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ANALYSİS OF WASTE-ENERGY POLICY IN DIFFERENT COUNTRIES; PRACTICES AND IMPLICATION FOR SUSTAINABLE DEVELOPMENT

mövzusunda

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YÜKSƏKTƏHSİLİNSTİTUTU

MAGİSTRANTIN ANDI

"Analysis of waste-energy policy in different countries; Practices and implication for sustainable development" mövzusunda təqdim etdiyim(iz) (Magistrlik dissertasiyasının mövzusu) magistrlik dissertasiyasını elmi əxlaq normalarına və istinad qaydalarına tam riayət etməklə və istifadə etdiyim bütün mənbələri ədəbiyyat siyahısında əksetdirməklə yazdığıma and içiriəm(ik) və magistrlik dissertasiyasının AzTU Kitabxana İnformasiya Mərkəzində saxlanılması, həmin mərkəz tərəfindən AzTU Rəqəmsal Repozitoriyasına daxil edilərək repozitoriyanın veb saytın dayerləşdirilməsinə icazə veririk.

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Tarix

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INTRODUCTION

The actuality of the subject: As we know, limitation of hydrocarbon reserves as a traditional source of energy and prevention of environmental pollution necessitates an increase in the amount of energy produced by renewable energy sources in the world and investments in this field. There is already positive experience in this direction and, for example, in a number of countries, the use of wind, solar, wave, nuclear and waste energy sources is expanding year by year. Qualitative and quantitative measures and studies of politicians, economists, industry experts and scientists, who examine comparative examples of specific aspects in the field under analysis, emerge. Such facts make the topic relevant.

In the presented thesis, the "waste to energy" policy of different countries is investigated, and analytical analyzes are carried out. Experiences and implications for the continued development of this field are presented.

Environmental monitoring adds another layer, revealing different approaches to air and water quality, greenhouse gas emissions, and overall environmental sustainability. Preliminary insights from the dissertation highlight the need for a nuanced approach that considers both positive and negative environmental impacts in waste-to-energy initiatives.

Dissertation work has the nature of analysis. In the studied area, world-known technologies, world experience, environmental effects, and economic problems are investigated.

Beneficial impact on the environment: Environmental scrutiny adds another layer, revealing divergent approaches to air and water quality, greenhouse gas emissions, and overall environmental sustainability. These initial insights emphasize the necessity for a nuanced approach that considers both positive and negative environmental impacts in waste-to-energy initiatives.

Waste-to-energy policies: The preliminary analysis underscores that waste-to-energy policies are intrinsically linked with socio-economic dynamics and regulatory frameworks. This foundational exploration lays the groundwork for a comprehensive understanding of global waste-to-energy policies, preparing us for a more intricate examination of each country's distinct approach in subsequent phases of our study.

Urbanization and spending on consumer goods increase, more solid waste is generated. Therefore, the amount of solid waste has increased in the last century.At present, 3 million tons of production waste are produced in the world every day. By 2025, its number is expected to double.A lot of money is spent on solid waste management.In greenhouse gas (GHG) emissions, air and odor with increasing solid waste in landfills pollution, soil and water pollution occur.There are almost 20 developed countries in our world. Some of them have made energy sources, which we call alternative energy, their priorities. As many as 134 countries (65%) generate most of their electricity from fossil fuels, 66 countries (31%) from renewable energy sources.

Statistically China leads the way by generating 90% of their electricity (13.3 oxyjoules) by renewable energy in 2022. When it comes to getting energy from waste, things are a little different. Statistically, the countries that get the most energy from waste are Japan, South Korea and Northern European countries. Waste-to-energy technology has attracted the attention of almost all Asian countries and they continue to develop further.

But there are some countries that have the technology to convert almost 52% of their waste into energy. It is possible to show Sweden as an example. This country continues to hold the 1st place in the world in energy production from waste.

Energy security: The garbage that is generated as a result of human activity causes climate change and pollutes the soil, water, and air. Small objects made of synthetic materials are eaten by birds and animals, which often leads to their death. Waste can be liquid or solid.There are 5 hazard classes of waste depending on the degree of impact on the environment. The first are extremely dangerous, which cause irreversible changes, and the fifth are almost harmless. Hazardous Waste:1, 2, 3, respectively, include highly dangerous, moderately dangerous and low-risk.

