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Swedish Waste Management: A Review Article

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Abstract: Urbanization is the integral part of the development process, especially for those nations who are rapidly growing. It brings about the social transformation, from traditional societies to present modern urban communities. The smart cities is a collaboration of technology into strategic approach of sustainability. The programme will provide the city where information technology is the principal infrastructure and the basis for providing the essential services to the residents. The need of the smart city arises with the huge migration of the rural population to cities. Preventing the creation of waste is the first step in the waste management. It is the focus of both Swedish and European waste legislation.This article focuses on the techniques in accordance to civil engineering like solid waste management, transportation system as contributed by the Government of Sweden. The solid waste management plan with emphasis on the putting the waste to beneficial work. The breakdown of waste generated in huge amount can be utilised for generating energy. The pre- occupied landfill can be cleared and be put to use for other work. It is recommended that new stakeholder groups are important to involve in smart city planning, but this may give rise to complications that must be acknowledged when setting up these kind of projects. The developed framework can be useful when organizing and staffing city planning processes as well as when evaluating project outcomes.
Keywords: Smart city, Swedish waste management.

I. INTRODUCTION

Cities are encroaching the advancement at the fastest pace. Each technology comes up with the challenges in terms of demography, social and economic conditions. Sustainable urban development is the current global priority.However, most cities lack the capacity and resources to ensure that the city develops in a sustainable manner. The concept of the smart city means differently to the different people. A smart city has different view point in India, to any other country such as Europe. As such no new way of fully defining the smart city is available. The imaginary picture of smart city consist of a long wish list of development with huge infrastructural facilities. A proper guidance across from every sphere would render a notable helping hand to the success of the mission of smart city.

Sweden has a long history as a pioneer in issues relating to the environment and sustainable development in a broader sense. With cutting-edge solutions within areas such as waste management, biogas and mobility, water, air and district heating & cooling, Sweden is leading the way to a more sustainable future. The story of Smart City Sweden began in 2016, with the aim to export solutions within environmental technology. In 2019, the project expanded to focus on Urban Planning, Digitalisation and Social Sustainability, in addition to the previous areas: Mobility, Climate, Energy and Environment. This article is focused on the success stories of the Swedish government in stepping forwards as the pioneers of giving smart city solutions to the world. We have stressed upon the importance of the solid waste management in our article, particularly.

Preventing the creation of waste is the first step in the waste management. It is the focus of both Swedish and European waste legislation. The objectives are:
I. Waste prevention
II. Reuse
III. Material recycling
IV. Other recycling, e.g. energy recovery
V. Disposal.

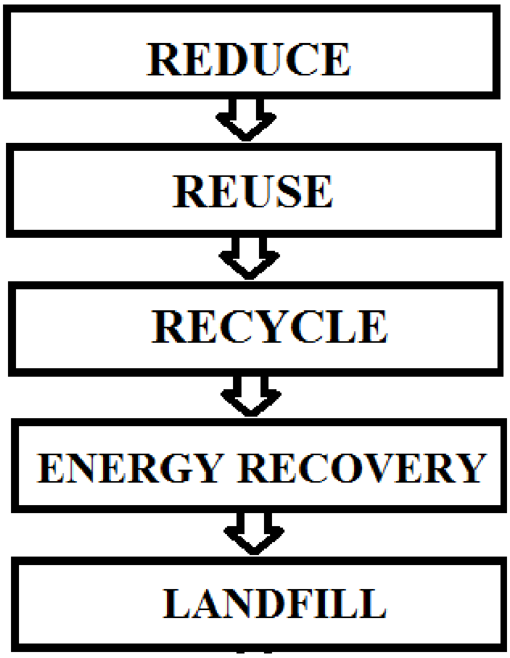

Figure 1: Basic Concept Adopted by Sweden Government.

I. Waste Prevention

The Environmental Protection Agency is responsible to reduce the amount of waste and focuses on four waste streams that have a major environmental impact. Textiles, food, electronics and construction and removal of waste. Targets was set by the EPE of Sweden is the quantity of waste going to landfill, not including mining waste, must be reduced by at least 50 % by 2005 along with Zero waste vision. Some Interim targets was set by the EPE of Sweden:

I. The quantity of waste going to landfill, not including mining waste, must be reduced by at least 50 % by 2005, as compared with 1994.

