ISSN: 2395-7852

International Journal of Advanced Research in Arts, Science, Engineering & Management

Volume 10, Issue 2, March 2023

INTERNATIONAL
STANDARD
SERIAL
NUMBER
INDIA

Impact Factor: 6.551

| ISSN: 2395-7852 | www.ijarasem.com | Impact Factor: 6.551 |Bimonthly, Peer Reviewed & Referred Journal|

| Volume 10, Issue 2, March 2023 |

Waste Heat Recovery Systems-Make Clients Happy By Removing Recyclable Waste From Garbage Containers Reducing From Landfills

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ABSTRACT: A waste heat recovery systems(WHRS) is an energy recovery heat exchanger that transfers heat from process outputs at high temperature to another part of the process for some purpose, usually increased efficiency. The WHRU is a tool involved in cogeneration. Waste heat may be extracted from sources such as hot flue gases from a diesel generator, steam from cooling towers, or even waste water from cooling processes such as in steel cooling. Waste heat found in the exhaust gas of various processes or even from the exhaust stream of a conditioning unit can be used to preheat the incoming gas. This is one of the basic methods for recovery of waste heat. Many steel making plants use this process as an economic method to increase the production of the plant with lower fuel demand.

KEYWORDS: waste heat recovery system, recyclable waste, garbage containers, landfills, wastewater, cooling towers

I.INTRODUCTION

There are many different commercial recovery units for the transferring of energy from hot medium space to lower one:[1]

- Recuperators: This name is given to different types of heat exchanger that the exhaust gases are passed through, consisting of metal tubes that carry the inlet gas and thus preheating the gas before entering the process. The heat wheel is an example which operates on the same principle as a solar air conditioning unit.
- Regenerators: This is an industrial unit that reuses the same stream after processing. In this type of heat recovery, the heat is regenerated and reused in the process.
- Heat pipe exchanger: Heat pipes are one of the best thermal conductors. They have the ability to transfer heat hundred times more than copper. Heat pipes are mainly known in renewable energy technology as being used in evacuated tube collectors. The heat pipe is mainly used in space, process or air heating, in waste heat from a process is being transferred to the surrounding due to its transfer mechanism.[1]
- Thermal wheel or rotary heat exchanger: consists of a circular honeycomb matrix of heat absorbing material, which is slowly rotated within the supply and exhaust air streams of an air handling system.
- Economizer: In case of process boilers, waste heat in the exhaust gas is passed along a recuperator that carries the inlet fluid for the boiler and thus decreases thermal energy intake of the inlet fluid.[2]
- Heat pumps: Using an organic fluid that boils at a low temperature means that energy could be regenerated from waste fluids.
- Run around coil: comprises two or more multi-row finned tube coils connected to each other by a pumped pipework circuit.
- Particulate filters (DPF) to capture emission by maintaining higher temperatures adjacent to the converter and tail pipes to reduce the amount of emissions from the exhaust.

A waste heat recovery boiler (WHRB) is different from a heat recovery steam generator (HRSG) in the sense that the heated medium does not change phase.[3]

According to a report done by Energetics Incorporated for the DOE in November 2004 titled Technology Roadmap[2] and several others done by the European commission, the majority of energy production from conventional and renewable resources are lost to the atmosphere due to onsite (equipment inefficiency and losses due to waste heat) and offsite (cable and transformers losses) losses, that sums to be around 66% loss in electricity value.[3] Waste heat of different degrees could be found in final products of a certain process or as a by-product in industry such as the slag in steelmaking plants. Units or devices that could recover the waste heat and transform it into electricity are called WHRUs or heat to power units:

- An organic Rankine cycle (ORC) unit uses an organic fluid as the working fluid. The fluid has a lower boiling point than water to allow it to boil at low temperature, to form a superheated gas that can drive the blade of a turbine and thus a generator.
- Thermoelectric (Seebeck, Peltier, Thomson effects) units may also be called WHRU, since they use the heat differential between two plates to produce direct current (DC) power.
- Shape-memory alloys can also be used to recover low temperature waste heat and convert it to mechanical action or electricity.[4]