Purpose of the study.World studies and every analysis,summarizing research and experience, based on optimal methods and technologies and applying them to the realities of Azerbaijan.

The research explores the various approaches countries take in turning waste into energy, looking at different technologies like burning, digestion, and new ways of converting trash into power.

Subject and object of research. To analyze the waste management methods, technologies and policies of the developed countries, as a result of the analysis, to put forward major projects in our country and advance in the field of energy procurement from waste. To achieve world-scale and important goals by further developing the waste energy policy in Azerbaijan**.**Applying and evaluate and compare waste-to-energy policies globally, identifying strengths, weaknesses, and best practices to inform the development of more effective and sustainable approaches. Improvement of waste-to-energy policies, fostering global collaboration and influencing practical advancements in waste management practices.

Scientific innovation. Recognizing the significance of practical experiences, the study engages in structured conversations withworld experience and statistical data, experts, policymakers, and individuals actively involved in waste-to-energy practices in various countries. These qualitative insights contribute a human element to the research, providing a deeper understanding of the complexities and challenges associated with policy implementation.

In order for the waste energy policy in Azerbaijan to reach the desired limits, it is planned to eliminate the differences and ensure the use of more modern and effective technology by comparing it with the countries of the world.

Environmental impact assessment is a critical component of the study, involving the scrutiny of air and water quality, evaluation of greenhouse gas emissions, and an overall assessment of sustainability resulting from waste-to-energy technologies. Data sourced from environmental agencies and research institutions play a pivotal role in this evaluative process.

Based on the implementation of this project, one of the main plans is to minimize the damage to the environment and immediately eliminate the damage. For this purpose, it is desirable to develop and apply special constructions, to improve the replacement devices.

Practical significance: In this research methodology, undertakes a comprehensive exploration of waste-to-energy policies across a spectrum of countries, employing a methodology that integrates rigorous data analysis with real-world insights.

Commencing with an extensive review of diverse sources ranging from academic papers to government reports and expert writings the study aims to unearth existing knowledge and identify gaps in understanding waste-to-energy policies. This foundational step provides a robust theoretical framework, ensuring a nuanced perspective on the subject.

Transitioning to the quantitative phase, the study focuses on a meticulous analysis of data related to energy extraction from waste and success rates in diverting trash from landfills. This involves a thorough examination of databases from environmental and energy agencies, applying statistical methods to discern patterns and correlations across different policy frameworks.

Research methods. Research methods are:

1. Literaryanalysis;
2. Analysis of research, studying the location and characteristics of the object;
3. Virtual construction of the project in specialized programs;
4. Modelingandsimulation;
5. Comparativeanalysis;
6. Financial issues, environmental protection, safety, and economic analysis.

In this study, a comparison of the waste-energy policy of developed countries and the waste-energy policy of our country is provided.This research is to strengthen our country's sustainable waste to energy policy, explore more efficient technologies, and help protect the environment from harmful waste and create possible waste-to-energy plants, mostly in our liberated territories.Shifting focus to the economic dimensions, the study explores how waste-to-energy policies influence jobs, economic growth, and community well-being. This multifaceted analysis includes stakeholder dialogue, survey research, and detailed analysis of economic data to ensure a comprehensive understanding of economic implications. This kind of analysis allows us to closely monitor the renewable energy policy of the countries of the world, as well as the policy of buying energy from waste, and to understand what is the important role in mutual energy economies.Through these observations, Azerbaijan's main task is to take its place in the world economy by increasing the efficiency of renewable energy sources.

The regulatory landscape governing waste-to-energy initiatives is thoroughly explored through a detailed analysis of policy documents, legal frameworks and regulations. This exploration aims to unravel the role of policy in shaping and guiding sustainable waste management practices, providing crucial insights into the regulatory environments ofdifferent countries.

Elements of scientific innovation: Scientific innovation in waste-to-energy includes improved conversion methods like incineration and anaerobic digestion, better sorting and material recovery techniques, and more efficient combustion and heat recovery systems. Emissions control advancements include advanced scrubbing and CO2 capture technologies.

Integrated waste management combines waste-to-energy with recycling and composting, enhanced by smart systems. Economic and policy innovations offer incentives and standards to support projects. Public awareness efforts engage and educate communities.