II. Long-term vision "Zero Waste".

Confidence is essential if the progress achieved is to be maintained. The total quantity of waste must not increase, and maximum possible use must be made of the resource that waste represents, while at the same time minimizing the impact on, and risk to, health and the environment. Reduced landfilling and increased recovery and recycling can largely be achieved by household sorting of waste at source.

II. Reuse

Facilitating the prevention and reuse work of the municipalities. European Week for Waste Reduction", which is also supported by the Swedish Environmental Protection Agency. The municipalities to collaborate on reuse at recycling centers with various charity organizations with aim at runs a project for one week in November when activities, aimed at reducing the amount of waste and the quantity of hazardous substances in waste are arranged all over Europe. . The project runs till 2016.

III. Recycle

Material recycling plays a key role in a sustainable society. Waste must be viewed as a resource and handled carefully. Material recycling means that separated materials can replace other production or construction materials. That leads to energy savings. Interim targets was set:

1. 50 % of household waste is to be recycled by recovery of materials, including biological treatment at least by year 2010.
2. Food waste from households, restaurants, institutional catering and shops which contributes about 35 % is to be recycled by biological treatment by 2010.
3. By 2010 food and similar waste from food manufacturing facilities etc are to be recycled by biological treatment. This target applies to waste arising without being mixed with other waste, whose quality renders it suitable for use as fertilizer after treatment.
4. Phosphorus compounds in sewage are to be recycled for use on productive land contributing about 60 %.

5. There should also be information on properties of chemicals handled in the market. Information on chemicals handled in large quantities or considered to be particularly hazardous should be available.

Sweden has one of the best recycling rates in the world, with an almost 50 % material recycling rate. The result is that less than 2 percent of waste ends up in landfills, and the remaining 48 % is converted into energy. Material recovery comprises recycling whereby other manufacturing or construction materials are substituted. Kinds of waste, such as ash and excavated materials, may be suitable for use as ballast in road building, where it can replace gravel and crushed rock. The quantity of household waste undergoing materials recovery is increasing forall types of material except refrigerators and freezers. Scrap, recycled paper and recycled plastics can replace a certain amount of new raw materials in manufacture. Recycle of MSW in Sweden till 2010 is shown in figure 4.2. And Amounts of packaging and paper collected from households for material recycling 2013 is shown in table 4.1.

Table 1: Amounts of Packaging and paper Collected from Households for Material Recycling 2013

Paper	332,780
Paper packing	128,880
Metal packing	16,530
Plastic Packing	53,840
Glass packing	188,550
Total	720,580

IV. Waste to Energy (Energy Recovery)

The efficient waste management in Sweden, the vast majority of this household waste can be recovered or reused. Over two millions ton of household waste is treated by waste to energy in Swedish plants every year. These plants incinerate a similar quantity of waste from industries as well. Waste incineration provides heat corresponding to the needs of 810,000 homes, around 20 per cent of all the district-heating produced. It also provides electricity corresponding to the needs of almost 250,000 homes. Waste to energy is a well-established source of energy in Sweden. The first incineration plant started operation in during the later part of the 1940s, the district-heating network was expanded in expanded in connection with the extensive construction of new buildings following the Second World War.

Environmental benefits of waste to energy

Waste should be managed based on its properties, and this means that there is no standard solution for choosing the treatment method. The different methods material recycling, biological treatment, and waste to energy must be combined to achieve the best results. The choice of treatment method varies based on type of waste, local and geographical conditions and how well the waste is source separated. When all the factors are considered, the objective is the optimum environmental and social benefit. The waste generated by households, industries and other activities reflects our consumption habits. . Hazardous substances found in commodities and products persist when the products become waste. This places tough demands on all waste management, so that harmful substances are not spread. During incineration, many harmful substances break down and the residual substances are bound in ash, which makes them easier to control, handle and recycle.

Waste incineration in Sweden produced as much energy in 2007 as 1.1 million m³ of oil, which reduces CO_2 emissions by 2.2 million ton per year, as much as 680,000 petrol-powered cars emit in a year.

