Solid Wastes Use as an Alternate Energy Source in Pakistan

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Abstract:

Unfortunately, none of the cities in Pakistan has a proper solid waste management system right from the collection waste up to its proper disposal. Globally, wastes are used to produce electricity or used for recycling. Recently, Europe and United States (US) are recycling waste about 41% and 32%. China is also investing US 6.3 billion dollar to achieve 30% recycling of its waste 2030. The problems arising from the solid waste can be solved by using innovative technologies. Now-a-days different types of waste-to-energy (W-T-E) schemes are available through which energy can be efficiently recovered and used. Different types of benefits could be achieved if energy recovering and natural resources are considered as creation of jobs, reduction of environmental impacts and provisions of economic opportunities. According to the Pakistan Environmental Protection Agency (2005) only 51-69% of the generated waste is collected and the rest remains in the streets or collection points.

Organic wastes include food, garden waste, street sweepings, textiles, wood and paper products. Most landfill gas is produced when organic waste is broken down by bacteria naturally present in the waste and in the soil used to cover the landfill. The treatment and disposal of solid waste are defiantly connected. Treatment is applied to recover useful substance or energy, to reduce waste volume or to stabilize waste remains to be dumped or disposal of in landfills. A disposal site where solid waste, such as paper, glass, and metal, is buried between layers of dirt and other materials in such a way as to reduce contamination of the surrounding land. One ton of wastes can produce 150-200m3 of gas. The greater the amount of organic waste present in landfill, the more landfill gas (i.e. methane, carbon dioxide, nitrogen, and hydrogen sulphide) is produced by the bacteria during decomposition.

Landfill gas production and utilization and mass burn incineration are most feasible technology at first and second position respectively for treatment of solid waste in Pakistan. It is because these two facilities have enough capacities to treat the current generated waste at lower costs per ton. These two technologies also having capabilities to expand their capacities, if needed to treat more waste in future. However the treatment cost per ton decrease with the increase in quantity of waste per day. This is good way to tackle the solid waste generated in Pakistan.

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Table of Contents

Lists of Figures:

Lists of Tables:

Abbreviations:

APO	Asian Productivity Organization
CH_4	Methane
CO_2	Carbon dioxide
Cfm	Cubic feet per minute
EPA	Environmental protection agency
GDP	Gross Domestic Product
GHGs	Green Housed Gases
ISWM	Integrated solid Waste Management
IME	Institute of Mechanical Engineering
LFG	Landfill Gas
MSW	Municipal Solid Waste
MW	Megawatt
Mega cities	industrial and big populated cities
NRP	NON-RECYCLED PLASTICS
O & M	Operation and Maintenance
PTCL	Pakistan Telecommunication limited
PVC	polyvinylchloride
PVA	Polyvinyl alcohol
PE	polyethylene
Rs	Pakistani currency in rupee
Scavenger	A Street cleaner
UNEP	United Nations Environment Programme
W-T-E	Waste to energy
WASA	Water and Sanitation Agency
3R	Reduce, Reuse, Recycle

1 Introduction:

Unfortunately, none of the cities in Pakistan has a proper solid waste management system right from the collection waste up to its proper disposal. As a consequence of the constantly increased consumption the growing quantities of the waste generated have drawn public attention. Much of the uncollected waste poses serious risk to public health. Although the consumption per citizen in Pakistan is still lower than in many other countries especially of the Western Europe. All these issues motivated me to investigate deeper into the subject of the evaluation of the waste management system in Pakistan. In order to point out the crucial issues regarding the future development of waste management in Pakistan.

There is a need to reduce the current levels of waste generation and increase in material and energy recovery, which are considered as the essential steps towards an environmental-friendly waste management system. Landfill is also no longer the first choice for the disposal among the other methods such as recycling in solid waste management practices. Initially, incinerators globally were used to reduce waste mass but energy is being recovered from the incinerators now-a-days. Electricity and heat is produced from the recovered bio-gas from landfill.

Globally, wastes are used to produce electricity or used for recycling. Recently, Europe and United States (US) are recycling waste about 41% and 32%. China is also investing US 6.3 billion dollar to achieve 30% recycling of its waste 2030 (state bank of Pakistan, 2009)[1]. Currently, out of more than 800 incineration plants working throughout world, about 236 are in Japan and 400 in Europe. The plants in Europe have capacity to provide electricity approximately 27 million inhabitants (state bank of Pakistan, 2009)[1]. The problems arising from the solid waste can be solved by using innovative technologies. Now-a-days different types of waste-to-energy (W-T-E) schemes are available through which energy can be efficiently recovered and used. Each type of technologies handles the specific composition and quantity of solid waste (Tatamiuk, 2007)[2]. It seems to be difficult to propose suitable waste management plans and technologies without determining the quantity and composition of generated waste (Idris et al. 2004)[3].

It is estimated that approximately 55,000 tons waste is generated per day (Pakistan Environmental Protection Agency, 2005)[7], based on the assumption that 0, 6 to 0, 8 kg waste is produced per capita per day. The amount of waste production is directly linked with the increase in gross domestic production. Steady increase in population growth rate and change of the life style (The World Bank, 2007)[4].

Energy can be produced and utilized from the generated solid waste, especially in mega cities like Lahore, Karachi and Multan etc. Due to lack of management, the generated waste which has potential to generate energy is dispersed all around the environment. Energy can be recovered from it in the following forms e.g. bio-gas, electricity. These beneficial components are currently either being released to the atmosphere due to open burning and dumping or into the ground water due to poor landfill conditions. In most cities largest part of the budget is fixed for solid waste services. But still approximately less than 50% of the generated solid waste is collected, but instead improperly disposed at landfills, road sides or burnt openly without taking care of air and water pollution control (Energy Sector Management assistance program, 2010)[5]. According to the recent study by (Batool et al., 2006)[6] in Lahore. Pakistan, if the recycling practices are adapted as an industry, they can generate revenue of Rs. 530 million i.e., US8.8 million/year with the saving of large quantities of energy and natural resources. Different types of benefits could be achieved if energy recovering and natural resources are considered as creation of jobs, reduction of environmental impacts and provisions of economic opportunities.

2 Objectives:

According to the Pakistan Environmental Protection Agency (2005)[7] only 51-69% of the generated waste is collected and the rest remains in the streets or collection points (Joeng et al., 2007)[8].The main objectives of this thesis are

- To analyze the solid wastes treatment in Pakistan and direct it towards fulfilling the main goals of waste management
- To find out the most cost effective and least polluting technology among the available options for the recovery of energy from generated waste.
- How Pakistani Government can make solid wastes as an alternate resource.
- To find out the processes of landfill Gas we can adapt to stop the environment be polluted.
- To find out the social, economic effects using landfill Gas as a resource energy.

This will help to develop a solid waste management system in Pakistan that will be environmentally effective, economically affordable and socially acceptable. In addition this will ensure a better quality of life of present and future generation.

2.1 Motivation:

The per capita consumption of plastic in Pakistan was 3, 1 kilograms per annum, while this was 3, 3 kg in India per annum and 7 kg in China per annum. The highest per capita consumption of plastics was in United States and Germany, where per capita consumption was 120 kg per annum. Globally, the per capita plastic consumption worked out to be around 24 kg per annum. The consumption of plastic was less in Pakistan as the local industries were not developing as rapidly as they were growing in the other parts of the world. There are 6,000 plastic products manufacturers in the country and 600,000 people were directly and indirectly engaged with this business.