Research and development involve collaborations and pilot projects to test new technologies. Sustainability metrics and life cycle analysis evaluate environmental impacts. Innovative financing models, like public-private partnerships and green bonds, provide project funding.

Global issues. It's impossible to avoid waste generation. Among the main reasons for their formation in various spheres of production and distribution are: overproduction, manufacturing errors, violation of storage conditions, damage during transportation, expiration of shelf life, consumers making unnecessary purchases.

Practical solution:A practical approach to waste-to-energy involves efficient waste sorting and collection with smart technologies. Use high-efficiency methods like incineration, gasification, and anaerobic digestion to convert waste into energy, maximizing energy recovery. Employ advanced emissions control and carbon capture to minimize environmental impact. Recover valuable materials before conversion to reduce waste and enhance economic benefits. Integrate waste-to-energy with recycling and composting for a circular economy. Educate and engage the community, advocate for supportive policies, and invest in research and sustainable financing models to promote widespread adoption of waste-to-energy solutions.

Results submitted for defense: Waste-to-energy technologies offer a promising solution for sustainable waste management and renewable energy production. This thesis has highlighted their potential to reduce landfill use, lower greenhouse gas emissions, and contribute to renewable energy goals. Future research and implementation should focus on optimizing efficiency, minimizing environmental impact, and fostering public acceptance to maximize the benefits of waste-to-energy in achieving a greener future.

Summary of Results: The main findings from the dissertation work have been published at the Republic Scientific-Technical Conference on "Advanced Technologies and Innovations" held at the Azerbaijan Technical University in 2024.

Structure and scope of work. Dissertation work is **57** pages, consists of introduction, **2** chapters, conclusion and list of used literature.

I CHAPTER. WASTE TO ENERGY POLICY OF DEVELOPED COUNTRIES

1.1. The practice of developed countries

Determining a standard method to gauge disparities among nations can be challenging. Several alternative indicators may also assess a nation's development. Certain metrics might offer greater precision than others. Neither approach is inherently incorrect. Furthermore, some nations are vast, intricate entities that defy simple classification. Consequently, many countries display attributes from multiple categories.

The use of waste for energy production in developing countries presents both opportunities and challenges. On the one hand, it offers a sustainable solution to manage the growing volume of waste while simultaneously providing a renewable energy source. However, the implementation of waste-to-energy technologies in these regions faces various obstacles, including limited financial resources, inadequate infrastructure, and technical capacity constraints.

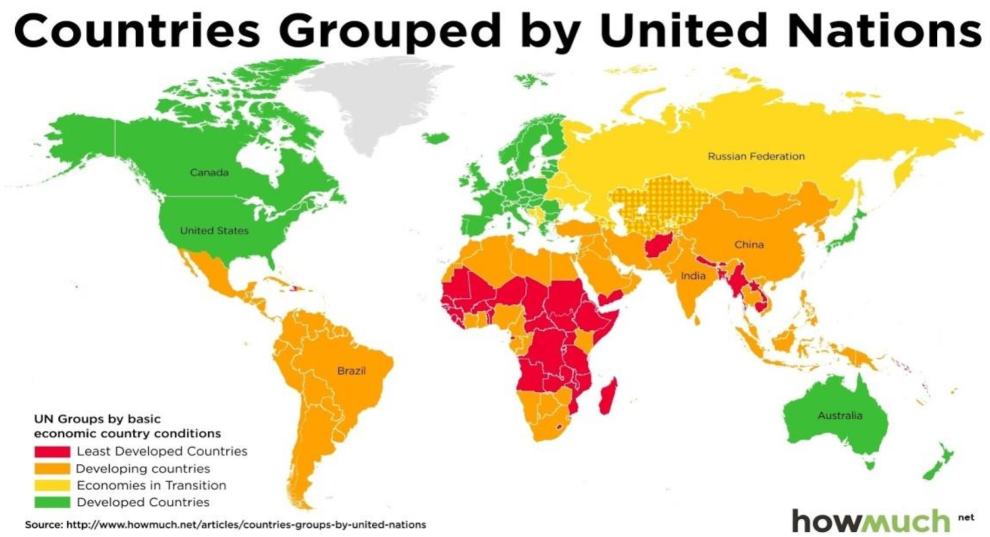
One of the main benefits of waste-to-energy initiatives in developing countries is the potential to reduce pressure on landfills and reduce environmental pollution. By converting waste to energy, these countries can reduce the negative effects of uncontrolled waste disposal practices on public health and the environment.In addition, waste-to-energy projects have the potential to contribute to energy security and diversification efforts in developing countries. By using domestic waste streams, these countries can reduce their dependence on imported fossil fuels and increase their energy independence.

