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Alternative Or Smart Waste Management (Global Experiences And Cooperation): Establishing A Database, Spatial Information, And Projects To Improve Waste Collection Systems

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Abstract

Alternative or smart waste management is a sustainable approach aimed at protecting the environment and improving public health. This approach can be achieved by applying global expertise and cooperation between countries and peoples, and by establishing a database, spatial information, and projects to improve waste collection systems.

Dubai relies on alternative waste management, aiming to reduce the amount of waste sent to landfills. This management includes a set of actions, such as recycling, converting waste to energy, and reducing waste. Dubai has made significant progress in the field of alternative waste management, reducing the amount of waste sent to landfills from 90% in 2000 to 55% in 2023. Dubai aims to reach 75% by 2025.

Keywords: *Alternative management, waste management, recycling, global expertise and cooperation, Dubai.*

1. Introduction

In the past decade, the amount of waste in the UAE has increased due to population growth and economic activities. Most waste ends up in municipal landfills or dumps, where organic waste generates large amounts of methane, a potent greenhouse gas. Currently, little waste is incinerated, and the rate of municipal waste recycling is rapidly increasing.

Local authorities in the country coordinate waste management among themselves, addressing waste issues through recycling, converting waste into energy, using modern resources and technologies, and implementing advanced systems for waste separation and collection.

The UAE issued Cabinet Decision No. (39) regarding the executive regulations for Federal Decree No. (12) of 2018 on integrated waste management[1]. This decision aims to regulate the waste management process and unify mechanisms and methods for proper disposal,

[1] - Based on the following:

- Cabinet Resolution No. (39) regarding the Executive Regulations,

- Federal Resolution No. (12) of 2018 concerning the Integrated Waste Management from the official website of the UAE Government Waste Management:

https://u.ae/en/information-and-services/environment-and-energy/waste-management. Access date 22/03/2024.

based on best practices and available technologies, to protect the environment and reduce harm to human health.[1]

Problem Statement:
The world is experiencing technological development that can be described as rapid, resulting in the emergence of sustainable smart cities, coinciding with an increase in the volume of waste that must be disposed of safely and properly. In light of this, the problem has been articulated in the following question:
To what extent can alternative or smart management contribute to optimal waste management within the framework of sustainable development?

Importance of the Study:
This topic is considered a new and sensitive issue on the economic and environmental landscape, with the waste sector being one of the important sectors. Valuing waste and reusing it is a significant source of raw materials and contributes to national income.

Methodology:
The study relies on a descriptive and analytical method, which allows for understanding the problem, its causes, and the various possible ways to address it.
Structure of the Study: The study is divided as follows:

I. Waste Treatment
1. Aerobictreatment
2. Anaerobictreatment
3. Thermal treatment of waste (incineration)

II. Negative Effects of Waste

III. Smart and Sustainable Waste Management
1. Smart sustainability oasis
2. Smart gateway system (Nafeth)
3. Project to improve collection circuits
4. Waste compression containers
5. Establishing a spatial database and vehicle tracking system (Rasid)

IV. The Largest Solid Waste-to-Energy Conversion Plant Project in Dubai
V. SanitationProjects
VI. HazardousWaste Transport
VII. Dubai'sAmbitiousStrategy
VIII. Developing Innovative Techniques and Advanced Solutions for Waste Collection

I. Waste Treatment
This includes aerobic (1), anaerobic (2), and thermal waste treatment (3).
1. Aerobic Waste Treatment (Composting):
- Definition: Composting is a biological process in which organic waste is converted into a nutrient-rich soil product, in the presence of oxygen, at a specific temperature, and under controlled conditions. The resulting product, called compost, is often used in agriculture.

[1] - from the official website of the UAE Government Waste Management: https://u.ae/en/information-and-services/environment-and-energy/waste-management. Access date 22/03/2024.

Waste suitable for composting includes green waste, peels, animal manure, and household waste paper, while plastic and inert heavy elements are excluded.

