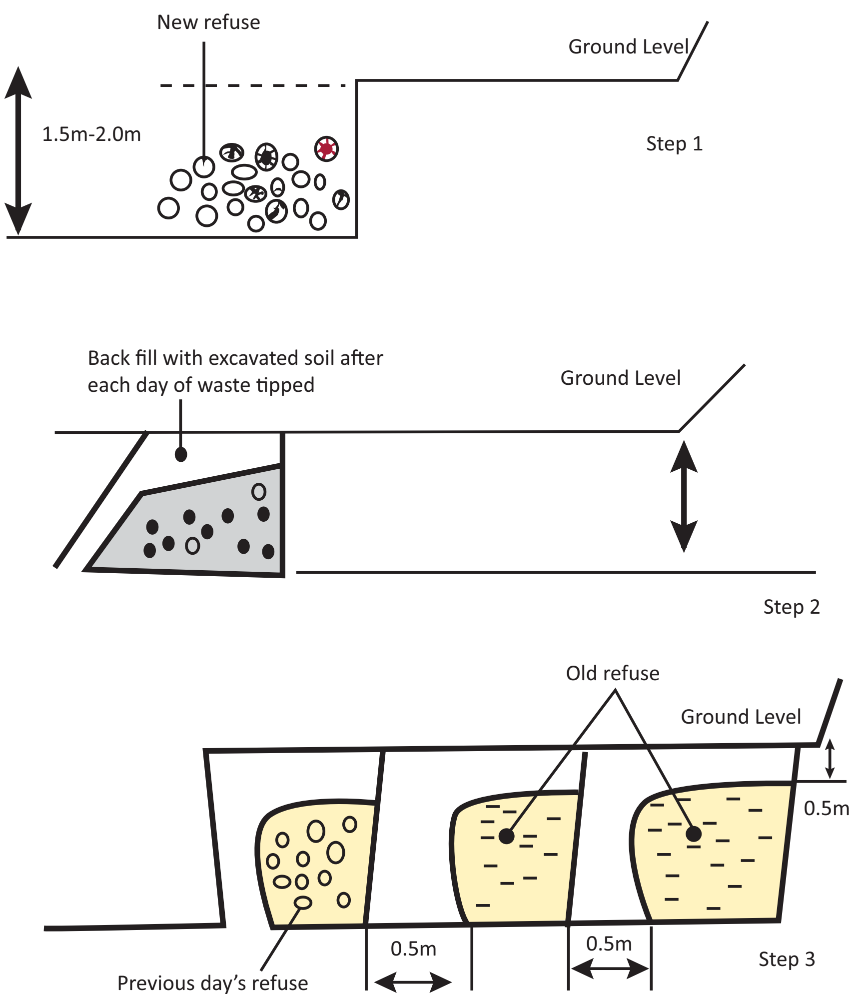

Figure 1: Open type land filling process

Microorganisms are used for the decomposition of solid waste and sludge which convert the solid waste into high energy value products, such as methane. An excess amount of oxygen and temperatures beyond 800 °C is required for burning the solid waste by incineration. This method is advantageous as it treats the organic as well as inorganic waste in a similar manner, reduces the volume of waste drastically, and at the same time, inhibits the emission of greenhouse gases like methane. Solid waste incineration technologies which were introduced by Japan, Denmark, Sweden, Switzerland, China, Spain, and Austria are a result of the energy crisis of the 1970s. Municipal solid waste generates electricity as well as heat. Pyrolysis is the thermal process which can be conducted in the absence of oxygen at temperature of 300 °C to 800 °C. Glass, metals, and various other inert materials are mechanically separated and then subjected to pre-treatment in the process of pyrolysis. The thermal decomposition of organic materials can be started at 300 °C. The temperature increases to 800 °C during the oxygen reduction in the non-reactive atmosphere of the heated chambers. Gases, liquid and solid residuals are the end bio-products of pyrolysis. Syngas chiefly composing of methane, carbon monoxide, carbon dioxide, and hydrogen is produced in the process of pyrolysis. A turbine and heat exchanger is required for the generation of electrical energy by thermal energy. Pyrolysis processes biomass as well as plastic materials. Pyrolysis is a highly advanced technology which converts the plastic waste with a high calorific value for syngas production. Hydrogen-rich syngas used for electricity production and inert materials used for the construction are the two bio-products produced via commercial plasma technologies. The technology which has high efficiency for recovering energy from solid waste is known as plasma technology. A thermochemical conversion process that makes use of gasifying agents, such as air and hydrogen, transforms the carbon in the waste into a high calorific value synthesis gas by reacting in an oxygen deficit environment. Though gasification technologies make use of unclassified waste, their potential greatly increases when the waste is classified. All the biodegradable and inert materials are