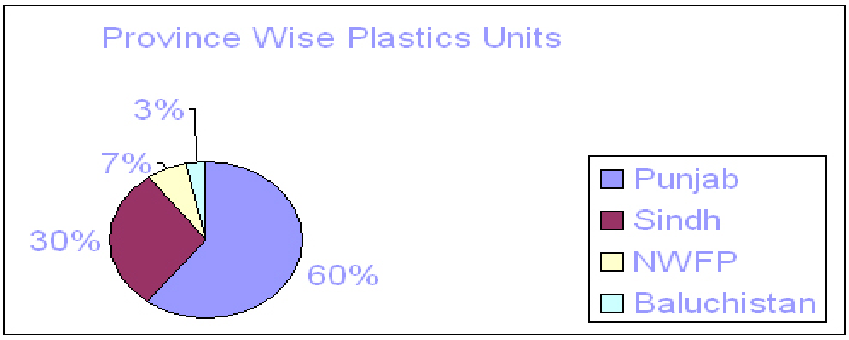

Figure 1: province wise plastics units

2.2 Methods of this thesis:

I used exploratory method, as we know that it based on literature review and web surfing. I took information from different publish articles related to my topic and information from different relevant websites. I used Microsoft Visio to display the layout structure of my power plant and landfill site. For statistical representation I used Microsoft Excel. Water, internet and telephone charges I took from the official websites. Capital, operational and managements costs based on my assumptions. I planned to take interview some officials of Lahore solid waste management but due to their busy schedule I could not able to take single interview.

Map of Pakistan:

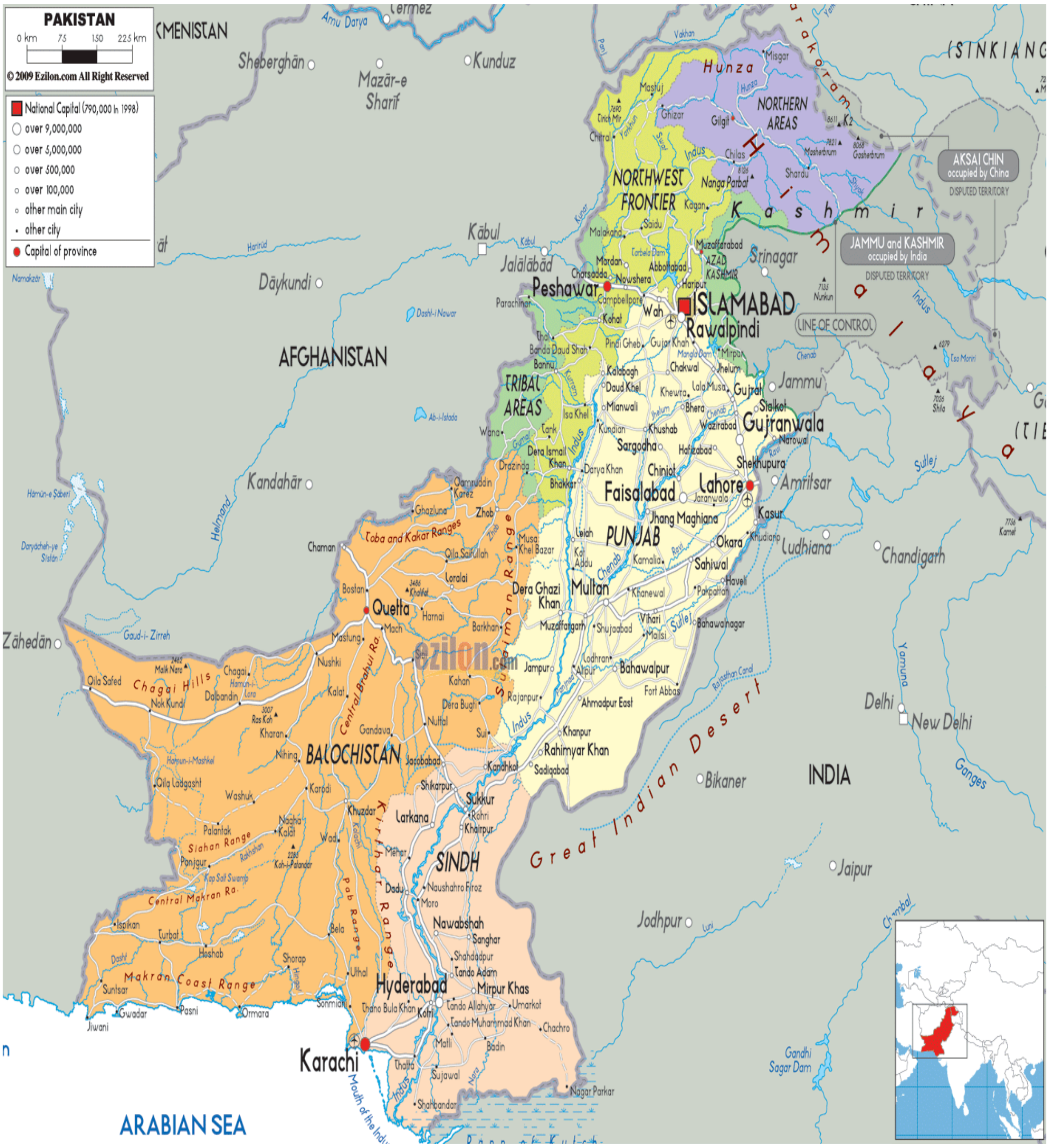

Figure 2: Map of Pakistan

http://www.ezilon.com/maps/asia/pakistan-maps.html

Country profile:

The Islamic republic of Pakistan emerged as an independent sovereign state on 14th August 1947, as a result of the division of former British India. It lies between 23-35 to 37-05 north latitude and 60-50 to 77-50 east longitude touching the Hindu Kush Mountains in the north and extending from the Pamirs to Arabian Sea. Pakistan covers 796,095sq.km with a population of 130.579 million according to population census 1998. 67% live in rural areas, while 33% live in urban areas. It is divided into the four provinces:

- Punjab
- Sindh
- Khyber Pakhtun khwa
- Baluchistan

Table 1: population of ten major cities of Pakistan

City	Households (million)	Population (million)
Karachi	1.436	9.269
Lahore	0.740	5.063
Faisalabad	0.278	1.977
Rawalpindi	0.220	1.406
Multan	0.162	1.182
Hyderabad	0.178	1.151
Gujranwala	0.151	1.124
Peshawar	0.149	0.988
Quetta	0.074	0.560
Islamabad	0.092	0.524

Source: population and housing census of Pakistan 1998

http://www.environment.gov.pk/ea-glines/swmglinesdraft.pdf (Accessed dated 20th November 2012)

In 1998 the last census held in Pakistan. After that we had no census because of instability of political and law and order situation. So this is a latest data which I got about Pakistani population.

The poor communities residing in urban settlement are often engaged in a number of initiatives on self-help basic e.g. solid waste management and recycling. Almost all the paper, plastics, metals and glass are collected and re-used/recycled. Thus the poor communities in urban areas play a key role in waste recycling. The only waste which remains on street and collection points is the organic waste.

The official language of Pakistan is English, but the national language is Urdu (which is close to Hindi language).interestingly Urdu is not spoken as native language by any of Pakistani's main ethic groups and was chosen as a neutral option for communication among the various peoples of Pakistan. Punjabi is the native tongue of 48% of Pakistanis, with Sindhi at 12%, Siraiki at 10%, Pashtu at 8%, Balochi at 3% and a handful of smaller language groups.

Climatically, Pakistan enjoys a considerable measure of variety. North and north western high mountains ranges are extremely cold in winter while the summer months of April to September are very pleasant. Pakistan has an agricultural economy with a network of canals irrigating a major part of its cultivated land. Wheat, cotton, rice, millet and sugar cane are the major crops. Among fruits: mangos, oranges, bananas, and apples are grown in abundance in different part of the country. The main natural resources are natural gas, coal, salt and iron. The country has an expanding industry, cotton. Textiles, sugar, cement and chemical play an important role in its economy.

3 Literature survey:

The main purpose to describe plastics here because plastics are used to manufacture an incredible number of products we use every day. That is not even counting all the plastics that go into furniture, appliances, computers and automobiles. As the use of plastics has increased over the year, they have become a larger part of the municipal solid waste. Recycling plastic products also keeps them out of landfill and allows the plastics to be reused in manufacturing new products.