- Different Composting Methods:
The conversion of waste into organic fertilizers relies on aerobic and anaerobic fermentation of organic waste. Results indicate that aerobic fermentation, which requires oxygen, is faster than anaerobic fermentation, which occurs in the absence of oxygen.

2. Anaerobic Fermentation:
This method has been used for years in India, where waste is placed in trenches in alternating layers, covered to isolate it from oxygen, and left undisturbed for several months. Anaerobic bacteria then act in the absence of aerobic bacteria, developing at the expense of nutrients. The resulting compost is then used as fertilizer.

3. Aerobic Fermentation:
In this method, waste is chopped into small pieces and placed in heaps, with each heap's base measuring 3.5m to 4m and height from 2.5m to 2.8m. The heaps are arranged linearly, and the process is completed within a short period (1 to 10 weeks), during which temperature rises noticeably and the compost mass decreases.

4. Incineration (Thermal Treatment)[1]:
- Definition:

Incineration is a thermal process that involves the complete destruction of waste, converting it into simple compounds (H2O, CO2, Na). This method is used for burning organic waste that cannot be recovered or buried in sanitary landfills, such as household waste, medical waste, slaughterhouse waste, and spoiled food.

- Incineration Facilities (Furnaces):

Incineration is carried out in a furnace at temperatures between 800°C and 900°C for simple organic waste, and between 1200°C and 1400°C for complex waste. There are three types of furnaces:

- Grate furnaces: where waste is mechanically moved and turned.
- Rotary kilns: where the rotational movement mixes the waste, allowing oxygen to penetrate and speed up combustion.
- Fluidized bed furnaces: where waste is mixed with sand, which is suspended by air blowing at the base.

- Advantages of Incineration:

- About 18% of urban solid waste contains non-renewable carbon (from petroleum, coal), while 82% contains renewable carbon (from wood, plants). Thus, incineration transforms waste into renewable energy.
- Incineration is a rational solution when landfill space is very limited or non-existent.

- Disadvantages of Incineration:

- The composition of waste varies over time, creating challenges in maintaining optimal combustion temperature.
- Environmentally, incineration emits pollutants such as dust, metals, and dioxins, affecting air quality.

II. Negative Effects of Waste

Waste has numerous adverse effects on all forms of life. Plants, animals, and humans all live in a shared environment; if one is harmed, the other elements are affected, disrupting the ecological balance. The negative effects can be summarized as follows:

[1] - Ministry of Environment and Regional Planning, Urban Solid Waste Management, Publication, 2003, p. 226.

1. Environmental Effects:

- **Emission of GreenhouseGases[1]:**

Scientists estimate that burning 1 ton of garbage produces 3000-6000 m³ of gases, varying in content depending on the organic or inorganic material, contributing to the expansion of the ozone hole.

- **Pest Production:**

Waste produces large numbers of pests, such as cockroaches, which transmit 26 diseases to humans, flies (42 diseases), and rats (16 diseases).