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III. Despite waste incineration increasing, emissions have fallen. For example, emissions of heavy metals from waste incineration into the air have fallen by almost 99 % since 1985. In addition, the total emissions of dioxins from all of the country's waste incineration plants have fallen from around 100 g to less than 1 g during the same period.

Laws and control measures that apply to the waste field

The government of Sweden has given some laws and regulation to reduce the amount of waste produce up to a certain extent. Some of the rule given by government of Sweden are mention in this study are as follow:

I. The environmental Code, which came into force on 1 January 1999.
II. The EU landfill directive was adopted in 1999.
III. The tax on waste for landfills (SEK 250 /ton) was introduced in 2000.
IV. The ordinance on landfilling of waste was introduced in 2000.
V. A ban on landfilling of sorted combustible waste was introduced in 2002.
VI. The landfill tax was raised to SEK 370 /ton in 2003.
VII. A ban on landfilling organic waste was introduced in 2005.
VIII. The landfill tax was raised to SEK 435 /ton in 2006.
IX. All landfills must have fulfilled the requirements of the 2008 landfill directive in order to be able to continue to receive waste.
X. The framework directive 2008.

At the same time, a number of other rules to regulate waste incineration have been introduced

I. An ordinance on waste incineration was introduced in 2002.
II. An ordinance and regulation about waste incineration came into force in 2005.
III. A tax on household waste for incineration was introduced on 1 July 2006. The tax payable is dependent on whether the incineration plant liable to pay tax produces electricity, and if so, how effectively. For plants without electricity production, the tax is around SEK 500 /ton, which then falls with increasing electricity production. If electricity production is effective, the tax is around SEK 100 /ton.

Waste as fuel

Recovering energy from waste exploits a resource that would otherwise be wasted. At the same time, it is important that waste has been source separated. It must not contain hazardous waste, batteries, light bulbs or other electrical waste. Nor should it contain packaging or newspapers. These should be sorted out and left for material recycling. Metal should also be removed, as metal is a raw material with a very high recycling value. Metals can also cause problems in the incineration process with unnecessary wear and unforeseen operational stoppages at the plant as a result.

Plaster should also be removed. Plaster, which is a chemical compound containing calcium and sulphur, provides no energy. The rest is waste from industries and other commercial activities. Waste from industries and other activities often contains sorted fractions with a more homogeneous composition, but the fractions differ significantly from various activities. Household waste sent for incineration varies slightly depending on which municipalities the plant has signed agreements with.

Normally, waste sent for incineration is source-separated combustible household waste. Requirements for fuel properties are set for other waste supplied to the plants. The waste should, for instance, not have too high a moisture content or contain material that is unsuitable for incineration. Random testing and inspections when the waste is received at the plant help to ensure that the requirements are fulfilled.

The waste route through the modern plant

1. The waste arriving at the plant must be weighed and quality-checked. The combustible waste is tipped down a bunker. This is often designed to hold several days of waste deliveries in order, for instance, to be able to cope with long weekends. The bunker in one of Sweden's largest plants contains 12,000 m^3 waste.
2. An overhead crane controls the grab bucket and the waste is released into the feed hopper, from where it is fed into the furnace. The overhead crane mixes the waste in the bunker before transferring it to the feed hopper. In order to ensure even, controlled incineration, it is also important that the feed from the feed hopper into the furnace takes place in a well-controlled way.
3. In the furnace, the temperature is normally around 1,000 ˚C, and no fuel other than the waste is required. The waste burns under a stream of air before dropping onto a bed or grate. The hot flue gases rise upwards. There is often also an oil burner in the furnace which is used to start and stop the furnace.
4. All combustible material is consumed. What is left is known as 'slag'. The slag drops down into a water-filled trough and is transported to be sorted and recycled.
5. The actual furnace contains long welded pipes. The total length can be tens of kilometers long. There, the furnace water is circulated and heated to steam by the hot flue gases. The greater the pressure and temperature of the steam, the greater potential for electricity production. At the same time, increased pressure and temperature also lead to a greater risk of corrosion and increased maintenance costs.