3.1 Plastic and other components in solid waste:

The word plastic comes from the Greek word “plastikos”. This means ‘able to be molded into different shapes’ (Joel 1995). The plastics we use today are made from inorganic and organic raw material, such as carbon, silicon, hydrogen, nitrogen, oxygen and chloride. The basic materials used for making plastics are extracted from oil, coal and natural gas (Seymour, 1989). The condensation and addition polymers came into the market since 1950s (Datta et al.., 1998). [10]

Plastic is the mother industry to hundreds of manufactured components and products used in our daily life like automobile parts, television, refrigerators, other electrical goods, plastic furniture, defense products, agriculture pipes, woven sacks, sanitary ware, pipes and fittings, tiles and flooring, PVC shoes and sleepers, artificial leather, bottles and jars, disposable syringes and hundreds of house hold items. Its consumption is increased at an unprecedented rate (Sabir, 2004). [10]

3.2 Types of plastics:

There are two main types of plastics:

- Thermoplastics
- Thermosetting plastics

Thermoplastics:

Plastics that become soft on heating and melt on heating and can be molded again and again are known as thermoplastics. Repetitive heating of thermoplastics does not cause permanent change in properties or composition. For example.

- Polyethene (PE)
- Nylon® (PA)
- PVC
- PVA

Thermosetting:

These are the plastics that can be softened on heating but they become permanently hard on cooling. They cannot be remolded again. They are insoluble in some solvent whether organic or inorganic. For example

- Bakelite
- Urea aldehyde
- Silicones

3.3 Plastic waste and environment concerns:

Plastics are one of the most useful materials of all time. Tragically, tons of this plastics end up in our landfills every year. Depending on the quality of the plastics, it may take anywhere from a few days to several years for it to break down in landfills but it never break down completely into particles that can be used in nature. It is possible that we may be able to take our plastic waste and turn it into a usable energy source and many scientists are working on the best way to do this. [1]

The world annual consumption of plastic materials has increased from around 5 million tons in the 1950s to early 100 million tons; thus, 20 times more plastic is produced today than 50 years ago. This means that more plastic waste is being generated. Due to the increase in generation, waste plastic are becoming a major problem in solid waste. After food waste and paper waste is the major constitute of municipal and industrial waste in cities. This increase has turned into a major challenge for local authorities, responsible for solid waste management and sanitation. [14]

Plastic waste can provide opportunities to collect and dispose of environmental friendly way and it can be converted into a resource. This resource conservation goal is very important for most of the national and local governments, where rapid industrialization and economic development is putting a lot of pressure on natural resources. Some of the developed countries have already established commercial level resource recovery from plastic waste.

Pakistan, like other developing countries, faces serious environmental and energy problems. Rapid population growth (average annual growth rate of 2.61 percent a year) and impressive GDP growth (of about 6 percent a year) have put enormous pressure on the country natural resources base and significantly increased level of pollution. Pakistan did not address the issue of sustainable development and environmental protection in the nation decision-making process. Present disposal methods for solid waste are totally inadequate. Disposal is by open dumping, primarily on flood plains and into ponds, causing significant environmental damage. [9]

The study revealed that the rate of waste generation on average from all type of municipal controlled areas varies from 0.283 kg/capita/day to 0,613 kg/capita/day or from 1,896 kg/house/day to 4, 29 kg/house/day in all the selected cities. [11]

3.4 Estimated plastic waste collection in Pakistan:

The plastic waste stream emerges from three main sources: agriculture, industrial and municipal solid waste, which account for 63, 16 and 21 percent respectively (Beukering, 1997). This ratio may be slightly different for Pakistan, but it is felt that the trend would be the same. The composition of municipal solid waste varies greatly from city to city. Table-1 gives plastics and paper waste generation in different cities of Pakistan. The estimated figure of plastics waste generation across the country is 1.240 million tons per annum. [12]

Table 2: Plastic and paper waste Generation in Different Cities of Pakistan

Sr. no	Cities	No.Of scavenges	Plastics waste (tons)		Paper waste (tons)	
			Per Day	Per Year	Per Day	Per Year
1	Faisalabad	1500	44.4	13320	19.4	5820
2	Gujranwala	1200	41.2	12360	20.6	6180
3	Karachi	7000	412.8	123840	264.5	79350
4	Hyderabad	1200	35.1	10530	23.4	7220
5	Peshawar	800	29.9	8970	17.0	5100
6	Quetta	600	31.0	9300	27.9	2490

Source:http://www.resol.com.br/textos/INVOLVEMENT%20OF%20INFORMAL%20SECTOR%20IN%20PLASTIC%20AND%20PAPER%20RECYCLING%20IN%20PAKISTAN.pdf

As a proportion of total municipal waste stream, the share of Plastic is more or less equal to the figure of some developed countries. However, it is important to note that the ratio of Plastic in municipal solid waste decrease to less than 1% as the informal Collectors pick up plastic, paper and metallic waste to sell them for their economic returns.[12]

3.5 Hazardous waste:

In Pakistan, there is no systematic mechanism for the collection and disposal of hazardous waste generated from hospital, industries and agriculture activities. Hazardous waste is any waste or combination of waste that poses a substantial danger, now or in the future, to human, plant or animal life and which cannot be handles or disposed of without special precaution. The hazardous solid waste is being generated in Pakistan from the following six sectors: [13]

Table 3: Sources of hazardous waste

Sectors	Sources	Type of waste
Agriculture	Planting areas and plant protection/agriculture department, warehouses	Obsolete pesticides herbicides insecticides, used chemical containers and contaminated soils
Hospitals, clinical and laboratories	Clinic consulting rooms, operation theaters, hospitals, wards, laboratories	Infected human tissues and organs, excreta, blood, sharp instruments, laboratory equipment and tissue cultures drugs etc.
Small scale industries	Metal processing, photo finishing, textile processing, printing, leather tanning	Acids, heavy metals solvents, acids, silver cadmium, mineral acid solvent, inks, dyes solvent, chromium etc.
Large scale industries	Bauxite processing, oil refining petrochemical manufacture, pharmaceutical manufacture, chlorine production	Rig mud, spent catalysts, oily waste, tarry residues, solvent, and mercury.
Commerce	Vehicles services and airports, dry cleaning, electrical transformers, bus station, workshop, petrol pumps	Oily hydraulic fluids, halogenated solvent, polychlorinated biphenyls (PCBs), water management, specialist tyres, plastics etc.
Household	Homes	Used fluorescent tubes, batteries, drugs, cosmetic, vehicle care material

Source: http://www.environment.gov.pk/ea-glines/swmglinesdraft.pdf (Accessed dated 20 November 2012).

3.6 Additives in plastic waste:

A wide variety of additives are used in production processes of plastics goods to protect them against undesired influence and premature mechanical failures. Plastics are processed at high temperature and many plastics products must be resistant to exposure to such factors like light, heat, humidity. Additives can contain hazardous substances which are of special concern in thinking of waste management of plastics and their longer-life impacts. Due to the role of waste management in the environment the problem of appropriate treatment of plastic waste, related to the hazardous substances they contain, should be of special importance for the modern societies. Even though the use of some hazardous substances decreases, e.g. due to serious toxicological and ecological concerns about cadmium and its compounds; it is successively replaced by other stabilizers, particular in Europe and Japan. It is also remembered that years or even decades after discontinuing its use in the production processes, cadmium will be still present in plastic waste stream, due to long life-spans of many plastics products manufactured in the past and still accumulated in the atmosphere. [9]

3.7 Waste as a Renewable Energy Source:

Now the world has become more environmentally aware than ever before. While on the other hand dumping and buring of waste is not popular solution anymore, to just loss the valuable daily waste that can produce a value to society. (IME, 2013)[19] the solid waste industries are continuously providing environmentally friendly waste disposal solutions in the world. According to World Bank report shows that urban areas in Asia spend 25USD million per year on solid waste management and it is expected to raise 47USD Million per year. But regardless of these expenditures most developing countries who are members of APO are still grappling with the challenges of preventing environment from damages due to burring of plastic waste and polluting the air. Solid waste management in developing countries like Pakistan has become a serious issue which cannot be solved without a strong integrated waste management system. (Hwa T. J, et. Al 2005)[18] in this part author describe some common waste management methods and try to suggest the best method for solid waste management in current circumstances of Pakistan. According to UNEP"Integrated Solid Waste Management" (ISWM) system should be based 3R (reduce, reuse and recycle) principle. (UNEP, 2005)[17].