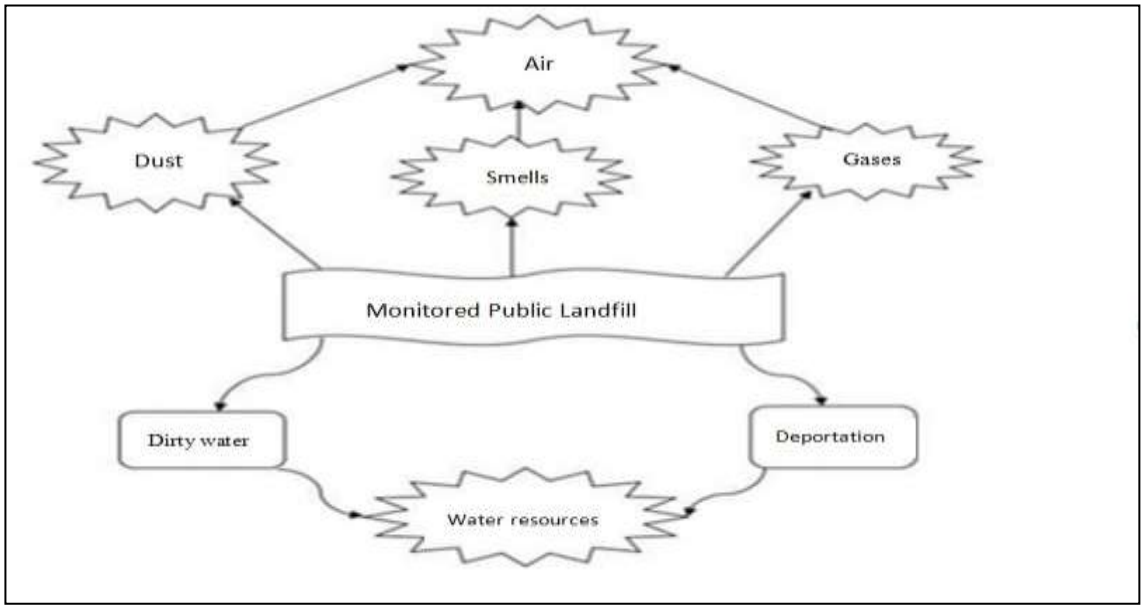
2. Negative Environmental Impact on Humans[2]:

- Psychological and social diseases.
- Visual pollution that harms human vision, causing psychological issues affecting health and physiological processes.
- Decreased productivity; a clean environment increases productivity by 20-38% compared to a dirty one.
- Waste leachate can contaminate surface and groundwater.
- Radioactive materials can pollute air and soil.
- Additionalcosts.
- Depletion of finite and non-renewable resources.
- Pollution in variousforms.
- Desertification and degradation of natural areas, including fertile agricultural lands.
- Global warming and ozone layer destruction.
- Acid rain.
- Growth of microorganisms and larger organisms, from bacteria to rodents.

These environmental effects are primarily caused by greenhouse gases from waste fermentation, such as:

- Methane, produced by decomposing garbage, equivalent to 1.6 million tons annually.
- Carbondioxide.
- Nitrogen oxide, produced by organic material decomposition, equivalent to 0.78 million tons annually.
- Sulfur oxide, emitted from waste, leading to acid rain.

Figure 01: Diagram Showing the Impact of Waste on Various Environmental Elements



Social Impacts:

Among the social impacts caused by waste are, but not limited to, the following:

- The aesthetic and touristic appeal of the city is affected due to the accumulated piles of waste, which also negatively impacts the morale and psychological state of the residents, causing them to feel constantly distressed and annoyed.
- People tend to avoid living in areas where waste collection and transportation are neglected, leading to a decrease in property and land prices in those regions.
- The accumulation of waste leads to a lack of a sense of belonging and loyalty, fostering negativity and irresponsibility among some community members, which reduces their willingness to participate in improving their conditions and joining environmental protection associations.

Economic Impacts: Waste results in several economic impacts, including:

- Studies on productivity have shown that people living in a clean environment produce 20-38% more than those living in a dirty environment.
- Depletion of renewable and non-renewable resources.
- Pollution of fresh and groundwater, increasing the economic costs of treatment.
- The national economy is affected when the expenses of waste collection are not offset by its valorization.
- The national economy is also impacted by the negative effects of waste on the tourism sector due to visual pollution and the accumulation of waste in streets and tourist areas.
- The national economy is further strained by the spread of epidemics due to pollution and waste, as the state spends a lot of money fighting these diseases.
- Economic costs arising from waste pollution include:
- Wages for treating those affected by epidemics.
- Costs of damaged agricultural crops in areas affected by waste accumulation or soil pollution.
- Waste has significant economic costs for the producing institutions, affecting their financial status (polluter pays principle).