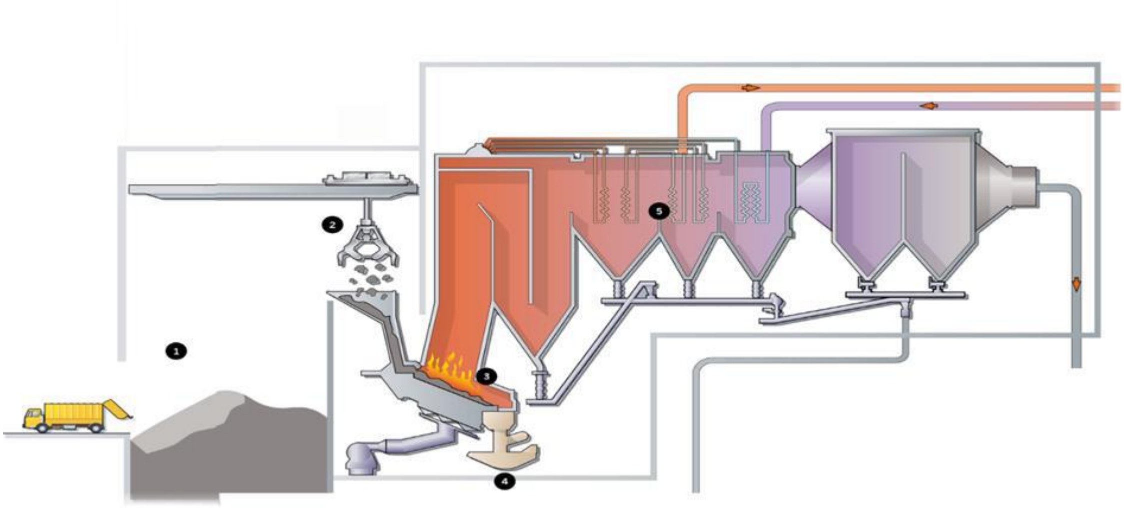

Figure 2: First Five Steps of Modern Waste Plant.

6. Due to the high temperature and steam pressure, it is possible to recover electricity, cooling and heat. The superheated steam is transported to the turbine, which then drives the generator.
7. In the generator, the movement of the turbine is transformed into electrical power, which is delivered to the electricity network.
8. Once the steam has passed through the turbine, it still contains a lot of energy, which is used as district-heating.in a heat exchanger, a condenser, heat is transferred from the steam to the water in the district-heating network. The steam is condensed into water and pumped back to the furnace.
9. The heat produced by Swedish waste to energy plants corresponds to heat demands of 810,000 homes. The hot district-heating water is distributed via well-isolated pipes out to customers. The temperature of the water varies between 70 ˚C and 120 ˚C, depending on the external temperature. The water is then transferred back to the plant to be reheated. District-cooling is based on the same principle as district-heating, but instead of providing heat, it provides cooling. Cold water is distributed in a pipe network and cools the air in the ventilation system. The water is then transferred back to the production plant to be cooled again.
10. Electricity from waste to energy plants in Sweden corresponds to the domestic requirements of 250,000 homes. (Figure 3)