However, the implementation of waste-to-energy technologies in developing countries is not without challenges. Limited financial resources and investment capital create significant obstacles to the implementation of large-scale waste-to-energy facilities. In addition, inadequate waste collection and separation infrastructure hinders efficient recovery of energy from waste streams.

Technical capacity constraints also pose challenges, as many developing countries lack the expertise and skilled labor needed to design, operate, and maintain waste-to-energy facilities. In addition, regulatory and institutional frameworks may be poorly developed, creating uncertainty for investors and project developers.

Despite these challenges, there is growing recognition of the potential benefits of waste-to-energy in developing countries. International cooperation and support, together with innovative financing mechanisms, can help remove barriers and accelerate the implementation of sustainable waste-to-energy solutions in these regions. By addressing both technical and institutional challenges, developing countries can harness the energy potential of their waste streams while contributing to the sustainable development goals.

According to the UN, 36 countries will be considered developed in 2023. In the picture 1.1. countries grouped by United Nations is shown. Almost all of the developed countries were located in North America, Europe, and "Developed Asia and the Pacific" (Carlsen, L., & Bruggemann, R. (2022)).



Picture 1.1.Most developed countries to least developed countries shown by colors.

Source: https://howmuch.net/articles/countries-by-united-nations

Developed countries often share other advantages:

1. Birth and mortality rates typically remain steady. Due to excellent healthcare and superior living conditions, infant mortality rates are minimal, thus birth rates do not surpass those observed in less developed nations.

2. They consume a disproportionate amount of global resources. In developed countries, more individuals drive cars and utilize electricity and gas to power their homes. Developing countries frequently lack access to technologies reliant on these resources.

3. They carry higher levels of debt. Economically developing countries lack the financial options available to more developed nations for managing debt.

Azerbaijan is an upper-middle-income country with high levels of economic development and literacy. Like many former Soviet republics, Azerbaijan had difficulty transitioning to a market economy.

1.2. The economy of Azerbaijan. Statistic information

It should be noted that Azerbaijan, like many others, is likely developing and implementing various programs and technologies for converting waste into energy, considering the importance of sustainable development and environmental sustainability.Azerbaijan has rich oil and natural gas reserves. According to BP's June 2021 World Energy Statistical Review, oil reserves of 7 billion barrels (1 Mt) at the end of 2020 represented 0.4% of global reserves.Oil is extracted both on land and at sea in the Caspian region, with marine operations contributing roughly 25% to the overall output.

Discovered in the early 1970s while Azerbaijan was still part of the Soviet Union, this field comprises numerous separate reservoirs located in the Caspian Sea at depths between 2000 and 3500 meters. In September 1994, the Azerbaijani government, along with a consortium of 11 foreign oil companies, signed the PSA Agreement in Baku.According to BP's 2021 World Energy Statistics Review, Azerbaijan holds approximately 2.5 trillion cubic meters of proven natural gas reserves. Although Azerbaijan is more renowned for its oil industry than its gas, it is anticipated that gas production will continue to play a significant role in the nation's economy in the coming decades(Hulgaard T. &Vehlow J., 2011).

The country's energy portfolio is heavily reliant on fossil fuels, with oil and gas making up more than 98% of the total supply. Although supply security is not an issue, this dependence on fossil fuels heightens GHG emissions and makes the country vulnerable to fuel price volatility. Additionally, despite significant modernization of aging natural gas networks with new compressor stations and infrastructure, concerns remain about distribution system losses and gas supply quality. Natural gas is the primary source for electricity production (90%), with large hydropower plants contributing 4%. Between 2007 and 2017, the reliability of electricity supply was enhanced by upgrading the generation system and bolstering the west-east transmission network. The addition of gas-fired generation capacity has decreased the frequency of power outages, and hydropower projects have also alleviated shortages. As resource-related incomes boost the growth of the middle class, the rising demand for electricity has necessitated further capacity expansions.