III. Smart and Sustainable Waste Management (Case Study of Dubai)

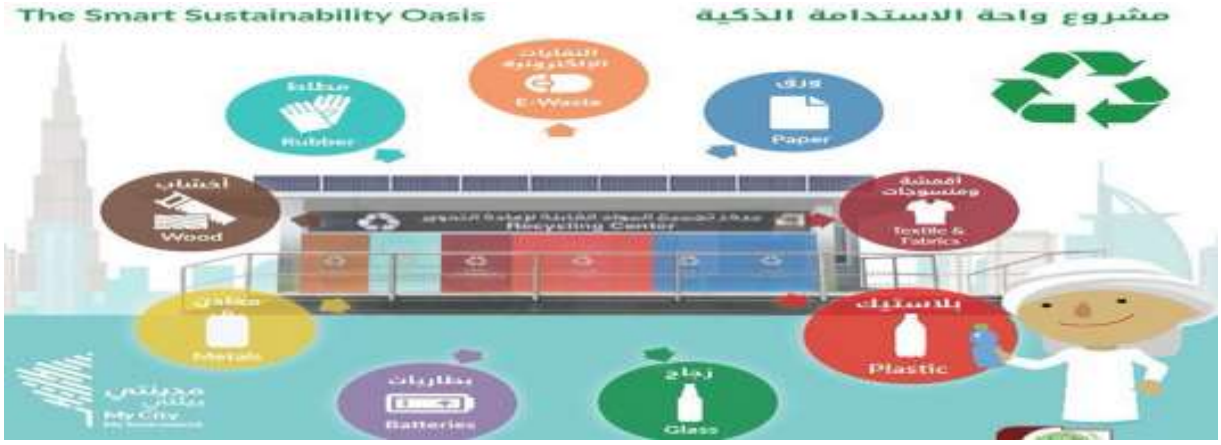
Smart management facilitates the process of managing municipal solid waste in an interconnected series, making it smooth, easy, and environmentally safe for public health, while also speeding up the process. Smart waste management plays a crucial role in minimizing pollution and keeping it at the lowest levels. Thus, we must leverage technological advancements by using information and communication technology to eliminate waste problems through digitizing waste collection management and city cleaning operations, leading to significant cost reductions, time savings, and increased overall citizen satisfaction.

IV. Global Expertise and Creation of Spatial Database and Information (Case Study of Dubai)

Dubai is a model for smart cities using information and communication technology to manage its waste. Within the project "Dubai, a Smart and Sustainable City," Dubai Municipality has implemented several measures and mechanisms for smart and sustainable waste management through[1]:

1. Smart Sustainability Oasis:

A self-sufficient recycling center powered by solar energy with sensors and surveillance cameras directly connected to central stations. The Smart Sustainability Oasis provides innovative recycling solutions in Dubai. Awareness services are offered through smart screens that encourage users via displayed messages.



2. Smart Gate System :

An entirely automated entry management system for Dubai Municipality's landfill sites. It uses identification technology and automatic recognition of digital plates and integrated software to control vehicle entry and gather weight information. This initiative will reduce vehicle entry time, minimize emissions, and increase efficiency. The new system will also reduce paper usage in entry transactions and reporting, as all information will be in an automated system.

3. Project to Improve Collection Circuits:

Transitioning from random waste collection schemes to using technology within waste containers.

4. Waste Compression Containers:

Bigbelly waste compression containers operate on solar power, providing 100% of their energy needs and are made of carbon. These containers can compress waste, allowing them to hold 6-8 times more than regular street waste bins. Volume sensors in the compression units alert when a certain level is reached. Geographical markers on the stations enable[2]:

- Monitoring container efficiency based on locations.

[1].-ECUB LABS, https://www.ecubelabs.com/ar/, Access date 22/03/2024.

[2] - ECUB LABS, op. cit.