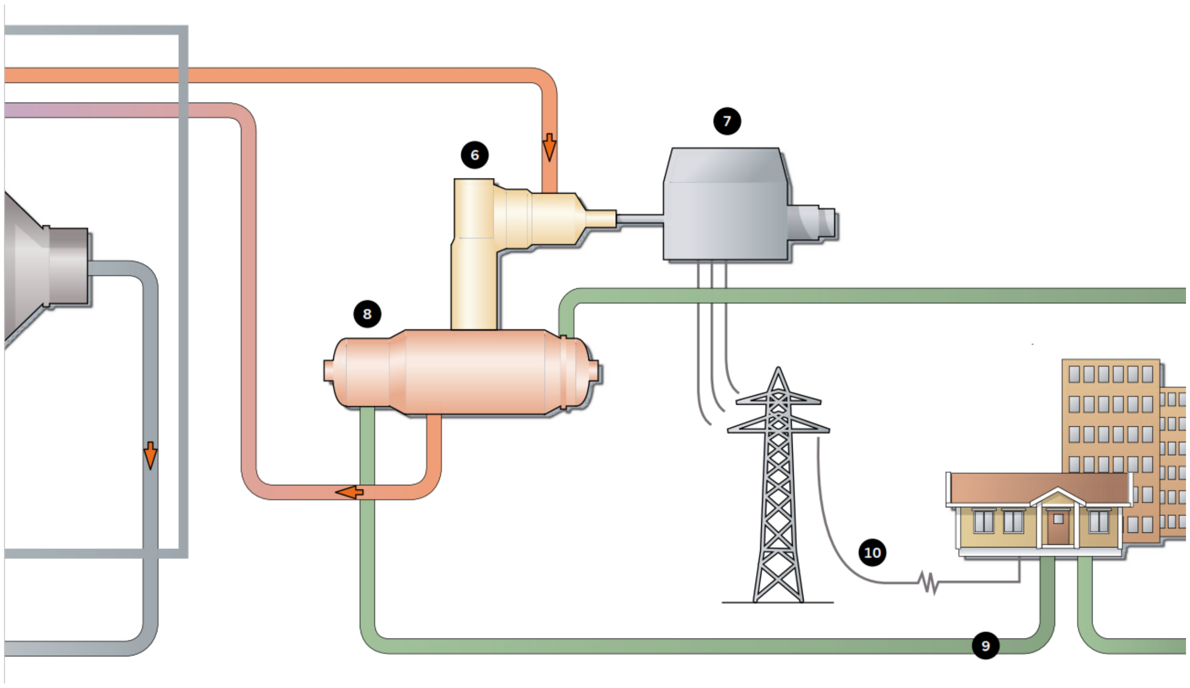

Figure 3: Fifth to Tenth Step of Modern Waste Plant.

11. Once the energy has been extracted from the waste, the flue gases are cleaned. First, they pass through an electrostatic precipitator, where most of the dust is removed. Here, electrodes give the dust particles a negative electric charge. The particles then stick to large metal plates that are positively charged. The dust particles are shaken from the plates, collected at the bottom, and then transported to an ash silo.
12. The next stage of cleaning involves washing the flue gases with water. This is done in towers, known as scrubbers. Nozzles spray a fine mist of water over the flue gases. The water contains various substances, scubas lime, which reacts with the gas and cleans it. In the first scrubber, heavy metals and acidic substances are washed out. The next scrubber removes sculpture dioxide, with the third condensing any moisture remaining in the gas. Heat is extracted from the condensed water using heat pumps. (Figure 4)

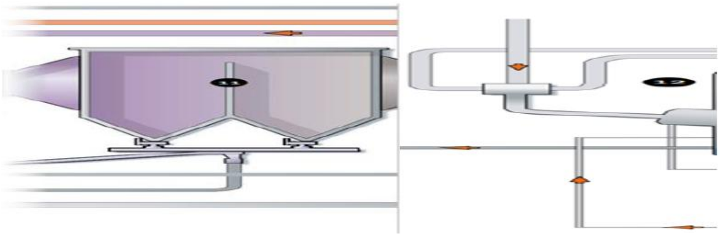

Figure 4: Eleventh and Twelfth Step of Modern Waste Plant.

15. The final stage of the cleaning process is a catalytic converter. This reduces the nitrous oxide and functions in principle in the same way as a catalytic converter in a car. The flue gases pass through a fine porous, ceramic material and, to achieve optimum effect, an ammonia water solution is added. The nitrous oxides, which have an acidifying effect, are then converted into nitrogen. 79 % of air consists of nitrogen. another common method is to reduce the nitrous oxides using SNCR or selective non Catalytic reduction
16. The cleaned gas is fed out through the chimney. Harmful substances have been removed, and what is released is, in principle, only carbon dioxide and water. (Figure 5)