Azerbaijan's renewable energy potential promises many advantages for the country. Greater dependence on renewable energy allows Azerbaijan to save natural gas for export and use in the petrochemical industry. Reduce the country's GHG emissions to meet its commitment under the 2030 Paris Agreement; and improving electricity security through diversification of production. As part of planned energy market reforms, the government has drafted a renewable electricity bill and aims to provide 30% of electricity generation capacity from renewable energy by 2030, up from 16% in 2018.

Additionally, in May 2021, the Law was enacted, establishing a legal framework for the development of renewable energy projects in the country. This law introduces auctions and tenders as support mechanisms and includes drafts of other legislative tools such as Power Purchase Agreements (PPAs) and connection agreements.

Oil pipelines connect Azerbaijan not only with its neighbors, but also with markets. Three main pipelines belonging to SOCAR pass through the country. Oil is transported safely through these pipelines (Huseynov[1], A., Abbasov[1], E., Salamov, O., &Salmanova, F. 2015).

1.3. Types and tiers to waste management

To reduce the impact on the environment, there are four levels of managing wastes:

1. Pollution prevention and source reduction: This involves taking measures to prevent pollution from occurring in the first place and reducing the amount of waste generated at its source. Strategies may include implementing cleaner production techniques, optimizing resource use, promoting environmentally friendly practices in industry and households, and implementing regulations to minimize emissions and waste generation.

2. Reuse or redistribute unwanted, surplus materials: Instead of discarding materials that are no longer needed or in excess of demand, efforts are made to find alternative uses for them. This may include repairing, refurbishing, or using items for other purposes to extend their life, or redistributing them to others who may use them. By encouraging reuse, valuable resources are conserved and the amount of waste sent to landfills or incinerators is reduced.

3. Processing, reclamation and recycling of waste materials: This level involves the treatment of waste materials to recover valuable resources or transform them into new products. Processing techniques may include sorting, breaking down, and compacting waste to facilitate recycling or extraction of energy from organic materials through anaerobic digestion or composting. Reclamation involves the recovery of materials such as metal, plastic or glass from waste streams for reuse or recycling.

4. Disposal by incineration, processing or landfilling: This is the final step in waste management and involves the safe and environmentally sound disposal of residual waste that cannot be prevented, reused or recycled. Disposal options include incineration, where waste is burned at high temperatures to obtain energy or to reduce its volume, processing methods such as pyrolysis or gasification, which convert waste into inert materials or energy-rich gases, and landfill, where waste is collected in

engineered facilities. landfills designed to minimize environmental impacts and risks to public health.

Each of these levels plays a crucial role in effective waste management, aiming to minimize the environmental impact of waste generation while maximizing resource efficiency and sustainability.

Different sources of waste are identified by recognizing the types of waste.

Solid waste: These are excess substances thrown away by human society. These include municipal waste, industrial waste, agricultural waste, biomedical waste and radioactive waste.

Liquid waste: Refers to the waste generated during the washing of industrial enterprises or during the production process.

Gaseous wastes: These wastes include gaseous wastes from cars, factories or burning fossil fuels such as oil. By mixing with other gases in the atmosphere, they can sometimes cause phenomena such as fog and acid rain and cause serious damage to the environment.

Medical or clinical waste: These wastes produced from healthcare facilities such as hospitals, clinics, surgical theatres, veterinary hospitals and laboratories are called medical or clinical wastes. This includes surgical instruments, medicines, blood, body parts, dressing materials, needles and syringes.

Agricultural waste: These wastes are generated as a result of agricultural activities and horticulture, animal husbandry, market gardens. Waste from this source includes empty pesticide containers, old silage husks, expired drugs and worms, used tires, excess milk and etc.

Industrial Waste: These wastes include waste from manufacturing and processing industries such as chemical plants, cement factories, power plants, textile industry, food processing industry, oil industry. These industries produce various types of waste products that are hazardous to the environment.

This management system is designed to streamline how organizations eliminate, reduce, and avert waste. Also referred to as waste ejection, this approach involves companies adopting comprehensive strategies to manage waste from its inception to its ultimate disposal. In the picture 1.2. waste management service and its service areas are shown. Potential waste ejection methods encompass recycling, , waste-to-energy conversion, and waste reducing.