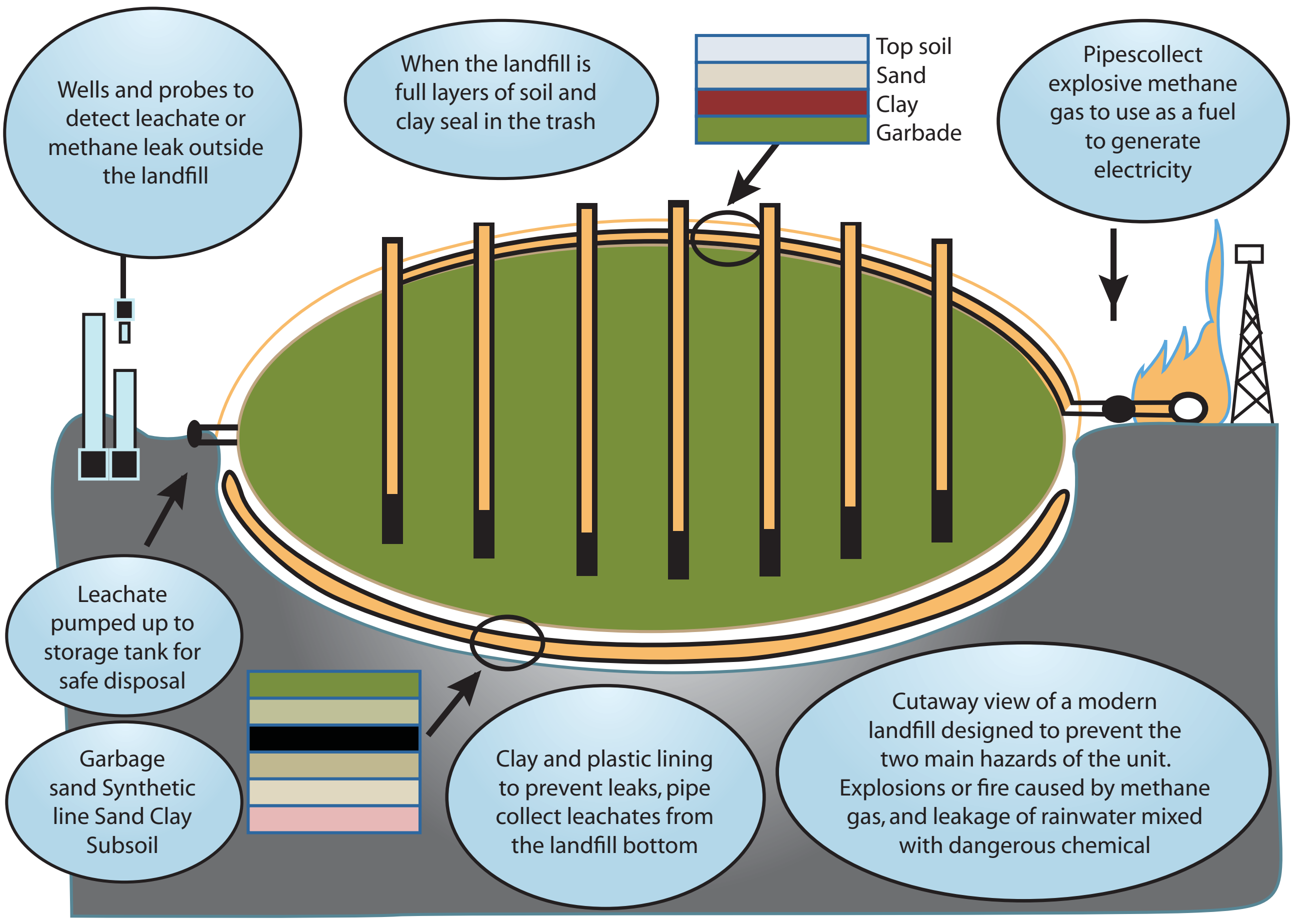

Figure 2: Closed type land filling process

discarded mechanically and the solid waste is subjected to gasification. This type of tool can inhibit the development of dioxins and reduction of acid gases. Through this process, the volume of the solid waste is reduced by an extent of about 50%–90%; also the construction of gasification plant requires a small piece of land located in industrial as well as urban areas. By the process of bio-decomposition, the waste can be used for the generation of bio-ethanol. Bio-hydrogen is also produced by the process of dark fermentation and photo fermentation. Biogas is produced by anaerobic digestion and from landfills. A bioconversion process where the organic fraction of the solid waste is utilized for the generation of biogas comprising of methane and carbon dioxide is termed as anaerobic digestion; achieved by anaerobic fermentation of biomass with the help of micro-organisms, such as bacteria. Wastes like rubbish, garbage, manure, sludge, and untreated wastewater are the main sources of biogas production. By the end of 2009, France implemented the anaerobic digestion for the production of electricity from biogas. Land fill gas, that is, methane comes from aerobic decay of the decomposable segment of municipal solid waste disposed off in the sanitary landfills. Basically, generation of biogas is achieved from the disposal of municipal solid waste. It consists of 50% methane and carbon dioxide, respectively. The gas extraction from the landfills is achieved by drilling wells with pipes which then burns to yield electricity. In the USA, the contemporary landfills collect about 2.6 million tonnes of methane that generate heat and electricity having a capacity of up to 50 MW turbine generators. Electricity can be generated by the landfill gas (methane) by making use of various other new and innovative energy system technologies like gas turbine in Brayton cycle, Organic Rankine Cycle, and Stirling cycle engine.