- Traditionally, waste heat of low temperature range (0-120 °C, or typically under 100 °C) has not been used for electricity generation despite efforts by ORC companies, mainly because the Carnot efficiency is rather low (max. 18% for 90 °C heating and 20 °C cooling, minus losses, typically ending up with 5-7% net electricity).
- Waste heat of medium (100-650 °C) and high (>650 °C) temperature could be used for the generation of electricity or mechanical work via different capturing processes.
- Waste heat recovery system can also be used to fulfill refrigeration requirements of a trailer (for example). The configuration is easy as only a waste heat recovery boiler and absorption cooler is required. Furthermore, only low pressures and temperatures needed to be handled.[4]

The recovery process will add to the efficiency of the process and thus decrease the costs of fuel and energy consumption needed for that process.[5]

Indirect benefits

- Reduced pollution: Thermal pollution Thermal and air pollution will dramatically decrease since less flue gases of high temperature are emitted from the plant since most of the energy is recycled.[5]
- Reduced equipment sizes: As fuel consumption reduces, the control and security equipment for handling the fuel decreases. Also, filtering equipment for the gas is no longer needed in large sizes.
- Reduced auxiliary energy consumption: Reduced equipment sizes means another reduction in the energy fed to those systems like pumps, filters, fans,...etc.[6]

Disadvantages

- Capital cost to implement a waste heat recovery system may outweigh the benefit gained in heat recovered. It is necessary to put a cost to the heat being offset.
- Often waste heat is of low quality (temperature). It can be difficult to efficiently utilize the quantity of low quality heat contained in a waste heat medium.
- Heat exchangers tend to be larger to recover significant quantities which increases capital cost.
- Maintenance of equipment: Additional equipment requires additional maintenance cost.
- Units add size and mass to overall power unit. Especially a consideration on the mobile power units of vehicles.[6]

Examples

- The Cyclone Waste Heat Engine is designed to generate electricity from recovered waste heat energy using a steam cycle.[7]
- International Wastewater Heat Exchange Systems is another company addressing waste heat recovery systems. Focused on multi-unit residential, publicly shared buildings, industrial applications and district energy systems, their systems use the energy in waste water for domestic hot water production, building space heating and cooling.[8]
- Motorsport series Formula One introduced waste heat recovery units in 2014 under the name MGU-H.[7]

II.DISCUSSION

A waste-to-energy plant is a waste management facility that combusts wastes to produce electricity. This type of power plant is sometimes called a trash-to-energy, municipal waste incineration, energy recovery, or resource recovery plant.[8]

Modern waste-to-energy plants are very different from the trash incinerators that were commonly used until a few decades ago. Unlike modern ones, those plants usually did not remove hazardous or recyclable materials before burning. These incinerators endangered the health of the plant workers and the nearby residents, and most of them did not generate electricity.

Waste-to-energy generation is being increasingly looked at as a potential energy diversification strategy, especially by Sweden, which has been a leader in waste-to-energy production over the past 20 years. The typical range of net electrical energy that can be produced is about 500 to 600 kWh of electricity per ton of waste incinerated.[1] Thus, the incineration of about 2,200 tons per day of waste will produce about 1,200 MWh of electrical energy. Most waste-to-energy plants burn municipal solid waste, but some burn industrial waste or hazardous waste.[9] A modern, properly run waste-to-energy plant sorts material before burning it and can co-exist with recycling. The only items that are burned are not recyclable, by design or economically, and are not hazardous.

Waste-to-energy plants are similar in their design and equipment with other steam-electric power plants, particularly biomass plants. First, the waste is brought to the facility. Then, the waste is sorted to remove recyclable and hazardous materials. The waste is then stored until it is time for burning. A few plants use gasification, but most combust the waste directly because it is a mature, efficient technology. The waste can be added to the boiler continuously or in batches, depending on the design of the plant.[10]

In terms of volume, waste-to-energy plants incinerate 80 to 90 percent of waste. Sometimes, the residue ash is clean enough to be used for some purposes such as raw materials for use in manufacturing cinder blocks or for road construction. In addition, the metals that may be burned are collected from the bottom of the furnace and sold to foundries. Some waste-to-energy plants convert salt water to potable fresh water as a by-product of cooling processes. The typical plant with a capacity of 400 GWh energy production annually costs about 440 million dollars to build. Waste-to-energy plants may have a significant cost advantage over traditional power options, as the waste-to-energy operator may receive revenue for receiving waste as an alternative to the cost of disposing of waste in a landfill, typically referred to as a "tipping fee" per ton basis, versus having to pay for the cost of fuel, whereas fuel cost can account for as much as 45 percent of the cost to produce electricity in a coal-powered plant, and 75 percent or more of the cost in a natural gas-powered plant. [11]The National Solid Waste Management Association estimates that the average United States tipping fee for 2002 was $33.70 per ton. Waste-to-energy plants cause less air pollution than coal plants, but more than natural gas plants.[2] At the same time, it is carbon-negative: processing waste into fuel releases considerably less carbon and methane into the air than having waste decay away in landfills or the lake.[3]