Picture 1.2. Waste Management Service

Source: https://www.researchgate.net/figure/Waste-management-services_fig4_331585560

Almost all waste system strategies and methods exist. Contemporary waste management strategies emphasize sustainability. Additional alternative methods for waste disposal include waste reduction, reuse, and recycling.

Thermal treatment is used in the application of heat for cleaning and decomposition of waste materials in different approaches. Open burning is one of the main methods of treatment of waste heat, but it is not considered to be a very environmentally friendly process. No pollution control device deals with open burning, which can cause pollutants to cause critical damage to the environment. This method is used in most countries as it provides a cheaper solution for solid waste treatment.

1.4. Plants and countries

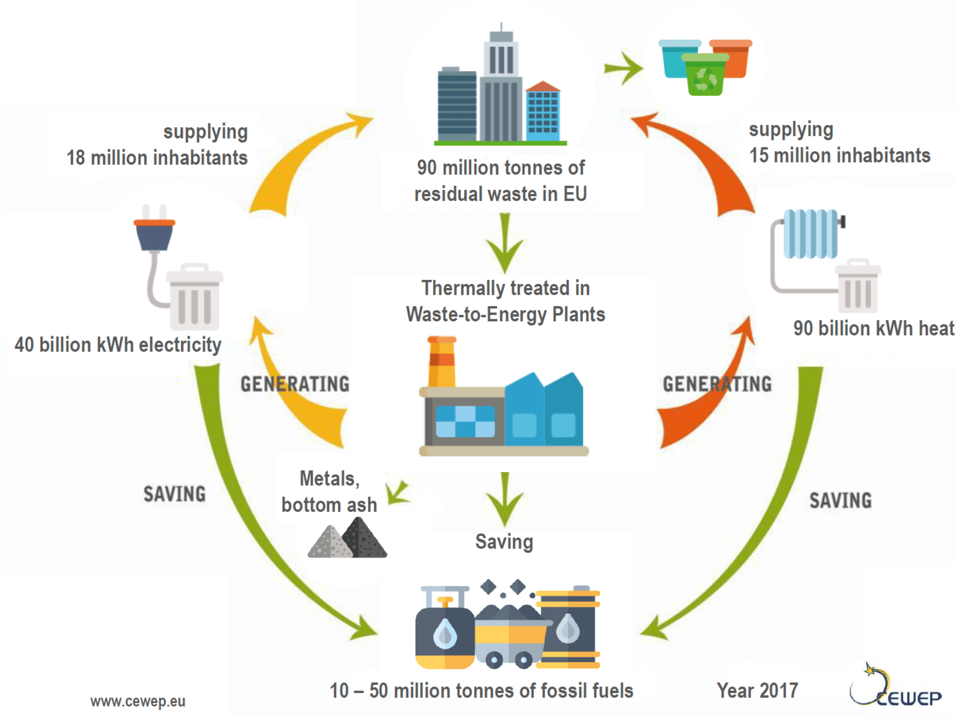
For decades, Japan, South Korea, Sweden, Finland, Great Britain and other wealthy countries have turned to incineration and other methods to deal with growing consumer and industrial waste. More than 1,000 incinerators in Japan and more than 500 in European countries such as Germany, Sweden, and Denmark burn thousands of tons of household waste every year, generating 6.3 gigawatts of energy in Japan and 11.2 GW in Europe.

Although there have been problems with dioxin and other heavy metal pollution from incinerators in the past, advances in pollution control technology have somewhat reduced these concerns.

Proponents of waste-to-energy, an industry group based mainly in European countries, Waste-to-Energy Technology Suppliers, say the technology has improved in recent decades, making it cleaner and more renewable. For Southeast Asian countries, it could be a useful tool in combating rising consumer waste, advocates say.

However, opponents say the Southeast Asian landscape of waste incineration, where the waste sector remains largely an informal industry, pollution controls are lax, and there are almost no systems in place to monitor the combustion products of dioxins and other highly toxic chemicals (Astrup, T. F., Tonini, D., Turconi, R., & Boldrin, A. (2015)).

European WtE plants are known for its efficiency. These plants, in addition to converting waste into energy, are also of great importance in protecting the environment (picture 1.3).