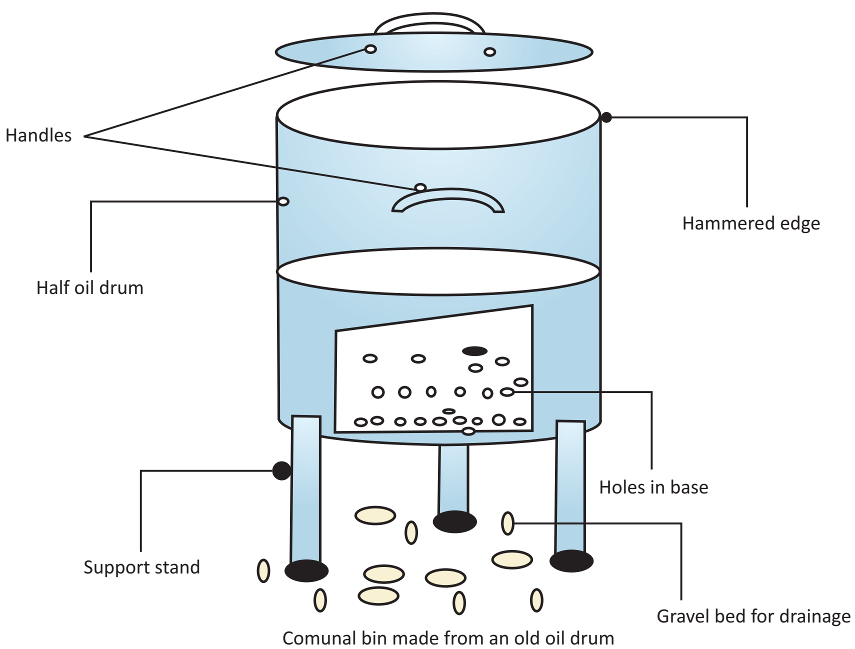

Figure 3: Communal bin made from an old drum

Integrated solid waste management process

In developing countries, the management of waste is a problem as compared to the resource for the recovery of energy. In 2011, the Resource Recovery Facility won an award from the Solid Waste Association of America for the excellent generation of power from solid waste as well as integrated solid waste management process. The Lee County where energy is obtained from waste by burning process is where 53 MW of electrical energy is generated. The process where the waste is reused in the form of compost and landfill is the best method for the generation of energy from waste. For waste management, communal bins are used for collecting waste where it will not be spread by the wind. This method is good for the management, transport, and disposal of waste. Communal pit technology is used for the waste on-site disposal and storage. Basically communal pit are used for the managing of solid waste in a particular site for the disposal of

waste. Fencing is important part to prevent small children falling in the pit. For the minimization of flies and other pests, pit should be covered for at least a week.

Impact of Dumping Waste on Health and the Environment

Waste dumps have a huge impact on environment and public health. When the waste is dumped openly, they release methane by the breakdown of biodegradable waste under the process of anaerobic condition. Methane is the main provider to global warming. The duration of summer odours is a serious problem for the health of human beings. The waste which is burned at dump sites releases small dust particles which directly affect the respiratory system of living things.

The waste which is not properly managed is quite effective for human health, especially breathing problems, immunity rate reduction, and occurrence of asthma.

Expected Outcomes: Government Initiatives and Challenges

Municipal solid waste, a valuable study for learning about the resources of renewable energy, is seen as a global opportunity for recovering energy by implementing 'waste to energy"'technology. In developed and developing countries, municipal solid waste is a potential energy source but it has not been implemented due to lack of technology transfer amongst these countries. A great number of technologies exist which are used for the production of energy from municipal solid waste and for biogas from anaerobic bio-digestion process. Energy is produced by making use of turbines and generators by the process of waste incineration. The potential renewable source of energy is gas which is utilized from landfill. The important by-products obtained from municipal solid waste are compost, recyclable materials, and energy. In biological waste treatment process, the anaerobic digestion occurs in the mesophilic temperature range between 35 °C–40 °C. Through this process, it is possible to enhance biomass efficiency through low operational temperature and a large cultivation process. The dry thermophilic anaerobic digestion technologies take a short span of time and operate at temperature above 55 °C to produce methane by the degradation of organic matter. The dry thermophilic anaerobic digestion technology gives an explicit higher microorganism's growth rate than the wet technology. In the process of pyrolysis, waste to energy working temperature can vary from 300 °C to 800 °C. Thermal treatment technology as well as gasification, used for the production of heat and electricity, decreases the waste volume by 90%. Globally, only 3% of the potential is used for energy or heat production. Bio refineries produce bio-fuels, bio fertilizers, and other value-added chemicals by converting the municipal solid waste biomass into usable end