- Sensor alerts to headquarters when containers are nearly full.
- Enhancinglogisticsefficiency.

Overall, this reduces fuel consumption due to fewer trips and decreases labor and equipment usage.

5. Creation of Spatial Database and Vehicle Tracking System:

A GPS-based technology providing real-time management and tracking for Dubai Municipality's fleet and registered private waste management companies. The system includes applications for efficiency and safety, enhancing vehicle productivity. Features include vehicle maintenance, tracking, fault diagnosis, driver management, speed and fuel management, and health and safety management. The emirate has takenseveralmeasures, including:

- Installing tracking devices to monitor waste transport vehicle movements.
- Equipping all waste collection and transport vehicles with a waste weight measurement system, transmitting data electronically to a central waste database.
- Coordinating and unifying penalties across the state, establishing deterrent penalties and fines for violators.

Advantages of Waste Transport Tracking:

- Tracking waste transport from collection points to licensed waste management facilities, preventing illegal dumping.
- Knowing the quantities and types of waste transported to processing facilities, ensuring proper funding for authorities to equip vehicles and databases.

Generating Additional Revenue Through Advertisements:

- Cleanliness bins can be fully wrapped and prepared for marketing purposes by printing advertisements on them.

Creating Reports for Data Analysis:

- Reports on waste generation, overflow, and collection performance allow users to focus resources efficiently by identifying high waste generation and overflow areas.

The Largest Solid Waste-to-Energy Conversion Plant Project in Dubai:

Dubai Municipality is planning to construct the largest solid waste-to-energy plant in the Warsan 2 area, with an estimated cost of approximately 2 billion dirhams. This initiative aims to transform Dubai into one of the most sustainable and smart cities by aligning with the national agenda to reduce landfill waste by 75%, conserve landfill space, and protect the environment from methane gas emissions. In its first phase, the plant will process 2,000 metric tons of solid waste daily, generating 60 megawatts of energy.

To support Dubai’s Clean Energy Strategy, which aims to source 7% of the city's energy from clean sources, Dubai Municipality is working closely with the Supreme Council of Energy and Dubai Electricity and Water Authority. They are conducting studies and proposing four green energy projects, including:

- Incinerating waste to produce electricity
- Treating organic waste from markets, restaurants, hotels, and food suppliers
- Generating electricity from landfills in Al Qusais and Jebel Ali
- Converting methane gas at wastewater treatment plants into energy[1].

V. Sanitation Projects

In 2015, Dubai announced the Century Sanitation Project, featuring deep tunnels as a flexible and integrated system to accommodate the emirate's expected population growth over the next 100 years. This project aims to eliminate odors from stations, remove pumping stations and transport tanks, thereby reducing costs and traffic congestion. The design, implementation, and operation costs are estimated at 12 billion dirhams over 50 years.

Additionally, Dubai's government approved the second phase of the Jebel Ali wastewater treatment plant, with a budget of 1.3 billion dirhams. The Jebel Ali plant, incorporating the latest advancements and modern technologies in wastewater treatment, has a total project cost of 2.849 billion dirhams. The plant's capacity will increase from the current 300,000 cubic meters to 675,000 cubic meters daily, effectively doubling its production rate. This expansion is designed to support Dubai's anticipated future growth, serving a population of 1.35 million people and ensuring no further expansions are needed until 2025.

VI. Hazardous Waste Transport

Hazardous waste is defined as waste or ash resulting from various operations and activities that include hazardous materials, as stated in Federal Law No. 24 of 1999 on Environmental Protection and Development.

The United Arab Emirates became a member of the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal (English only) in 1990. The UAE's Ministry of Climate Change and Environment issued a decision to regulate the transit and export of hazardous waste shipments across the UAE borders. The ban includes the transport of hazardous waste by sea, land, or air within the country without obtaining a written permit from the ministry, in line with the aforementioned Basel Convention[2].