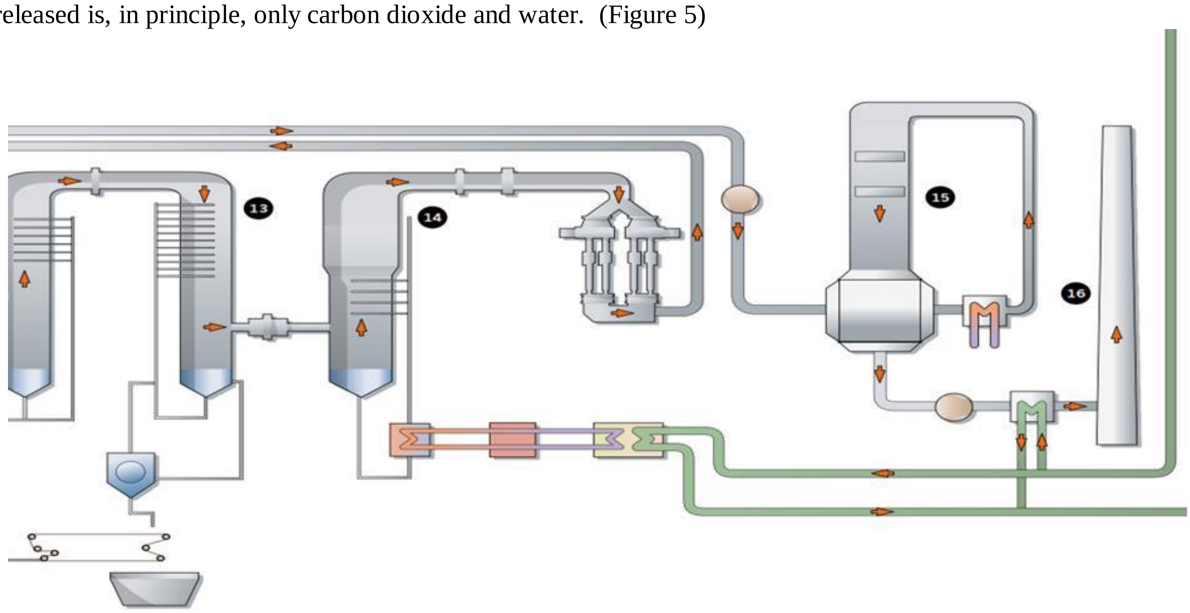

Figure 5: Thirteenth to Sixteenth Step of Modern Waste Plant.

17. Much of the pollution that was previously contained in the flue gas has ended up in the water from the scrubbers. This water undergoes a number of cleaning treatments. With the help of various chemicals, heavy metals, among other things, are precipitated and form a sludge that sinks to the bottom of the largest tank, from where it is drained.
18. The pH of the water is adjusted and the water is filtered through a sand filter and a carbon filter before it is released.
19. The sludge from the water purification process is dealt with and finally stored in a safe way. (Figure 6)

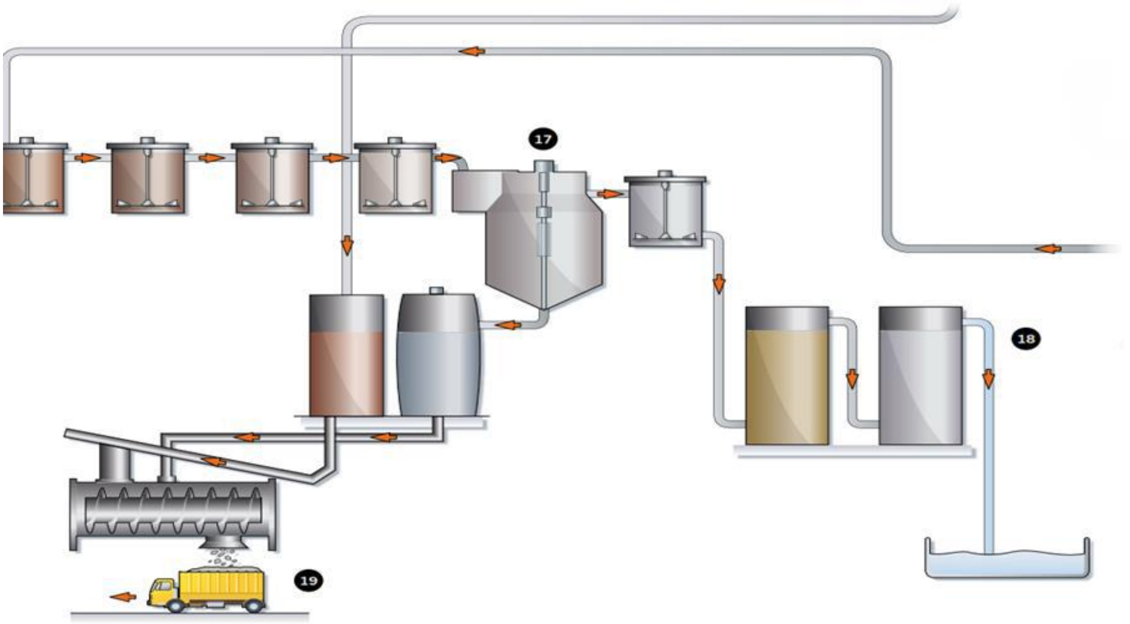

Figure 6: Seventeen to Nineteenth Step of Modern Waste Plant.