Is a complete chart that guides how to handle the solid waste for renewable resources. The solid waste needs to go through four major phases to become a usable renewable resource.

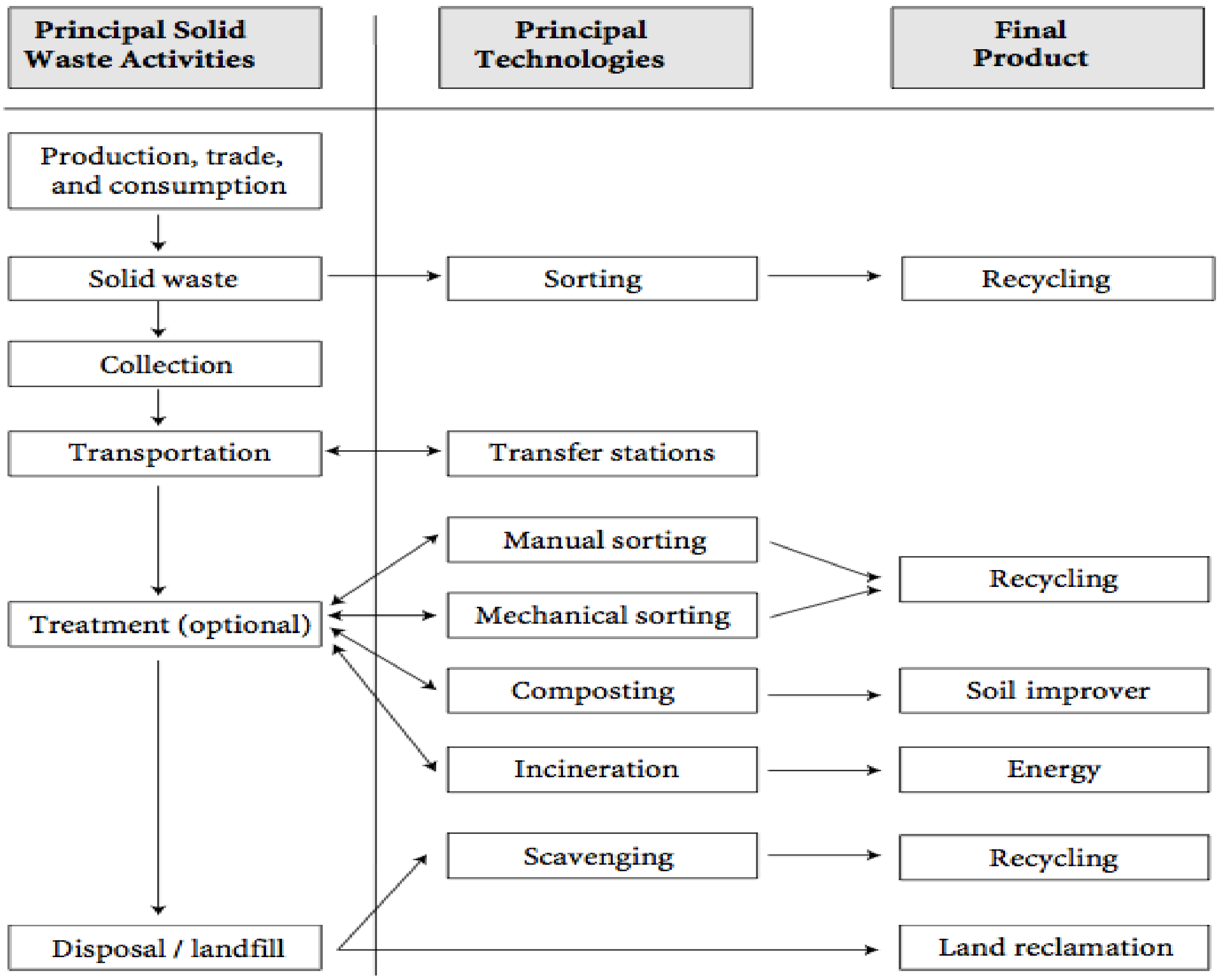

Figure 3: By" Kristalina Georgieva, Keshav Varma of the World Bank Washington D.C" (Solid waste handling and treatment system components)
http://www.unep.org/ietc/Portals/136/SWM-Vol1-Part1-Chapters1to3.pdf

3.8 Basic Principal Activities:

For any waste solution for most activity are the estimation, collection and transportation of waste. Waste is generated through human and commercial activities and it increases with the urban development and population while the quality is depended on per capita income of country. It is important to consider that if it is not handled properly, it create negative impacts on society and environment. However an efficient and hygienic collection and transportation system is fundamental need for 3R (reduce, reuse, recycle).

3.9 Selection of Principal Technology

Second highly important phase is to make design about technology/method that how you want to treat your solid waste and what end product you want to have. But it is totally dependent on the characteristics of waste and government policies, investment and budgets. Furthermore design should also include the size and scale of waste treatment facility.

3.10 Final Product

The priority introduced by UNEP for"Integrated Solid Waste Management" (ISWM) is reuse/recycle. Waste reuse and recycling are the preferred options when managing waste. There are many environmental benefits that can be derived from the use of these methods. They reduce or prevent green house gas emissions, reduce the release of pollutants, conserve resources, save energy and reduce the demand for waste treatment technology and landfill space. Beside this top priority, second option could be renewable energy through incineration. While dumping of waste should be the last option. Recycling is the initial process of any waste, where waste is just sorted manually or mechanically

3.11 Collection, treatment and disposal of waste:

The collection of waste is usually organized on a communal basic; in developing countries though, it may be organized (to a greater or lesser extent) on an informal basic (e.g. through the activities of night soil collectors, scavengers, etc.) for statistical purpose, two variable of the organization seem important: costs of the service, and personal employed.

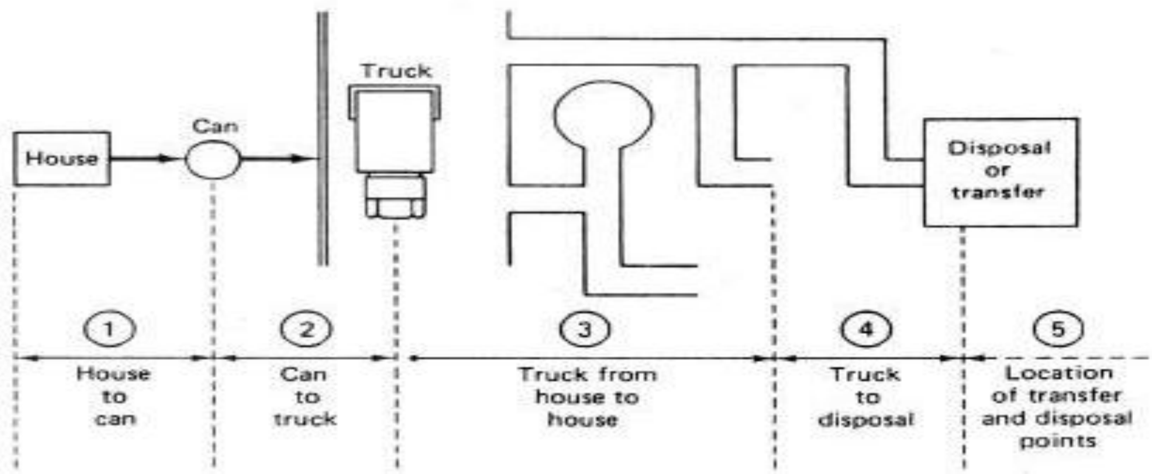

Figure 4: Various phases of the municipal waste collection system

The treatment and disposal of solid waste are definitely connected. Treatment is applied to recover useful substance or energy, to reduce waste volume or to stabilize waste remains to be dumped or disposal of in landfills.