VII. Dubai's Ambitious Strategy

The Dubai Waste Management Center is designed to convert 1.9 million tons of solid waste annually into sustainable energy, making it the largest waste-to-energy plant in the world under construction to date. Dubai's waste management strategy considers this project a significant initiative, providing a new source of sustainable energy using waste that has been a persistent issue for Dubai. This enhances Dubai's vision to become the most sustainable city globally. The project will help achieve Dubai's strategic goals by supporting the pillars of environmental protection and enhancing the sustainability of natural resources.

- Integrated Waste Management in the Local Community

[1] - the official portal of the UAE Government Waste Management. https://u.ae/en/information-and-services/environment-and-energy/waste-management,

[2] - Federal Law No. 24 of 1999

- Permanent conversion of waste present in landfills.

The Dubai Waste Management Center project is being developed through a build, operate, and transfer contract by "Dubai Holding" on behalf of Dubai Municipality. Dubai Holding will be responsible for designing, building, and operating the Dubai Waste Management Center for 35 years. In addition to producing sustainable energy, the plant will recover valuable metals from the remaining ash for use in construction materials. The electricity generated from this project will be used for local consumer applications and Dubai's electricity grid after meeting the plant's energy needs.

Developers:
The project is financed through global facilities and lending institutions, including the Japan Bank for International Cooperation and Nippon Export and Investment Insurance Agency. The project adheres to Dubai's strictest social and environmental standards and complies with international guidelines and performance standards for international finance companies, as well as environmental guidelines such as the Equator Principles and the World Bank Group's health and safety standards.

a) Description of the Plant:
The plant is situated near the current landfill site in the Warsan area. Equipped with five operational furnaces, it will process approximately 5,666 tons of solid waste daily to generate around 190 megawatts of electricity. After fulfilling the plant's internal energy requirements, it will export 132,000 volts to Dubai's electricity grid. The Dubai Waste Management Center will utilize an advanced combustion system by Hitachi Zosen Inova. Upon arrival, solid waste will be stored in an environmentally sealed bunker. Cranes will then transfer the waste into hoppers that feed into the combustion furnace. The inclined furnace is integrated with a boiler feed system, a combustion air system, a flue gas recirculation system, and a bottom ash handling system. The furnace features a combination of fixed and movable grates, as well as hydraulically operated grates, to agitate the waste and facilitate its movement through the combustion chamber, ensuring optimal and complete combustion. There will be five boiler lines with combustion chambers designed to mix gases emitted from the waste with secondary air and recirculated flue gases above the ignition furnace, ensuring thorough combustion. Gas recirculation enhances energy efficiency and allows precise control of combustion conditions, thereby reducing emissions.

Flue Gas Treatment Plant:
The flue gas treatment plant is one of the most advanced waste treatment facilities of its kind. It integrates municipal waste recycling to ensure minimal air emissions, adhering to the strictest European emission standards. After combustion, the residual ash will be collected in a bottom ash extractor for removal. This ash will then undergo metal recovery and recycling processes for commercial use.

High-Pressure Steam Boilers:
The plant will include high-pressure steam boilers that produce superheated steam at 500°C, which will drive high-efficiency steam turbine generators. An air-cooled condenser will be used to recycle the water utilized in the process. The plant's efficiency is anticipated to reach 34%, making it one of the highest efficiency rates globally for this type of facility.

Operating Procedures of the Plant:
The facility is designed to meet Dubai's stringent environmental standards and regulations, aligning with the strictest European industrial emission standards through the use of advanced flue gas treatment technologies. Emissions from the waste storage bunker will be continuously monitored via a 24-hour emissions monitoring system, providing real-time reports to Dubai Municipality's Environment Department in accordance with Dubai's air

quality strategy. Additionally, air, odor, and noise quality monitoring stations, supervised by Dubai Municipality, will ensure the facility consistently complies with all standards and regulations throughout its operation.