Waste-to-energy plants are designed to reduce the emission of air pollutants in the flue gases exhausted to the atmosphere, such as nitrogen oxides, sulfur oxides and particulates, and to destroy pollutants already present in the waste, using pollution control measures such as baghouses, scrubbers, and electrostatic precipitators. High temperature, efficient combustion, and effective scrubbing and controls can significantly reduce air pollution outputs.[12]

Burning municipal waste does produce significant amounts of dioxin and furan emissions[4] to the atmosphere as compared to the smaller amounts produced by burning coal or natural gas. Dioxins and furans are considered by many to be serious health hazards. However, advances in emission control designs and very stringent new governmental regulations, as well as public opposition to municipal waste incinerators, have caused large reductions in the amount of dioxins and furans produced by waste-to-energy plants.[13]

Waste-to-energy plants produce fly ash and bottom ash just as is the case when coal is combusted. The total amount of ash produced by waste-to-energy plants ranges from 15% to 25% by weight of the original quantity of waste, and the fly ash amounts to about 10% to 20% of the total ash.[1] The fly ash, by far, constitutes more of a potential health hazard than does the bottom ash because the fly ash contains toxic metals such as lead, cadmium, copper, and zinc as well as small amounts of dioxins and furans.[5] The bottom ash may or may not contain significant levels of health hazardous materials. In the United States, and perhaps in other countries as well, the law requires that the ash be tested for toxicity before disposal in landfills. If the ash is found to be hazardous, it can only be disposed of in landfills which are carefully designed to prevent pollutants in the ash from leaching into underground aquifers.

Odor pollution can be a problem when the plant location is not isolated. Some plants store the waste in an enclosed area with a negative pressure, which prevents unpleasant odors from escaping, and the air drawn from the storage area is sent through the boiler or a filter. However, not all plants take steps to reduce the odor, resulting in complaints.

An issue that affects community relationships is the increased road traffic of garbage trucks to transport municipal waste to the waste-to-energy facility. Due to this reason, most waste-to-energy plants are located in industrial areas.[14]

Landfill gas, which contains about 50% methane, and 50% carbon dioxide, is contaminated with a small amount of pollutants. Unlike at waste-to-energy plants, there are little or no pollution controls on the burning of landfill gas. The gas is usually flared or used to run a reciprocating engine or microturbine, especially in digester gas power plants. Cleaning up the landfill gas is usually not cost effective because natural gas, which it substitutes for, is relatively cheap.[15]

III.RESULTS

Incineration is a waste treatment process that involves the combustion of substances contained in waste materials.[1] Industrial plants for waste incineration are commonly referred to as waste-to-energy facilities. Incineration and other high-temperature waste treatment systems are described as "thermal treatment". Incineration of waste materials converts the waste into ash, flue gas and heat. The ash is mostly formed by the inorganic constituents of the waste and may take the form of solid lumps or particulates carried by the flue gas. The flue gases must be cleaned of gaseous and particulate pollutants before they are dispersed into the atmosphere. In some cases, the heat that is generated by incineration can be used to generate electric power.[16]

Incineration with energy recovery is one of several waste-to-energy technologies such as gasification, pyrolysis and anaerobic digestion. While incineration and gasification technologies are similar in principle, the energy produced from incineration is high-temperature heat whereas combustible gas is often the main energy product from gasification. Incineration and gasification may also be implemented without energy and materials recovery.

In several countries, there are still concerns from experts and local communities about the environmental effect of incinerators .