products. These technologies integrated with apposite solid waste management systems is an example of integrated solid waste management systems around the globe. Similarly, government initiatives in recent years impart an emphasis on awareness and education on waste management strategies and its potential for the energy sector. The Swachh Bharat Abhiyan, that started in 2014 became a 'Jan Andolan' and received remarkable support and attention from the common people of the country. A large number of citizens of the country have pledged for a neat, clean, and hygienic India. After the launch of Swachh Bharat Abhiyan, sweeping the streets with brooms, disposing the garbage, attention towards proper sanitation, to maintain a healthy and hygienic environment, proper roads and infrastructure of India's cities, smaller towns, and rural areas have become the targets of the Mission. Construction of household-owned and community-owned toilets and instituting a responsible mechanism of monitoring toilet use are the objectives of the Mission. In order to achieve a defecation-free India till October 2, 2019, the primary focus is on manufacturing toilets, more specific to the rural and semi-urban areas of the country.

This type of initiative is the need of the hour and requires critical implementing strategies to develop these at the grass root level. The special tools required for the construction and operation of energy from waste are very expensive in comparison to incineration. In the economics and engineering sector, the heat energy which is recovered from waste is a sustainable solid waste management option for the generation of electricity. For the production of energy from waste, the collection, transportation process, and treatment plan plays a vital role. As we know that the fossil energy sources are becoming costlier day by day and diminishing, so waste to energy is the requirement of the hour. Furthermore, as a result of the scientific and mechanical advancements, the hurdles on the path towards waste to energy techniques can be resolved as a key component for a clean and green economy.

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CLEAN ENERGY FARMING

A Step towards Sustainable Development

Energy is a major parameter indicating growth and progress of a country, to the extent that people's standard of living is directly contingent on the per capita energy consumption. In agricultural systems, energy is available from different sources, such as animals, the sun, wind, biomass, coal, fertilizer, seeds, agro-chemicals, petroleum products, electricity, etc. Wind, solar, and biomass energy can be harvested forever providing farmers with a long-term source of income. These renewable sources of energy are becoming an increasingly important source of alternative energy, especially in the agricultural sector as it is also a major source of energy consumption. Increasing attention is focussed on the installation and use of these non-conventional energy sources in the agricultural sector in several countries of the world, purposely leading to environment-friendly, sustainable, and viable sources of energy to reduce the dependency on depleting fossil fuels, thereby minimizing the emission of greenhouse gases. As the energy industry grows, farmers will be able to tap their local resources, such as wind, water, soil, etc., to find the best energy sources. In this context, **Kirtika Sharma**, **Arjun Paul,** and **Neelam Rathore**, through this article, explain the role of renewable energy sources in the agricultural sector, focussing in particular on how agriculturalists can use renewables as a growing source of energy and rural income in India. It is also a means of enhancing sustainable food security in the country and presents the existing technologies and emerging opportunities in renewable energy application in the agricultural sector.

Introduction

Energy is the most important resource for progress and growth of agriculture. India, an agro-based country, is facing energy and water scarcity problems, despite other low productivity and soil conservation concerns. Increased food production to meet the rising demand of the ever-increasing population will also be a great challenge for agriculture. In order to mitigate climate change and reduce the greenhouse gas (GHG) emissions, there is a need to shift the current fossil fuel-based energy generation to non-fossil based renewable energy generation. Energy and water scarcity problems can be solved by the use of these sustainable, clean, and renewable energy sources which will ultimately become instrumental in the elimination of environmental damages and climate change.

New renewables, such as small hydro, modern biomass, wind, solar, geothermal, and bio-fuels accounted for another 2.4% and are growing rapidly. Even in 2008, about 19% of global final energy consumption came from renewable energy, with 13% coming from traditional biomass which was mainly used for heating and 3% came from hydroelectricity [1]. The share of renewable in electricity generation is around 18%, with 15% of global electricity coming from hydroelectricity and 3.4% from new renewables [2].