3.12 Landfill with Energy Recovery:

Landfill is a method, where solid waste is buried between the layers of dirt to fill in or reclaim low-lying ground. " A disposal site where solid waste, such as paper, glass, and metal, is buried between layers of dirt and other materials in such a way as to reduce contamination of the surrounding land. Modern landfills are often lined with layers of absorbent material and sheets of plastic to keep pollutants from leaking into the soil and water. Also called sanitary landfill" (dictionary.com, 2013)[21] Landfill gas land filling of solid waste stream, usually we get.

Landfill waste management method requires big piece of land and it is suitable for the countries, which have geographically plain land available away from residential areas. It is most common method has been used by even great industrialized countries of the world. Over 70% of municipal wastes in North America and Western Europe are land filled with little or no treatment. "According to a study released by scientists at Columbia University, landfills across the country contain enough plastic waste to provide power for 5.2 million American homes, fuel six million cars for a year, and potentially much more" (Hall, 2011) [15]

Landfill gas (LFG) recovered from municipal solid waste landfills as a source of renewable energy. As solid waste decomposes in landfills, a gas is emitted that is approximately 50 percent methane (CH4) and 50 percent carbon dioxide (CO2), both of which are GHGs (U.S. EPA, 2011)[20]. LFG energy technologies capture CH4 to prevent it from being emitted to the atmosphere, and can reduce landfill CH4 emissions by between 60 and 90 percent (depending on project design and effective- ness) (U.S. EPA, 2011).

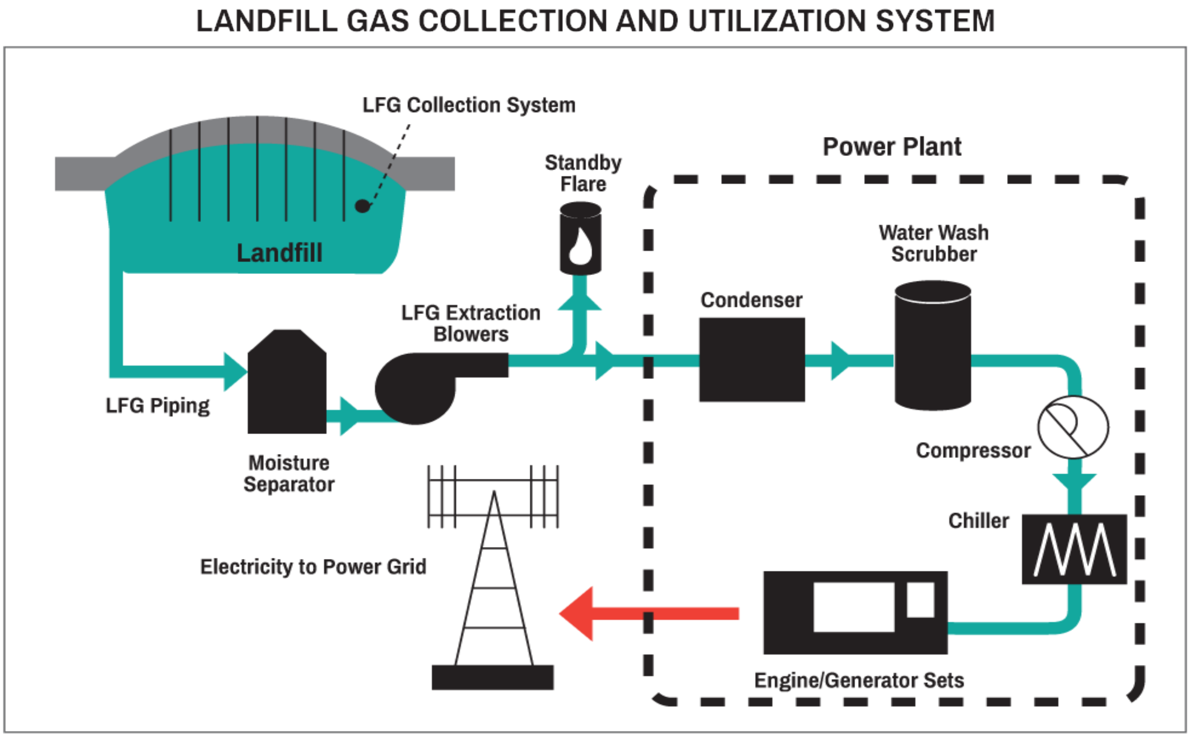

Figure 5: landfill gas collection and utilization system

Source: http://www.wt-energy.com/wte-solutions/landfill-biogas-captation/

3.13 Design:

The design of a landfill gas consists of a detailed description and drawing of the system. Introductory sections can include the following:

- Generation information about the location, client and consultant
- A general description of LFG plants
- An overall description of the specific LFG plant with the planned extraction and utilization system
- Instructions for bidders with information and requirements valid for the bidding procedure
- General and special conditions for the total project
- Time and payment schedule

The technical part of the design is generally divided into two sections, the extraction and the utilization systems. The extraction system normally includes the following:

- Leveling of the landfill to determine the level of the wells and pipes and the slopes for pipes
- Drilling of gas wells, including installation of a perforated gas extraction pipe in the well [figure 6]
- Dimensioning of horizontal gas pipes from wells to a pump station [figure 7]
- A water knockout system for condensate
- Dimensioning of the pump/compressor for the gas extraction and distribution[figure 9]
- A manual or automatic regulation system for the gas extraction [figure 10]
- Electrical installations
- A control system
- A security and alarm system

The utilization system normally includes the following:

- Dimensioning of the gas transmission pipeline
- Dimensioning and description of the energy utilization system which can be a power plant, a boiler plant or another more specialized utilization system
- Electrical system
- A control system
- A security and alarm system
- Environmental installations, noise, emission and so on.

Figure 6: Drilling equipment for a gas well and installation of the gas pipe

Source: http://www.cityofbath.com/recycling/image/Gas%20Well%20Drilling.jpg

Figure 7: Connectiing a horizontal gas pipe to a gas pipe in a well

source: http://www.lhup.edu/hemlock/Pipeline2.jpg

Figure 8: Installing of a container with a compressor and gas cooling system

Source: http://www.entec.co.nz/?page=portfolio

Figure 9: Connection of gas pipes to a pump and regulation container

Source: http://www.entec.co.nz/images/portfolio/biogas/Hampton.jpg

Figure 10: Measuring equipment on an enclosed flare

Source: http://www.johnzink.com/wp-content/uploads/biogas_ztof.jpg

4 Method:

Organic wastes include food, garden waste, street sweepings, textiles, wood and paper products. Most landfill gas is produced when organic waste is broken down by bacteria naturally present in the waste and in the soil used to cover the landfill.

- Truck in and truck out
- Landfill site
- Power plant (condenser, scrubber, compressor, chiller, generator, watch room)
- Office (4 rooms)
- Electricity to power grid
- Parking area