In some countries, incinerators built just a few decades ago often did not include a materials separation to remove hazardous, bulky or recyclable materials before combustion. These facilities tended to risk the health of the plant workers and the local environment due to inadequate levels of gas cleaning and combustion process control. Most of these facilities did not generate electricity.[17]

Incinerators reduce the solid mass of the original waste by 80–85% and the volume (already compressed somewhat in garbage trucks) by 95–96%, depending on composition and degree of recovery of materials such as metals from the ash for recycling.[2] This means that while incineration does not completely replace landfilling, it significantly reduces the necessary volume for disposal. Garbage trucks often reduce the volume of waste in a built-in compressor before delivery to the incinerator. Alternatively, at landfills, the volume of the uncompressed garbage can be reduced by approximately 70% by using a stationary steel compressor, albeit with a significant energy cost. In many countries, simpler waste compaction is a common practice for compaction at landfills.[3]

Incineration has particularly strong benefits for the treatment of certain waste types in niche areas such as clinical wastes and certain hazardous wastes where pathogens and toxins can be destroyed by high temperatures. Examples include chemical multi-product plants with diverse toxic or very toxic wastewater streams, which cannot be routed to a conventional wastewater treatment plant.[18]

Waste combustion is particularly popular in countries such as Japan, Singapore and the Netherlands, where land is a scarce resource. Denmark and Sweden have been leaders by using the energy generated from incineration for more than a century, in localised combined heat and power facilities supporting district heating schemes.[4] In 2005, waste incineration produced 4.8% of the electricity consumption and 13.7% of the total domestic heat consumption in Denmark.[5] A number of other European countries rely heavily on incineration for handling municipal waste, in particular Luxembourg, the Netherlands, Germany, and France.[2]

An incinerator is a furnace for burning waste. Modern incinerators include pollution mitigation equipment such as flue gas cleaning. There are various types of incinerator plant design: moving grate, fixed grate, rotary-kiln, and fluidised bed. The burn pile or the burn pit is one of the simplest and earliest forms of waste disposal, essentially consisting of a mound of combustible materials piled on the open ground and set on fire, leading to cause pollution.[19]

Burn piles can and have spread uncontrolled fires, for example, if the wind blows burning material off the pile into surrounding combustible grasses or onto buildings. As interior structures of the pile are consumed, the pile can shift and collapse, spreading the burn area. Even in a situation of no wind, small lightweight ignited embers can lift off the pile via convection, and waft through the air into grasses or onto buildings, igniting them. The burn barrel is a somewhat more controlled form of private waste incineration, containing the burning material inside a metal barrel, with a metal grating over the exhaust. The barrel prevents the spread of burning material in windy conditions, and as the combustibles are reduced they can only settle down into the barrel. The exhaust grating helps to prevent the spread of burning embers. Typically steel 55-US-gallon (210 L) drums are used as burn barrels, with air vent holes cut or drilled around the base for air intake.[9] Over time, the very high heat of incineration causes the metal to oxidize and rust, and eventually the barrel itself is consumed by the heat and must be replaced.

The private burning of dry cellulosic/paper products is generally clean-burning, producing no visible smoke, but plastics in the household waste can cause private burning to create a public nuisance, generating acrid odors and fumes that make eyes burn and water. A two-layered design enables secondary combustion, reducing smoke.[10] Most urban communities ban burn barrels and certain rural communities may have prohibitions on open burning, especially those home to many residents not familiar with this common rural practice[20]

As of 2006 in the United States, private rural household or farm waste incineration of small quantities was typically permitted so long as it is not a nuisance to others, does not pose a risk of fire such as in dry conditions, and the fire does not produce dense, noxious smoke. A handful of states, such as New York, Minnesota, and Wisconsin, have laws or regulations either banning or strictly regulating open burning due to health and nuisance effects.[11] People intending to burn waste may be required to contact a state agency in advance to check current fire risk and conditions, and to alert officials of the controlled fire that will occur. The typical incineration plant for municipal solid waste is a moving grate incinerator. The moving grate enables the movement of waste through the combustion chamber to be optimized to allow a more efficient and complete combustion. A single moving grate boiler can handle up to 35 metric tons (39 short tons) of waste per hour, and can operate 8,000 hours per year with only one scheduled stop for inspection and maintenance of about one month's duration. Moving grate incinerators are sometimes referred to as municipal solid waste incinerators (MSWIs).