Sustainable Agriculture and the Role of Renewable Energy

The goal of sustainable agriculture is to meet the needs of the present without compromising the ability of future generations to meet their own needs. Sustainable agriculture integrates three main objectives—environmental health, economic profitability, and social and economic equity. The system is envisioned from an individual farm to the local ecosystem and the communities affected by this farming system, both at the local and global levels. There are many practices commonly used by the people working in sustainable agriculture and sustainable food systems. Farmers may use methods to promote soil health, minimize water use and lower pollution levels on the farm. Consumers and retailers concerned with sustainability look for 'value-based foods that are grown using environment-friendly methods, aid in promoting farmers' wellbeing, and also strengthen the local economy.

Sustainable agriculture research and education play a key role in building public support for agricultural land preservation by helping farmers to adopt practices that reduce chemical use and conserve scarce energy resources. Sustainable farmers maximize their reliance on natural, renewable, and

on-farm inputs to promote soil health, reduce the need for heavy fertilizer, pesticide, and herbicide application, minimize water use, and reduce pollution levels on the farm. A shift of emphasis towards renewable energy will, therefore, enhance sustainable agriculture.

Clean Energy Farming

All over the world, as energy prices are increasing, farmers and ranchers are turning more towards efficient clean energy practices, be it energy-saving light bulbs or using solar panels or fuel grown and processed on the farm. The process of generating renewable energy and using fossil fuel more efficiently brings profit and reduces dependence on foreign oil, thus providing local and national energy security [3].