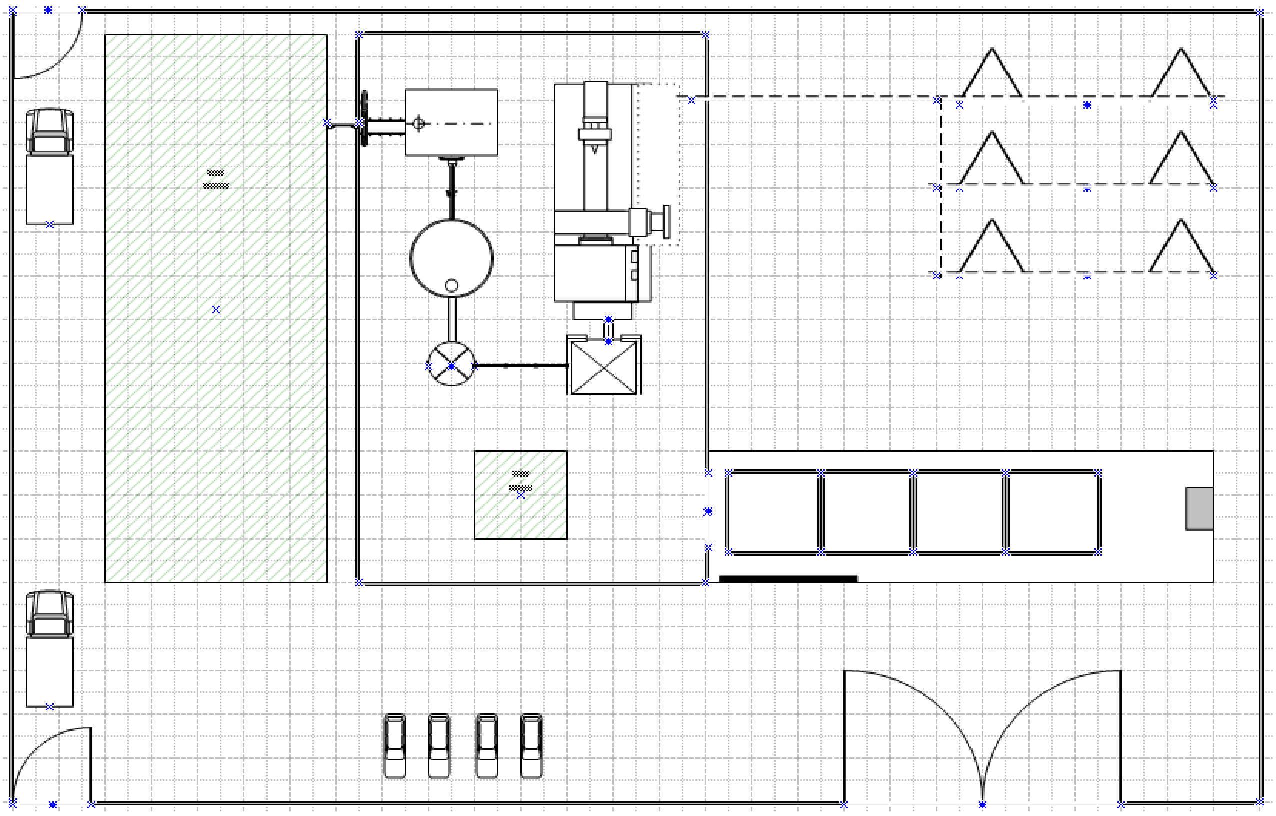

Figure 11: Layout structure of the plant

Source: Self drawn

- We assume the total area for the landfill energy plant is 15 acre. 1 acre = 4 046.85642 m^2 than (15*4046, 85642) is equal to 60702,846336 $m^{2.}$.
- Office rooms are attached to the machinery area. Machine area is 355 m^2.

The above figure 11 is a layout structure of the power plant. The figure shows the equipment use in the system to produce electricity. The processes are following:

- The process begins when waste is collected.
- Once the waste inside the landfill, waste decomposes and after 6 months start to produce methane. Landfill gas about 50% of CH_4 is collected using an underground network of pipes and wells.
- From this network, the gas is drawn to a renewable energy facilities compression system where the gas is dewatered, pressurized and filtered to make it clean.
- When the landfill gas enters this system, it first passes through the filter, which removes any large pieces of debris and some liquids that may have mixed with the gas.
- After initial filtering, it enters a compressor, which raises its pressure until its high enough for the gas to be used as a fuel. During compression, the temperature of the gas rises and must be cooled down by an after cooler.
- Inside cooler the temperature of the gas is lowered, which allows for any remaining moisture to be condensed.
- The gas is than filtered the second time to remove the condensed moisture. At this stage the gas is reheated to prevent any further condensation, and is ready to be used as a renewable energy fuel.
- The whole process from start to finish takes seconds.
- In figure 11 there is an engine or a turbine to generate power. Both follow the same principle to produce electricity. Engine equipped with pistons and air filter, exhaust, radiators and even batteries. Landfill gas enters the engine and is combusted, causing the pistons to spin a drive shaft. The drive shaft is connected to a generator, which convert the power into the electricity.
- The electricity is than sent to the state of the art control system. To ensure that the plant is meeting the needs of the utility.
- Control system direct electricity to transforms located on site which either raise or lower the voltage.
- High voltage electricity is exported to the grid to supply energy for the communities and businesses.

4.1 Capital and operation & management costs:

Landfill gas energy costs may include costs for gas collection and flaring, electricity generation, or other project options. LFG project will involve the purchase and installation of equipment and the expense of operation and maintaining project.

4.2 Capital costs:

- **Land**: The cost of acquiring land and buffer zone. The cost is depending on the location.
- **Design and Construction**: structure of the building including boundary surrounding the factory, machinery house, office house.
- **Regulatory application**: The costs of environmental assessment and regulatory compliance.
- **Electricity connection**: installation of electricity connection through the factory and power house assembly.
- Startup costs and working capital

4.3 Operation and management costs:

- **labor**
- **Closure**: maintenance, financial assurance.
- **Furniture**: furniture for office rooms.
- **Environmental monitoring**: ongoing monitoring and pollution controls to meet regulations.
- **Gas piping equipment**
- **Taxes**
- **Administration**

Table 4: Plant building construction investment

No	Unit	Items	Cost (Pakistani currency in rupees)	Total cost
1	1	Machinery room, office room	3,000,000	
2	1	Truck for waste collection	3,200,000	
3	1	Electricity connections, security system installation	650,000	
4	1	Furniture & electronics equipment	250,000	
5	1	Power plant boundary and gates	150,000	
6	1	Water supply fee	300,000	7,776,000 Rs

4.4 Management costs:

Landfill gas power plant runs only one director who will control the whole power plant. Production engineers will look all the engineering and lab works. Assistant engineers will perform under his decision. Every shift will has one assistant engineer and two workers.

Table 5: monthly salaries for the employers

No	Number of person	Job title	Unit wages in Rs	Total wages in Rs	Total monthly wages Rs
1	1	Director	45,000	45,000	
2	1	Production engineer	36,000	36,000	
3	1	Production boy	11,000	11,000	
4	3	Assistant engineer	20,000	60,000	
5	6	Workers	15,000	90,000	
6	6	Security	12,000	72,000	
7	1	Accountant	25,000	25,000	
8	1	Cleaning boy	8,000	8,000	347,000 Rs

4.5 Land line and internet connection charge:

Table 6: Land line and internet expense per month

Land line connection charges		Free
Internet connection	2 Mb	1000+1250 Rs
Monthly rate for landline	1,10 per min (300min*30 days=9000)	9,900 Rs

total		12,150 Rs

Source: Pakistan telecommunication company Ltd.
http://www.ptcl.com.pk/pd_content.php?pd_id=107

4.6 Water:

Monthly water bill depend on the use of consumption. WASA (water and sanitation agency) provide water to big city. The price for 1000 gallons commercial charges 50 Rs. [19].let assume monthly water consumption will be 6000 gallons

Table 7: cost of water

Unit price Rs	Total monthly unit	Monthly cost Rs	Yearly cost Rs
50	6	300	3600

Source: water and sanitation agency

http://www.wasa.rda.gov.pk/Tariff.htm

4.7 Overhead costs:

Salary of all employees, electricity consumption for the office, office expense water bill internet bill, telephone bill are related to the overhead cost.