Picture 1.3. European WtE Plant

Source: https://www.cewep.eu/waste-to-energy-cycle/

Globally, it is estimated that 2.24 billion tons of waste were generated in 2020, a figure expected to rise to 2.88 billion tons by 2050. This leads to pollution of our environment and serious risks to the health of some of the world's most vulnerable people. Disposing of this abundant waste responsibly while striving for environmental sustainability is a growing challenge. These innovative devices are key to turning waste into valuable resources and generating electricity and heat while minimizing environmental impact. As demand for safe waste management and sustainable energy solutions grows, Waste-to-Energy plants provide an efficient and environmentally conscious means of progress.

This refers to non-recyclable, household solid waste. This is waste generated from households, offices and other small businesses that is not sorted for recycling, composting or other specific waste streams and is collected separately as residual waste. The composition may vary according to local regulations and procedures, as well as individual habits, but in general, a mixed household waste bin may contain the following items:

Non-recyclable or difficult-to-recycle plastics such as composite materials, laminates and certain types of plastic films; multi-layer packaging materials that cannot be easily separated for recycling; soft plastics such as plastic bags, wrappers and packaging materials that are not accepted in conventional plastic recycling or are lightweight and non-biodegradable, such as foam cores and airbags and Styrofoam commonly used in packaging and disposable containers; rubber gloves, disposable knives made of non-recyclable plastic; metal or plastic-coated paper, non-recyclable wrapping paper, etc.

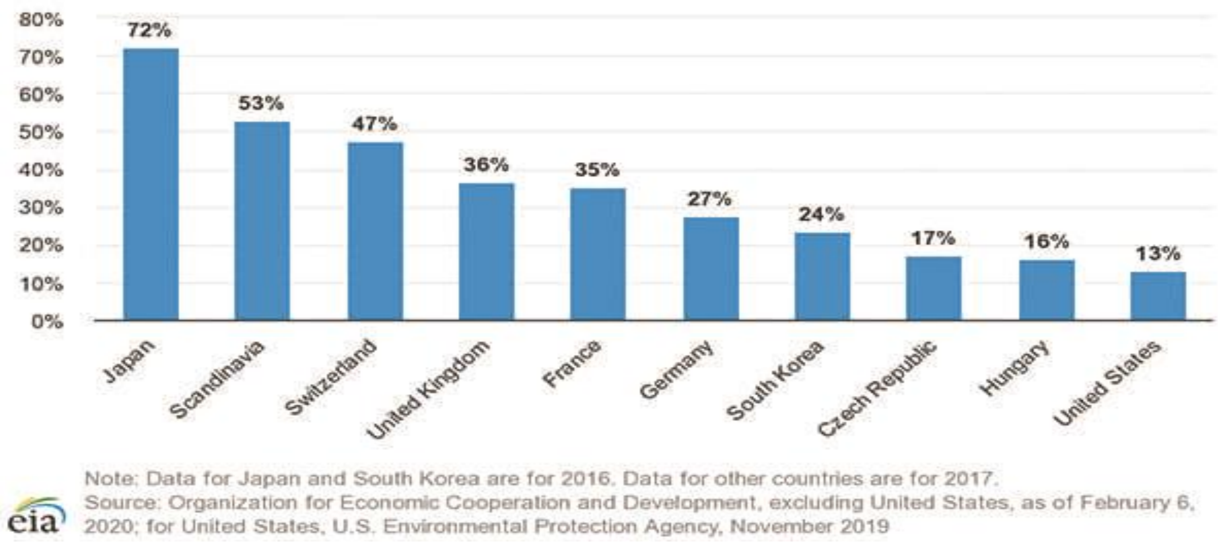
1.5. Waste to energy policy

Addressing global imperatives for enhanced waste management and sustainable energy, this examination meticulously explores how countries worldwide approach the conversion of waste into energy. The primary goal is to closely assess the effectiveness of these policies across diverse social, economic, and environmental contexts. With population growth and increased industrial activity worldwide, innovative approaches are essential to manage rising waste levels while meeting growing energy needs.

Commencing the analysis of waste-to-energy policies across diverse countries reveals a mosaic of methodologies and challenges. Our preliminary investigation involves an in-depth review of scholarly works, governmental reports, and expert perspectives. This foundational step provides a theoretical framework, elucidating historical contexts and nuanced trends that shape global waste-to-energy policies.