The waste is introduced by a waste crane through the "throat" at one end of the grate, from where it moves down over the descending grate to the ash pit in the other end. Here the ash is removed through a water lock.[21]

Part of the combustion air (primary combustion air) is supplied through the grate from below. This air flow also has the purpose of cooling the grate itself. Cooling is important for the mechanical strength of the grate, and many moving grates are also water-cooled internally.

Secondary combustion air is supplied into the boiler at high speed through nozzles over the grate. It facilitates complete combustion of the flue gases by introducing turbulence for better mixing and by ensuring a surplus of oxygen. In multiple/stepped hearth incinerators, the secondary combustion air is introduced in a separate chamber downstream the primary combustion chamber.

According to the European Waste Incineration Directive, incineration plants must be designed to ensure that the flue gases reach a temperature of at least 850 °C (1,560 °F) for 2 seconds in order to ensure proper breakdown of toxic organic substances. In order to comply with this at all times, it is required to install backup auxiliary burners (often fueled by oil), which are fired into the boiler in case the heating value of the waste becomes too low to reach this temperature alone.

The flue gases are then cooled in the superheaters, where the heat is transferred to steam, heating the steam to typically 400 °C (752 °F) at a pressure of 40 bars (580 psi) for the electricity generation in the turbine. At this point, the flue gas has a temperature of around 200 °C (392 °F), and is passed to the flue gas cleaning system.

In Scandinavia, scheduled maintenance is always performed during summer, where the demand for district heating is low. Often, incineration plants consist of several separate 'boiler lines' (boilers and flue gas treatment plants), so that waste can continue to be received at one boiler line while the others are undergoing maintenance, repair, or upgrading.[22]

Implications

Waste management or waste disposal includes the processes and actions required to manage waste from its inception to its final disposal.[1] This includes the collection, transport, treatment and disposal of waste, together with monitoring and regulation of the waste management process and waste-related laws, technologies, economic mechanisms.

| ISSN: 2395-7852 | www.ijarasem.com | Impact Factor: 6.551 |Bimonthly, Peer Reviewed & Referred Journal|

| Volume 10, Issue 2, March 2023 |

Waste can be solid, liquid, or gases and each type has different methods of disposal and management. Waste management deals with all types of waste, including industrial, biological, household, municipal, organic, biomedical, radioactive wastes. In some cases, waste can pose a threat to human health.[2] Health issues are associated throughout the entire process of waste management. Health issues can also arise indirectly or directly: directly through the handling of solid waste, and indirectly through the consumption of water, soil and food. Waste is produced by[3] human activity, for example, the extraction and processing of raw materials.[4] Waste management is intended to reduce adverse effects of waste on human health, the environment, planetary resources and aesthetics.[23]

The aim of waste management is to reduce the dangerous effects of such waste on the environment and human health. A big part of waste management deals with municipal solid waste, which is created by industrial, commercial, and household activity.

Waste management practices are not uniform among countries (developed and developing nations); regions (urban and rural areas), and residential and industrial sectors can all take different approaches.[5]

Proper management of waste is important for building sustainable and liveable cities, but it remains a challenge for many developing countries and cities. A report found that effective waste management is relatively expensive, usually comprising 20%–50% of municipal budgets. Operating this essential municipal service requires integrated systems that are efficient, sustainable, and socially supported.[6] A large portion of waste management practices deal with municipal solid waste (MSW) which is the bulk of the waste that is created by household, industrial, and commercial activity.[7] According to the Intergovernmental Panel on Climate Change (IPCC), municipal solid waste is expected to reach approximately 3.4 Gt by 2050; however, policies and lawmaking can reduce the amount of waste produced in different areas and cities of the world.[8] Measures of waste management include measures for integrated techno-economic mechanisms[9] of a circular economy, effective disposal facilities, export and import control[10][11] and optimal sustainable design of products that are produced.[24]