Table 8: Total overhead costs

Item	Total Rs in one month
Salary	347000 Rs
Water	300 Rs
Internet	1250 Rs
Telephone	9900 Rs
Office expense or maintaining cost	15000 Rs
Total overhead cost	373450 Rs

4.8 Collection system costs:

Total collection system costs vary widely, based on a number of site-specific factors. For example, if the landfill is deep, collection costs tend to be higher because well depths will need to be increased. Collection costs also increase with the number of well installed. The estimated capital required for a 40-acre collection system designed for 600 cubic feet per minute (cfm) of LFG (including a flare) is $991,000 approximately $24,000 per acre, assuming one well is installed per acre. Typical annual operation and maintenance (O&M) costs for collection system are $2,250 per well and $4,500 per flare. Electricity costs to operate the blower for a 600 cfm active gas collection system average $44,500 per year. If an LFG energy project generates electricity, often a landfill will use a portion of the electricity generated to operate the system and sell the rest to the grid in order to offset these operation costs. [23]

4.9 Landfills gas production and utilization:

Landfills gas recovery not only meets the energy requirements by displacing the conventional energy resources which are getting scarce and also has positive impacts on environment. Now days, landfill gas utilization for power production is considered as a commercial technology for energy generation. Under optimum conditions, one ton of wastes can produce 150-200m^3 of gas. The greater the amount of organic waste present in landfill, the more landfill gas (i.e. methane, carbon dioxide, nitrogen, and hydrogen sulphide) is produced by the bacteria during decomposition [26]. Several landfill gas waste-to-energy projects have been implemented and most of them are in America and Europe (Karapidakis et al., 2010).

4.10 Type of waste for landfill:

Waste composition has crucial rule in valuation of landfill gas recovery technology especially the moisture content, organic fraction and degradability level of different waste stream components. Large quantity of food fraction in landfill is easily degraded and tends to generate landfill gas within short period of time (SCS ENGINEERS, 2005)[31].

4.11 Number of LFG plants worldwide:

It is difficult to find out exact figures about the number of plants implemented worldwide because only few countries have centralized data about landfill gas projects. Landfill gas plants were initially practiced in US and afterward in Europe and today more number of plants are present in Europe than in US. However their capacity is half than the US landfill gas recovery projects. Now total 1,150 landfill gas recoveries for power production are operating worldwide and their capacity is varying from 2 million tons to 2,850 million tons of amount of waste (Willumsen, 2009).

Table 9: number of landfill plant worldwide

Region	Number of Plants	Energy Production (MW)
Europe	734	1,275
United State	354	2,378
Asia	19	72
Australia	18	76
Canada	15	106
South America	8	18
Africa	4	4

4.12 Evaluation:

The landfill gas facility is suitable for recovery and utilization of gas from high quality of generated organic waste from Pakistan waste steam. This facility requires relatively small capital cost compared to waste-to-energy recovery technologies. Landfill gas facilities located near communities could be used as a source of CH_4 gas recovery and use it for energy purposes in houses and industries at lower cost to conventional power plants sources.

Table 10: Landfill gas facilities cost

Waste quantity (ton/day)	Cost ($/ton)	Location	Source
274	-1	Canada	Tatarmiuk, 2007[2]
360	-3.55	Canada	Tatarmiuk, 2007
550	4.6	Canada	Tatarmiuk, 2007
1230	-0.25	Canada	Tatarmiuk, 2007
192	6.73	Denmark	Johannessen, 1999[27]
274	4.04	Poland	Johannessen, 1999
562	7.32	Indonesia	Johannessen, 1999
1918	3.89	Latvia	Johannessen, 1999

It is attempted to find out the cost per ton of some landfill gas plants. It is clear to see that cost is decreased per ton with the increase in total quantity of waste for processing and negative sign indicates the generation of revenue.

4.13 Environmental impacts of landfills gas:

Produced landfill gas is not only utilized for the energy production to cope with energy crises but also helpful in reduction of environmental damage and greenhouse gases emission impacts (Karapidakis et al., 2010)[28]. Often some of the environmental impacts are associated with landfill such as groundwater and surface water pollution. These environmental impacts could be reduced thoroughly engineered landfills (FCM, 2004)[29].

4.14 Social impacts of a landfill gas:

It is given preference that landfill sites should be closed to solid generated communities by taking consideration of easy transport of waste with minimal cost, but the communities have opposition to landfills to be closed to the housing. This result is difficulty to find out more appropriate site for landfill setting. Additionally, the construction of landfill site is very costly and having a limited time span. To maximize the efforts to minimize the total amount of waste disposal in landfills that make assure available free space over long period of time for waste disposal (Holroyd City. 2010)[30].

4.15 Incineration with Energy Recovery:

Instead of dumping incineration is the best option, but just need some more technical investment and integrated waste management system. " container for burning refuse, or plant designed for large-scale refuse combustion. In the second sense, an incinerator consists of a furnace into which the refuse is charged and ignited (usually by a gas burner), a secondary chamber in which burning at a high temperature is continued to complete the combustion process, and flues to convey the gases to a chimney. Auxiliary equipment may include steam boilers for using waste heat to generate electricity or to heat nearby buildings and devices for removing ash and other pollutants from the flue gases." (dictionary.com, 2013a)

In late 1970's and early 1980's many countries from eastern Europe and Asia consider incineration for MSW, but unfortunately these plants cannot be completed due to lack of financial, managerial and technological shortcomings. Mechanical solution of MSW requires significant technical skills and budget. Any unskillful planning can bring a huge bill to pay for society. Therefore incineration projects need extra ordinary planning and care.

Incineration is getting more popular solution since now it is sensible to not loss the valuable waste and especially in the countries where empty land is problem for land filling like eastern European countries. There are several types of incineration technologies; the most common one is "Mass Burning Incineration". The mass burning technology with movable grate mature and tested technology, which comply with latest techniques and environmental standards. Generally mass burning technology accept the MSW without pre-treatment, but its good if the material has been graded already to put through grates of rotary kiln incineration plant (Georgieva et. al. 1999). A further innovation in incineration/combustor system has been initiated by the students of Northeastern University USA, by introducing NRP to electricity plant, which also require mass burning " The waste combustor processes non-recyclable plastic within two tanks. The top tank converts the plastic to gas through pyrolysis. The gas then travels to a lower tank, where it is burned to generate heat and steam. The steam powers a turbine to produce electricity" (Mahony M. 2010)[2] Fluidized bed incineration is another MSW incineration method, but it is not matured yet.

4.16 Social impacts of incineration:

Communities rarely accept the incineration facilities for management of solid waste stream because of strong opposition from the local residents due to their concern about sewer health and environmental effects. Public awareness and information is therefore important while construction a waste-to-energy facility like incineration (Gruner, 2007)[32].

4.17 Production rate of landfill gas:

LGF production varies considerably from one plant to another, depending on the situation in the individual country and landfill. The production rate depends on the following parameters:

1. **Waste age:**

LFG production reaches its maximum capacity after 3-8 years and normally decreases after 15-30 years, when it is no longer profitable to extract the gas for energy purposes.

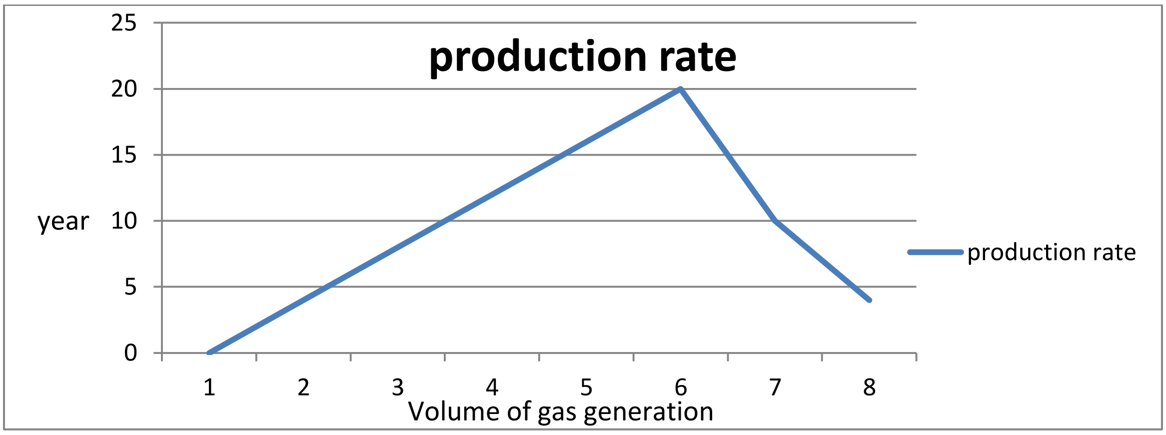

Figure 12: production start after 6 months and increase till 20 than decrease

2. **Waste structure:**

Because degrading microorganisms are active in the water film around the waste particles, smaller particles of organic materials produce more LFG.