The energy was recovered through waste to energy, an increase of 19 per cent that is equivalent to the domestic electricity demands of almost 250,000 normal-sized homes and heating for 810,000 homes. A small amount of the energy is now also being used to provide district cooling. District-heating is produced by heating water and then pumping it into district-heating pipes to homes, offices, hospitals, industries, schools or other premises. The district-heating pipes are buried in the ground and well insulated. The temperature of the hot water entering the district-heating network normally varies between 70 ˚C and 80 ˚C. At low external temperatures, the water temperature may be as high as 100 ˚C to 120 ˚C.

The unit contains two heat exchangers, one for hot water for the taps and one for the radiators. The hot water, which is used in the house, and the district-heating water, then circulates in two different systems. The cooled district heating water goes back to the district-heating plant to be reheated. Water is heated to steam at a high temperature and under high pressure, which makes it possible to produce electricity and heat simultaneously, known as combined. Heat and power production. The steam is fed into steam turbine, which drives an electricity generator. District-cooling is based on the same principle as district-heating, but instead of providing heat, it provides cooling. Cold water is distributed in a pipe network and cools the air in the ventilation system. The water is then transferred back to the production plant to be cooled again. The temperature of the water being sent out to the properties is around six degrees and the return water is around 16 ˚C. District-cooling is mainly used in larger properties such as shopping centers, industries, schools, hospitals and workplaces with heat-generating computers and technical equipment. (Table 2)

Table 2: Energy Recovery from the Plant Year

Year	**2009**	**2010**	**2011**	**2012**	**2013**
Household waste	2,173,000	2,123,680	2,235,720	2,270,650	2,235,930
Other waste	2,322,120	2,704,370	2,671,760	2,771,370	3,043,160
Total (Tonnes)	**4,495,120**	**4,828,050**	**4,907,480**	**5,042,020**	**5,279,090**
Heating	11,502,820	11,752,870	12,798,018	13,031,240	13,762,940
Electricity	1,637,360	1,696,400	1,872,204	1,703,350	1,786,910
Total (MWh)	**13,140,180**	**13,449,270**	**14,670,222**	**14,734,590**	**14,734,590**

Cost of Modern Plant

Cost required to set up a modern Waste to energy plant is approx. 100 core and maintenance and operation cost required approx. 10 core per annum .

V. Landfill

In 2013, 33300 tons of household waste were sent to landfill. This is an increase of 700 tones, 2.1 %, compared to 2012. In 2013, a total of 1,391,900 tons of waste was sent to Swedish municipal landfill sites, a reduction of

163,400 tons compared to the previous year. However, at Individual plants the total amounts of waste going to landfill can vary significantly from year to year, depending on a varying need to send contaminated excavated material to landfill. Most waste treatment plants also sort waste materials for transport to reuse and recycling and for energy recovery. Sometimes landfill sites also serve as temporary storage for waste fuel and waste that falls under producer responsibility, such as paper and glass. Plants often also treat biodegradable. In 2013, approximately 245 GWh of landfill gas was collected in total at 58 waste treatment plants, of which 194 GWh was used for energy. Energy recovery consisted of 12 GWh in the form of electricity and the rest in the form of heating. In all, 51 GWh of landfill gas was flared. Flaring does not produce energy but reduces methane emissions. Gas is recovered from 43 active landfill sites.

Output of Sweden Modern Waste Plant
Average total waste generated form (2009-2013) = 4910352 tons
Average energy generated from (2009-2013) = 14145770.4 MWh.
Average energy produced by 4910352 tones = 14145770.4 MWh.
Average energy produced by 1 tone = 14145770.4/4910352 = 2.88 MWh.

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