Types of renewable energy

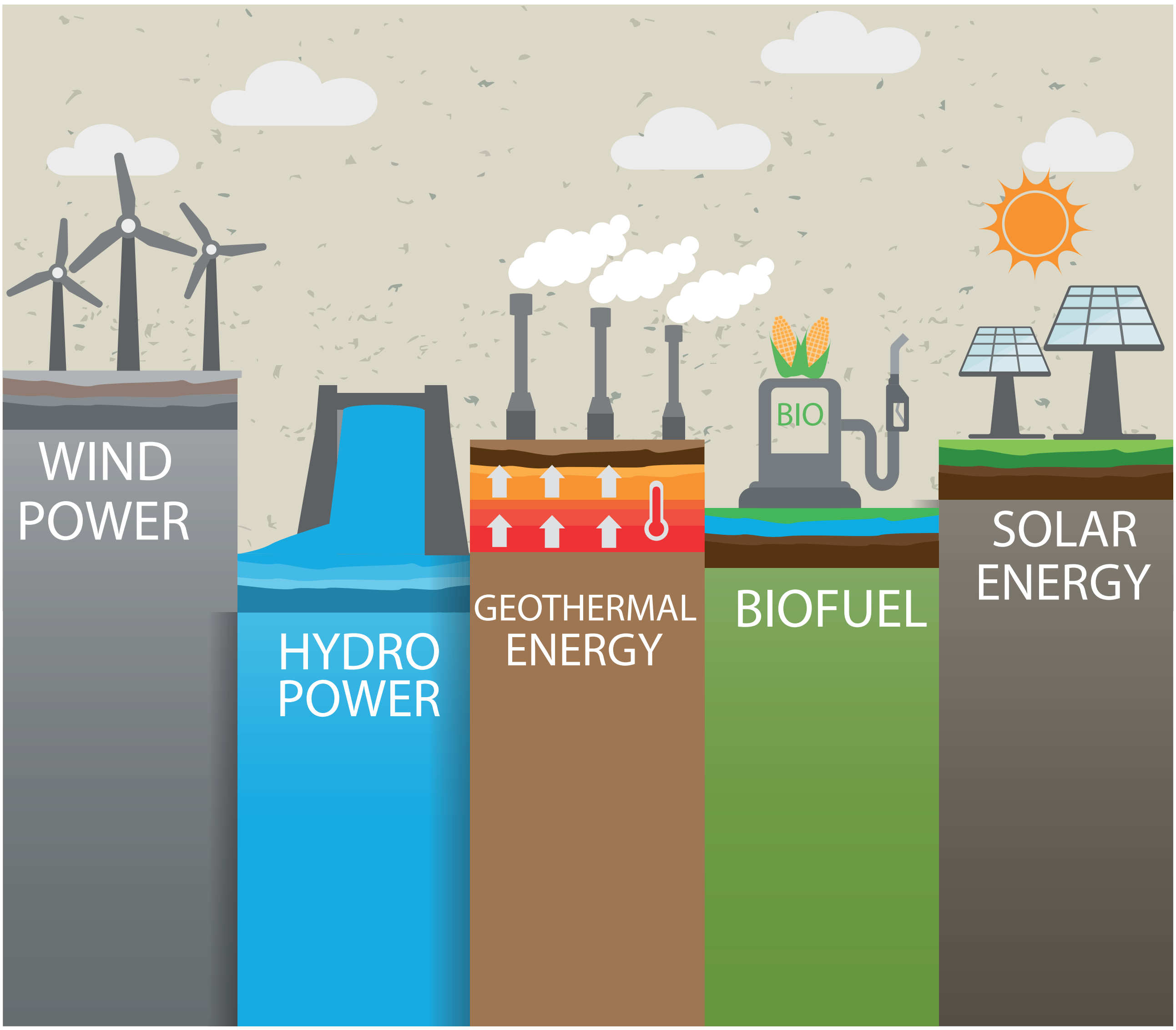
I. Biomass

Biomass (organic, non-fossil material) can be converted into bio-energy through different processes (direct combustion, thermo-chemical process, bio-chemical process, pyrolysis, anaerobic fermentation, landfills, ethanol fermentation, bio-diesel, etc.).

Biofuels: These are liquid and gaseous fuels produced from biomass which includes biogas, bio-ethanol, and bio-diesel. Biofuels are primarily used as transportation fuels, as competitors to petrol and diesel. Biofuel plants generate value-added economic activity that increases demand for local feedstock which raises commodity prices and farm incomes and creates rural employment opportunities. Using biodiesel in a conventional diesel engine provides the advantage of substantial reduction of harmful emissions. Biogas production, utilizing waste from agricultural enterprises, may be used for heating or electricity generation [4].

II. Solar energy

Solar energy technologies, being one of the most promising unconventional energy sources for the future, have



been used in agriculture since long, thus reducing a farm's electricity and heating bill costs, pollution, and the environmental burden [5]. Solar thermal technology inclusive of water heating, space heating, drying, cooking, and solar photovoltaic technology is used to generate decentralized power and distribution systems.

III. Wind Energy

Farms have long used wind power to generate electricity by wind turbines which can be used for running farm machinery, pumping, air-conditioners, and poultry equipment. Small and medium systems ranging from 400 W to 40 kW or more can be installed at farms where wind speed is available to meet the needs of an entire farm or can be targeted to specific applications [6]. With coastal areas of Karnataka, Maharashtra, Gujarat, etc., accounting for the maximum number of wind power plant installations, farmers in many more states could derive the benefits, since some of the best wind resources are found on agricultural lands.

IV. Hydro energy:

Hydropower is the most widely used renewable energy resource due to its significance over other renewable resources, such as high energy density, zero pollution, low cost, and reliability. Today, there are many hydroelectric power stations in the world and together they provide about more than 20% electricity across the globe [7]. Micro-hydroelectric plants are ideal for powering small services, such as processing machines, small farms, and communities while large hydroelectric systems can power large communities and cities.

V. Geothermal

Geothermal energy has emerged as a cost effective and reliable source of renewable energy, capable of producing about 10,000 MW of energy per year in India. It is produced from naturally occurring steam and hot water from under the Earth's surface by rotating a turbine to power an electric generator or to directly heat buildings. The GSI (Geological Survey of India) has identified 350 geothermal energy locations in the country [8].

Conclusion

Renewable energy is the next alternative option that will suit the agricultural sector of this country, since it is an economical, non-exhaustible, and environment-friendly source of energy and also other renewable energy technologies such as solar dryer, solar PV, etc., are significantly advantageous to the local farmers. Use of renewable energy sources in the agricultural production process will not only solve energy problems but will ensure food security and enhance sustainable agriculture in India. The shift towards

increase of renewable energy will reduce dependence on fossil fuel and import bills and provide greater saving to the country.

Therefore, the only realistic solution to the problem of going 'non-renewable' is to find sources of renewable energy to replace today's dwindling supplies of fossil energy by depending on the local renewable resources and the energy markets with the help of support from federal and state government. Provision of net metering makes it easy and affordable for farms to generate power from renewables. Other states provide funds for renewable energy development while certain companies who directly sell renewable energy to customers. Renewable energy and farming are a winning combination hence, it is only logical to look towards both agriculture as a renewable source and renewable sources in agriculture for the future.