3. **Moisture content of the waste:**

Methane generation bacteria live in the water film around the waste particles. Sufficient water is needed to cover the organic particles. Moisture can accelerate bacterial activity or smother it completely if the waste is completely saturated.

4. **Temperature in the landfill:**

Methane bacteria find optimum mesophyll conditions at 35^0 C. this temperature is found in deep landfills. In shallower landfills (10-15 meters deep) the temperature is normally as low as 20^0C.

5. **Landfill cover:**

Landfills must be covered to keep out atmospheric air, which will disturb the anaerobic conditions. The cover material should allow penetration of rainwater to maintain adequate humidity in the waste. [24]

5 Discussions:

Most Feasible forms of technologies:

Different types of waste-to-energy recovery technologies were studied by considering the main factors such as social, environmental and economic which play an important role while the section of best energy recovery technologies for large population country like Pakistan. The cost associated with each type of energy recovery technology is directly linked with the available quantity of waste steam for processing as well as its composition. From social and environmental issues, environmental impacts of technologies are more important and must be considered separately.

Landfill energy recovery technology is the most socially acceptable, environmentally friendly and the cheapest one among all other available worldwide waste-to-energy technology for Pakistan.

Mass burn incineration is the second best option because it is relatively socially unacceptable more source of pollution and likewise more costly than the landfill recovery facility.

A. Environmental impacts

Noise:

Noise could be a source of pollution when waste transporting vehicles enters and comes out of the waste-to-energy facility. The noise pollution produced from waste transporting vehicles could be reduced by regular maintenance and responsible use of these vehicles. Certain hours of the day and specific routes for the waste transportation are also other factors to reduce garneted noise from trucks (Weinstein 2006)[33].

Air pollution:

Combustion systems from the waste-to-energy facilities are the main source of chemicals emission to the atmosphere. These emissions include dioxins, mercury, particulate matter and hydrochloric acid etc. however, these emissions are enormously reduced to minimum level through reduction of toxic containing substance, improvement in combustion facilities and use of gaseous control system etc. (Weinstein 2006).

Diesel emission reduction

Mostly the energy recovery facilities require small area for establishment relative to landfill and are built near the municipalities. This will eventually not only reduce time by shortening the distance but also emissions from diesel engines. Diesel engines of waste transporting vehicles are the major source of emission of NOx, particulate matters and hydrocarbons etc. these gases contribute in ground level ozone formation but this threat also reduces with reduction of travelling distance (Weinstein 2006).

Greenhouse gases and clean energy production:

The material left over after the segregation of recyclables and organics for composting came from renewable sources, this derived component of waste stream could be used as clean, sustainable and renewable fuel for heat and electricity. It has been made confirmed by many independent studies that waste-to-energy facilities have capacity to generate electricity and avoid the greenhouse gases emissions and are more effective than landfills (Psomopolos et al., 2009).

B. **Social Impacts:**

Land use:

The implementation of waste-to-energy facilities faces the opposition and protest from local people or neighbor for its construction due to reduction of land value and production of bad odor from waste. So it is better to install new waste-to-energy plant on old and out dated industry sites to improve local conditions (Weinstein 2006).

Traffic:

The installation of new waste-to-energy plant will require more waste on regular basic for its feeding. Ultimately the increase in numbers of garbage vehicles will occur its surrounding. Traffic congestion on roads and its surrounding can be controlled through proper management like fixed hours in a day and also through special designed corridors for garbage vehicles (Weinstein 2006).

Aesthetic value:

Proper design and implementation of waste-to-energy facility and improved landscape site are helpful in improving the aesthetic value of an area. However, proper design of facility and selection of site can the perception of local people for its implementation. The emitted gases or smoke from chimneys having negative impact could be reduced or eliminated by installation of control equipment's (Weinstein 2006).

C. **Economic impacts**

Land requirement

Well maintained waste-to-energy facilities can operate more than 30 years. The waste-to-energy facilities require specific land area according to their size during their establishment. These can be expanded over more area by increasing their solid waste handling capacities. These energy facilities do not need periodic cost for more land. It is important that waste-to-energy facilities need significantly small land area as compared to landfills for handling of same quantity of waste (Psomopolos et al., 2009)[25].

Employment:

The construction of new waste-to-energy facility generates new job opportunities during its construction and operation phase as well. This may helpful for local people to improve their livelihood social situations (Weinstein, 2006)[25].

Real Estate value:

Uncontrolled dumping sites for waste disposal have opposition from local residence or communities because of its negative impacts on the real estate price. However implementation of waste-to-energy facilities not only improved the local area condition but also increased its value. It is better to select a site for new waste-to-energy treatment plant where an old transfer station or industry can be built aiming to improve previous environmental conditions of that site (Weinstein 2006)[25].

6 Conclusion:

The selection of feasible technology for Pakistan, social, environmental, economic, and composition & quality of waste factors were considered during evaluation process of different waste-to-energy options. Municipal collection of household waste is quite irregular and limited to influential areas. As a result solid waste remains scattered throughout the remaining area. Municipal street sweeping services are irregular and limited to main roads and influential areas. Many vehicles available with respective municipalities are reported out of order while remaining is used for many other purpose besides the misuse by staff. The operations of loading and unloading of municipal solid waste are manual. The most of municipalities have been unable to manage some reasonable piece of land either owned or no lease for the disposal of waste owing to the lack of fund.

There is a poor management of hazardous waste, under the current disposal practice; no proper method is being employed. Hazardous hospital and industrial wastes are being simply treated as ordinary waste. Open burning of waste especially non-degradable components like plastic bags are adding to air pollution. Municipalities do spend considerable portion of their budgets on solid waste management but as a return receive limited tax which is insufficient to meet their operation and maintenance costs. This is one of the main reasons why these municipalities cannot afford latest techniques and equipment to make solid waste management a profitable enterprise and to achieve the desired standards of environmental quality.

Landfill gas production and utilization and mass burn incineration are most feasible technology at first and second position respectively for treatment of solid waste in Pakistan. It is because these two facilities have enough capacities to treat the current generated waste at lower costs per ton. These two technologies also having capabilities to expand their capacities, if needed to treat more waste in future. However the treatment cost per ton decrease with the increase in quantity of waste per day. This is good way to tackle the solid waste generated in Pakistan.

7 Recommendation:

The thesis about the solid waste use as an alternate resource in Pakistan has been carried out. The options available for solid waste management in Pakistan have to be considered bearing in mind both the present and future needs. It has been tried to estimate the current composition and quality of produced waste in Pakistan and also to explore the social, environmental and economic issues closely related to improper solid waste management and in-depth study of technologies which are especially designed for the handling of waste. After studying the solid waste condition in Pakistan I have some recommendations which local municipalities can adopt to improve the current situation they are facing now.

- Increase the number of containers and street bins and make their design compatible with the collection and transportation systems.
- Establish regional collection systems in rural areas.
- Encourage people not to throw their garbage loosely at the roadside or into drains.
- Establish proper monitoring and supervision mechanisms for waste collection and transportation to ensure reliability and satisfactory operation of the service.
- Improve working conditions of solid waste management employees by providing them with uniforms and other protective gear, etc. Raise salaries and incentives to increase their motivation and thus increase waste collection efficiency.
- Improve vehicle selection in urban centers, taking into the account waste quantities and characteristics, the condition of roads and distance to disposal sites.
- Encourage community-based collection systems and clean-up campaigns organized by NGOs.
- Raise funds and lobby for additional allocations of local government budget for solid waste management from the Federal and Provincial Governments.
- Strengthen the enforcement of law and regulations on solid waste management as this will simulates residents, construction waste contractors to obey the law and it will increase the authority of the municipality.

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