To mitigate the environmental and social impacts of the project, several initiatives are planned. These include comprehensive waste management, continuous air, odor, and noise monitoring, and active stakeholder engagement initiatives.

VIII. Eighth Developing Innovative Technologies and Advanced Solutions for Waste Collection

One of the key technological innovations introduced in the region is the creation of a new waste database by the Ministry of Climate Change and Environment. This bilingual system collects and analyzes data on waste generated nationwide, tracking both hazardous and non-hazardous waste levels. It produces monthly and annual reports detailing waste quantities, treatment methods, and the percentage of waste treated in each emirate. Such initiatives are at the forefront of the waste management sector, highlighting the necessity for dedicated waste management facilities. Efficient waste management technologies are promoted across the nation, enhancing environmental and economic sustainability.

Dubai Municipality's efforts in installing electronic gates and smart weighing bridges at all disposal sites are revolutionizing traditional waste management technologies throughout the GCC region, making them more intelligent and sustainable. The entire region is moving towards an integrated waste management practice, with a strong emphasis on converting waste into valuable resources through recycling, renewal, and refining facilities, as well as various other waste-to-energy methods[1].

Conclusion:

The municipal solid waste management sector should be prioritized in national policies for its added value by recovering and revalorizing recyclable materials. Utilizing the best practices, such as modern technology and creating smart, sustainable cities, aids in environmentally safe waste management, ensuring a healthy environment and public health while aligning with the United Nations' environmental and sustainable development goals. Key findingsinclude:

- Smart, environmentally sustainable cities use technology to achieve sustainable development goals.
- Environmental sustainability, while possibly the most crucial aspect of sustainable development, integrates with other dimensions.
- Municipal solid waste includes household waste and similar types, collected at the municipal level or by its order.
- Smart sustainable cities facilitate municipal solid waste management within an interconnected series, making it smooth, easy, and environmentally safe for public health, in addition to speeding up the process.

Dubai is a model for smart cities using information and communication technology to manage waste. Regarding alternative waste management in Dubai, the city strives for environmental sustainability in all fields, including waste management. Therefore, the city relies on a range of alternative methods for waste management, including:

- Recycling: About 70% of solid waste in Dubai is recycled, contributing to reducing greenhouse gas emissions and conserving natural resources.
- Organic Disposal: Organic waste is converted into compost used in agriculture and land rehabilitation.

[1] - Source: https://www.mordorintelligence.com/ar/industry-reports/uae-industrial-waste-management-market

- Thermal Conversion: Non-recyclable solid waste is incinerated to produce electricity.
- Thermal Recycling: Non-recyclable solid waste is converted into thermal energy.

- These alternative waste management methods have provided many benefits to the city, including:
- Reducing the volume of waste sent to landfills, thus minimizing environmental pollution.
- Conserving natural resources by reusing recyclable materials and converting organic waste into compost.
- Producing energy, with electricity and thermal energy generated from waste.

Dubai aims to continue developing these alternative waste management methods to achieve full environmental sustainability.

Recommendations:: Several recommendations can be suggested to enhance waste management in Dubai:

- Transition to Smart Sustainable Cities: Aim for environmental sustainability by developing smart, sustainable urban areas.
- Leverage Technological Advances: Use information and communication technology to address waste management issues.
- Adopt Best Practices from Global Leaders: Learn from successful international examples to mitigate environmental degradation risks.

- To maximize the benefits of alternative waste management methods in Dubai, it is advisable to:

- Raise Community Awareness: Educate the public on the importance of recycling, organic waste disposal, and other alternative waste management practices.
- Enhance Infrastructure: Provide the necessary facilities for efficient waste collection and recycling.
- Invest in Research and Development: Focus on developing innovative and effective waste management solutions.
- Implementing these recommendations can position Dubai as a leader in sustainable waste management.

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[1] - Based on the following:
- Cabinet Resolution No. (39) regarding the Executive Regulations,
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