In the first systematic review of the scientific evidence around global waste, its management and its impact on human health and life, authors concluded that about a fourth of all the municipal solid terrestrial waste is not collected and an additional fourth is mismanaged after collection, often being burned in open and uncontrolled fires – or close to one billion tons per year when combined. They also found that broad priority areas each lack a "high-quality research base", partly due to the absence of "substantial research funding", which motivated scientists often require.[12][13] Electronic waste (ewaste) includes discarded computer monitors, motherboards, mobile phones and chargers, compact discs (CDs), headphones, television sets, air conditioners and refrigerators. According to the Global E-waste Monitor 2017, India generates ~ 2 million tonnes (Mte) of e-waste annually and ranks fifth among the e-waste producing countries, after the United States, the People's Republic of China, Japan and Germany.[14] The waste hierarchy refers to the "3 Rs" Reduce, Reuse and Recycle, which classifies waste management strategies according to their desirability in terms of waste minimisation. The waste hierarchy is the bedrock of most waste minimization strategies. The aim of the waste hierarchy is to extract the maximum practical benefits from products and to generate the minimum amount of end waste; see: resource recovery.[15] The waste hierarchy is represented as a pyramid because the basic premise is that policies should promote measures to prevent the generation of waste. The next step or preferred action is to seek alternative uses for the waste that has been generated, i.e., by re-use. The next is recycling which includes composting. Following this step is material recovery and waste-to-energy. The final action is disposal, in landfills or through incineration without energy recovery. This last step is the final resort for waste which has not been prevented, diverted or recovered.[16] In some jurisdictions unsegregated waste is collected at the curb-side or from waste transfer stations and then sorted into recyclables and unusable waste. Such systems are capable of sorting large volumes of solid waste, salvaging recyclables, and turning the rest into bio-gas and soil conditioner. In San Francisco, the local government established [25] its Mandatory Recycling and Composting Ordinance in support of its goal of "Zero waste by 2020", requiring everyone in the city to keep recyclables and compostables out of the landfill. The three streams are collected with the curbside "Fantastic 3" bin system – blue for recyclables, green for compostables, and black for landfill-bound materials – provided to residents and businesses and serviced by San Francisco's sole refuse hauler, Recology. The city's "Pay-As-You-Throw" system charges customers by the volume of landfill-bound materials, which provides a financial incentive to separate recyclables and compostables from other discards. The city's Department of the Environment's Zero Waste Program has led the city to achieve 80% diversion, the highest diversion rate in North America.[26] Other businesses such as Waste Industries use a variety of colors to distinguish between trash and recycling cans. In addition, in some areas of the world the disposal of municipal solid waste can cause environmental strain due to official not having benchmarks that help measure the environmental sustainability of certain practices. This is the separation of wet waste and dry waste. The purpose is to recycle dry waste easily and to use wet waste as compost. When segregating waste, the amount of waste that gets landfilled reduces considerably, resulting in lower levels of air and water pollution. Importantly, waste segregation should be based on the type of waste and the most appropriate treatment and disposal. This also makes it easier to apply different processes to the waste, like composting, recycling and incineration. It is important to practice waste management and segregation as a community. One way to practice waste management is to ensure there is awareness. The process of waste segregation should be explained to the community.[26]

IV.CONCLUSIONS

A landfill site, also known as a tip, dump, rubbish dump, garbage dump, or dumping ground, is a site for the disposal of waste materials. Landfill is the oldest and most common form of waste disposal, although the systematic burial of the waste with daily, intermediate and final covers only began in the 1940s. In the past, refuse was simply left in piles or thrown into pits; in archeology this is known as a midden.

Some landfill sites are used for waste management purposes, such as temporary storage, consolidation and transfer, or for various stages of processing waste material, such as sorting, treatment, or recycling. Unless they are stabilized, landfills may undergo severe shaking or soil liquefaction of the ground during an earthquake. Once full, the area over a landfill site may be reclaimed for other uses. Recycling is a resource recovery practice that refers to the collection and reuse of waste materials such as empty beverage containers. This process involves breaking down and reusing materials that would otherwise be gotten rid of as trash. There are numerous benefits of recycling, and with so many new technologies making even more materials recyclable, it is possible to clean up the Earth. Recycling not only benefits the environment but also positively affects the economy. The materials from which the items are made can be made into new products.[37] Materials for recycling may be collected separately from general waste using dedicated bins and collection vehicles, a procedure called kerbside collection. In some communities, the owner of the waste is required to separate the materials into different bins (e.g. for paper, plastics, metals) prior to its collection. In other communities, all recyclable materials are placed in a single bin for collection, and the sorting is handled later at a central facility. The latter method is known as "single-stream recycling. The most common consumer products recycled include aluminium such as beverage cans, copper such as wire, steel from food and aerosol cans, old steel furnishings or equipment, rubber tyres, polyethylene and PET bottles, glass bottles and jars, paperboard cartons, newspapers, magazines and light paper, and corrugated fiberboard boxes.[25]

PVC, LDPE, PP, and PS (see resin identification code) are also recyclable. These items are usually composed of a single type of material, making them relatively easy to recycle into new products. The recycling of complex products (such as computers and electronic equipment) is more difficult, due to the additional dismantling and separation required.