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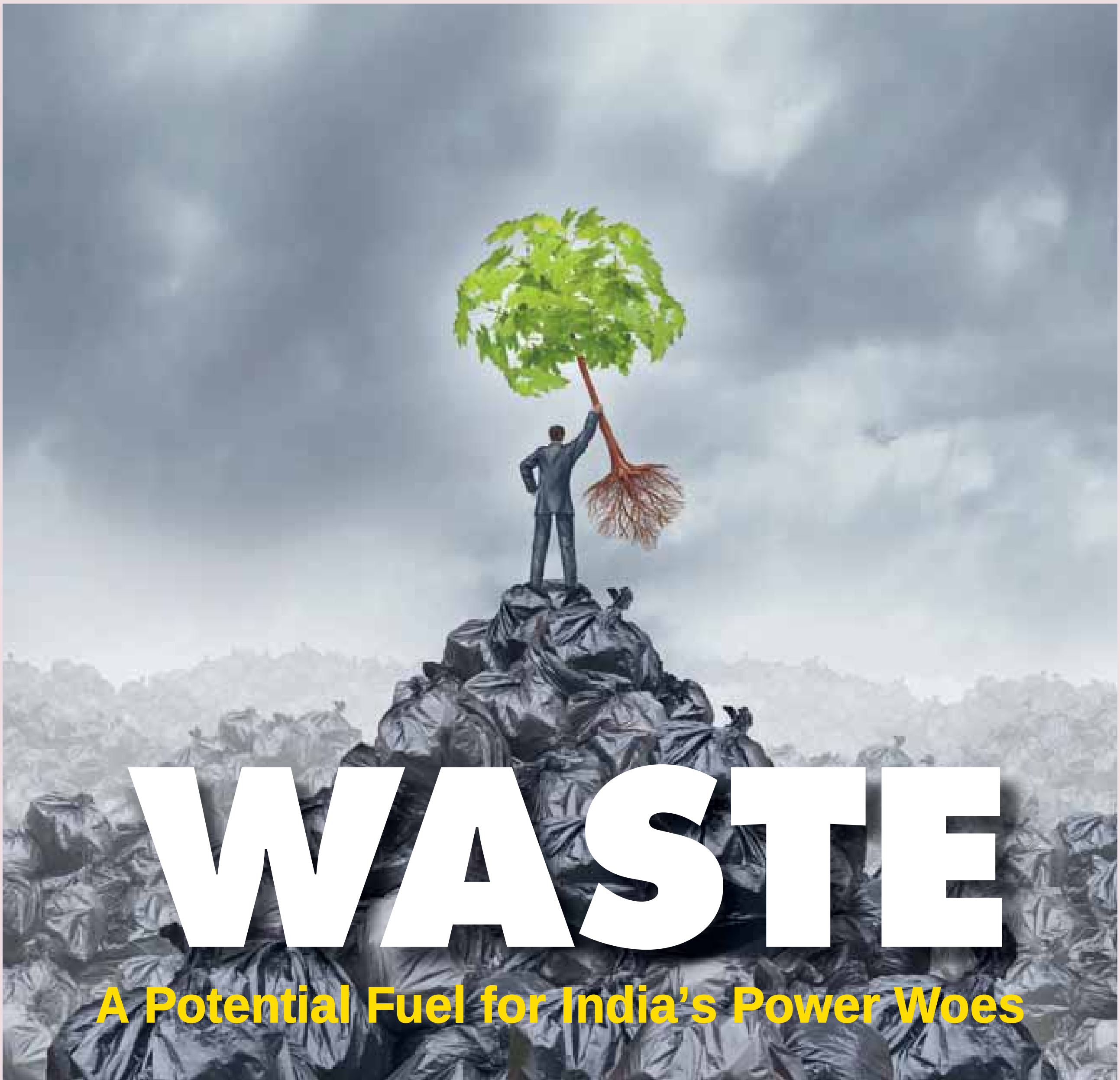

WASTE

A Potential Fuel for India's Power Woes

India has enormous potential to not just address its energy woes, but to also become a zero-waste economy through the implementation of right policies as well as a futuristic look at how not to let trash go to landfills. In this article, **Preeja Aravind** takes us through the Indian policy scenario and the quest towards utilizing waste as the new source of energy.

Introduction

India has always been known as a country that finds optimal use for everything. We were always a zero-wastage economy; from coconut husk to cow dung we found use in what was always thought of as 'useless'. Wastage as a concept was alien to the Indian way of life; that was until capitalism and material luxuries became important and the industrial and agricultural revolutions hit us.

Now, however, things are looking up again. With the recent announcement of amendments to the National Policy on Biofuel by the Ministry of New and Renewable Energy (MNRE), Government of India, there is hope that India's golden era as a no-waste economy will return. Our country's energy woes as well as the ever-ballooning issue of increasing waste across landfills, can be solved in one stroke—it is all a matter of the right implementation of a government-sponsored mandate.

According to a 2011 MNRE estimate, there was a potential of about 1460 megawatt (MW) from municipal solid waste (MSW) and another 226 MW from sewage itself. And these were the conservative estimates. This was apart from the potential to recover about 1300 MW power from industrial waste.

There are enough and more waste-to-energy opportunities within India. Like Sweden, it can become a zero-waste economy, and it wouldn't even have to import garbage from other countries like Sweden does!

To start with, there is food wastage—not the kind where leftover food is pushed to the back of the refrigerator only to be forgotten till it resurfaces during a spring cleaning. This is the kind of wastage where tonnes of foodgrains and food items, such as potatoes, corn, sugar, and beetroot, in warehouses rot due to poor storage.