The type of material accepted for recycling varies by city and country. Each city and country has different recycling programs in place that can handle the various types of recyclable materials. However, certain variation in acceptance is reflected in the resale value of the material once it is reprocessed. Some of the types of recycling include waste paper and cardboard, plastic recycling, metal recycling, electronic devices, wood recycling, glass recycling, cloth and textile and so many more.[40] In July 2017, the Chinese government announced an import ban of 24 categories of recyclables and solid waste, including plastic, textiles and mixed paper, placing tremendous impact on developed countries globally, which exported directly or indirectly to China.

Recoverable materials that are organic in nature, such as plant material, food scraps, and paper products, can be recovered through composting and digestion processes to decompose the organic matter. The resulting organic material is then recycled as mulch or compost for agricultural or landscaping purposes. In addition, waste gas from the process (such as methane) can be captured and used for generating electricity and heat (CHP/cogeneration) maximising efficiencies. There are different types of composting and digestion methods and technologies. They vary in complexity from simple home compost heaps to large scale industrial digestion of mixed domestic waste. The different methods of biological decomposition are classified as aerobic or anaerobic methods. Some methods use the hybrids of these two methods. The anaerobic digestion of the organic fraction of solid waste is more environmentally effective than landfill, or incineration. Energy recovery from waste is the conversion of non-recyclable waste materials into usable heat, electricity, or fuel through a variety of processes, including combustion, gasification, pyrolyzation, anaerobic digestion, and landfill gas recovery. This process is often called waste-to-energy. Energy recovery from waste is part of the non-hazardous waste management hierarchy. Using energy recovery to convert non-recyclable waste materials into electricity and heat, generates a renewable energy source and can reduce carbon emissions by offsetting the need for energy from fossil sources as well as reduce methane generation from landfills. Globally, waste-to-energy accounts for 16% of waste management. [24]

The energy content of waste products can be harnessed directly by using them as a direct combustion fuel, or indirectly by processing them into another type of fuel. Thermal treatment ranges from using waste as a fuel source for cooking or heating and the use of the gas fuel (see above), to fuel for boilers to generate steam and electricity in a turbine. Pyrolysis and gasification are two related forms of thermal treatment where waste materials are heated to high temperatures with limited oxygen availability. The process usually occurs in a sealed vessel under high pressure. Pyrolysis of solid waste converts the material into solid, liquid and gas products. The liquid and gas can be burnt to produce energy or refined into other chemical products (chemical refinery). The solid residue (char) can be further refined into products such as activated carbon. Gasification and advanced Plasma arc gasification are used to convert organic materials directly into a synthetic gas (syngas) composed of carbon monoxide and hydrogen. The gas is then burnt to produce electricity and steam. An alternative to pyrolysis is high temperature and pressure supercritical water decomposition (hydrothermal monophasic oxidation). Pyrolysis is often used to convert many types of domestic and industrial residues into a recovered fuel. Different types of waste input (such as plant waste, food waste, tyres) placed in the pyrolysis process potentially yield an alternative to fossil fuels. Pyrolysis is a process of thermo-chemical decomposition of organic materials by heat in the absence of stoichiometric quantities of oxygen; the decomposition produces various hydrocarbon gases. During pyrolysis, the molecules of object vibrate at high frequencies to an extent that molecules start breaking down. The rate of pyrolysis increases with temperature. In industrial applications, temperatures are above 430 °C (800 °F).

Slow pyrolysis produces gases and solid charcoal. Pyrolysis hold promise for conversion of waste biomass into useful liquid fuel. Pyrolysis of waste wood and plastics can potentially produce fuel. The solids left from pyrolysis contain metals, glass, sand and pyrolysis coke which does not convert to gas. Compared to the process of incineration, certain types of pyrolysis processes release less harmful by-products that contain alkali metals, sulphur, and chlorine. However, pyrolysis of some waste yields gases which impact the environment such as HCl and SO_2. [26]

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