As the Cabinet has approved expansion of the scope of raw material for production of ethanol—there is a renewed wave of progress in the waste-to-energy section. The amended policy has categorized biofuel into three divisions—first generation (1G) biofuels such as ethanol produced from molasses and bio-diesel from non-edible oil seeds; second generation (2G) ethanol from MSW; and a third generation (3G) biofuel, such as bio-CNG.

According to a statement released by the Press Information Bureau of India, the new National Policy on Biofuel 2018 expects multiple benefits from the expanded biofuels definition: reduce import dependency, cleaner environment, MSW management, employment generation, infrastructural investment in rural areas as well as additional income to farmers.

With this new categorization, a lot of food items that have starch and/or sugar have become unfit of human production—damaged wheat, rice, corn along with rotten or rotting sugarcane, potatoes, sugar beet, sweet sorghum—can be utilized to create ethanol to add to the fuel requirements of the country. This addition not only helps farmers earn a good price for damaged crops but also reduces the need for adulteration or the illegal sale of these items for human consumption.

Not just revisiting the definition of biofuel, the amended policy also touches upon what can only mean the correct direction to be a bit more farsighted about the Indian economy. There has been a mention of development or licensing of the technology to convert waste and plastic to fuel that can use the more than 60 million metric tonne, that is India's collective MSW.

Last year, in a conference paper presented at the Global Waste Management 2017, the contributing authors argued in favour of producing ethanol from the organic fraction of the MSW produced in the country. The biomass fuel is being heralded as a promising alternative source of energy. Considering Mumbai and Delhi produced nearly 20,000 tonnes per day of solid waste in just 2015/16, the prospect of ethanol-to-energy is a proposal a developing economy like ours should not push aside.

Apart from the energy production, biomass fuel production will also be a good way to reduce the demands of the existing landfills in India as they already seem to be bursting at the seams. From the figures of the current special waste-to-energy power plants that are operational in the other countries, on an average, the biomass material in the MSW used account for about 65%, producing about 50% of the energy. The rest is a combination of several non-biomass combustible

materials, a majority of which is plastics.

For instance in 2014, the entire US generated around 258 million tonnes of MSW; 29 million tonnes of this waste was incinerated in 71 specialized waste-to-energy power plants, along with four other power plants to generate about 14 billion kilowatt-hours of power.

If the numbers compiled by the Central Pollution Control Board (CPCB) are any indicators—the potential for waste-to-energy in India is at least 10 times that of the 2014 waste-to-energy numbers of the US.

Waste to energy is just one of the reasons to burn the MSW—it also reduces the overall volume of garbage that goes to landfills; after the incineration, the MSW is only about 15% of its original amount.

Landfills, An Energy Goldmine

And when it comes to landfills, there is a huge untapped energy section, waste in landfills and this can be mined for methane gas. When not disposed of in a more scientific manner, the waste in landfills produces high amounts of methane, adding to the greenhouse gas emission statistics of India.

Converting landfills to biofuel generating places can kill two birds with one stone: reduce the power shortage as well as decrease the country's carbon footprint by capturing and rerouting the methane from waste-to-fuel power plants, instead of just releasing into the atmosphere.

We can go the US and Canada way where several large landfills—which have been redesigned and reconfigured to accommodate structures to supply the naturally-forming methane—generate electricity by using the gas that is produced from decomposing biomass in landfills.

According to the report, *Challenges and Opportunities Associated with Waste Management in India* (published in March 2017 in Royal Society's Open Science) by 2050, the waste production across the world would be at 27 billion tonnes per year, with a third of that coming just from Asia; China and India being the major contributors.

The report also estimates that by 2025, urban India will produce about 0.7 kg per person per day waste. Currently, the waste production of urban areas is at 170,000 tonnes per day (TPD) and will only increase, by at least 5% per year as the urban dwellers rise in numbers.

Methane as a fuel is not a new concept in India. The biogas revolution that was promoted by the Indian government over the past couple of decades was to power up rural and agricultural communities where solid refuse as well as agricultural waste could be put to good use. Methane was the byproduct in that; the waste residual after the gas production was marketed as the non-chemical fertilizer. As far as renewable alternative source of energy goes, biogas has been one of the oldest source promoted by the Indian government. The new age bio-fuel, however, is a category in itself and not just one energy source.

Biogas: Methane before landfills

While the Indian government and the MNRE, in particular, is campaigning hard to move to naturally-occurring methane from coal deposits—to move towards a greener and more efficient fuel source, bio-methane (methane produced from the decay of organic matter) has been in a way overlooked.

Chemically speaking, methane (CH_4) is the simplest saturated hydrocarbon in existence—its chemical formula is CH_4 where four atoms of hydrogen are attached to a single atom of carbon. Even though methane is a major component of natural gas and it occurs