Supplementing this academic review is a quantitative analysis, wherein we scrutinize data concerning energy output, waste diversion rates, and other pertinent metrics. Early observations underscore variations in energy generation and disposal methods, contributing to initial comparative insights.

Concurrently, qualitative dimensions emerge from our comparative case studies, involving interviews with policymakers, industry experts, and stakeholders. In the picture 1.4. countries with the most energy production is shown. Early findings suggest that the success or challenges faced by each country extend beyond technological choices, encompassing socio-economic factors, political will, and community engagement (Blanco, M. I. (2009)).



Picture 1.4. Most energy producing countries in 2016-2020

Source: https://frankdiana.net/2019/10/23/which-u-s-state-generates-the-most-wind-energy/

The daily per capita waste production is projected to rise by 40% in developing countries and 19% in developed countries by 2050. According to the World Bank, total waste generation is expected to triple in Sub-Saharan Africa and double in South Asia by 2050. These statistics underscore the growing challenges and opportunities for waste-to-energy production in developing regions.Sub-Saharan Africa is the one of the promising land that locates in Africa Region.

Greenhouse gas emissions from various sectors, including electricity generation, are one of the vital barriers to sustainable development.

Average waste generation for some small is about 1.35 kg per day, compared to 1.45 for OECD countries. In the table 1.1. average waste generation for small island countries is shown. In developing countries, organic materials (45%) and recyclables (42%) predominated in the waste composition, respectively. A recent study found mass incineration to be the best option in Pacific Island Developing States (PSIDS), followed by "hybrid mechano-biologically treated anaerobic digestion and combustion of waste-derived fuels." Although their findings indicated that incineration was suitable option in these countries about 51% of other total waste and to be most suitable with incineration, gasification compared to landfill (Guerrero, L. A., Maas, G., & Hogland, W. (2013)).

Table 1.1. Waste to energy statistics for small island countries.

	Redang	Tioman	Pangkor	Langkawi
Size (km^2)	10.7	131	8	478.5
Population	1,400	3,400	26,000	79,000
Waste generated	2.7	6.95	13	85
Waste generation rate	0.86	0.87	0.48	1.08

Source:https://www.researchgate.net/publication/341089372_The_Sustainability_of_Solid_Waste_Management_on_Kapas_Island_Terengganu_Malaysia

1.6. Discussion and Policy Implications

In most developing countries, food and green waste ranges between 51% and 61%. The increase in organic waste is inversely related to the country's economic development. Only 21% of the waste generated in the developing world can be recycled. In contrast, around 55% of waste in the developed world can be recycled. Collection of waste for production and processing opens the way for developed and developing countries to differ from each other. Waste collection rates for upper-middle-income countries in high-income countries range from 82% to 96%.

In developing countries, it ranges from 39% to 51%. The process of waste collection and disposal or recycling also depends on the country's GDP per capita. That is, there is a general relationship between GDP waste collection and disposal of waste. The Maldives alone has 26% organic waste.

In many countries, waste-to-energy recovery is an important element of the waste management system. Thus, according to the Confederation of European Waste-to-Energy Plants, the share of waste incinerated for energy production in 2018 was 28% on average in European countries. Among the leaders in the field of energy from waste, countries known for their high environmental responsibility are Finland (57%), Sweden (53%), Denmark (51%).

Landfilling is one of the main methods of waste management in Russia: 94% of solid household waste is landfilled today. However, in the coming years, serious reforms will be carried out in the waste management system.

Currently, wood processing and pulp-paper agro-industrial enterprises operate their own waste-based energy sources, producing electricity, steam and hot water from wood waste: plywood, wood chips, bark, sawdust, etc. Another area with important prospects in the field of energy recycling of industrial waste is agro-industrial production. Sunflower husks, rice husks, corn husks, straw - all these wastes generated during the collection and processing of agricultural products can be fuel for your own thermal power plant or waste boiler, providing up to 98.5% of the energy demand.

It has been observed in the public consciousness that the burning of waste releases toxic substances into the atmosphere, their accumulation and creates a danger to human health.

In fact, thermal power plants using RDF fuel do not burn landfill waste, but are part of the entire waste management system, whose first and foremost link is waste sorting. At this stage, all waste that can release toxic substances during combustion is separated.

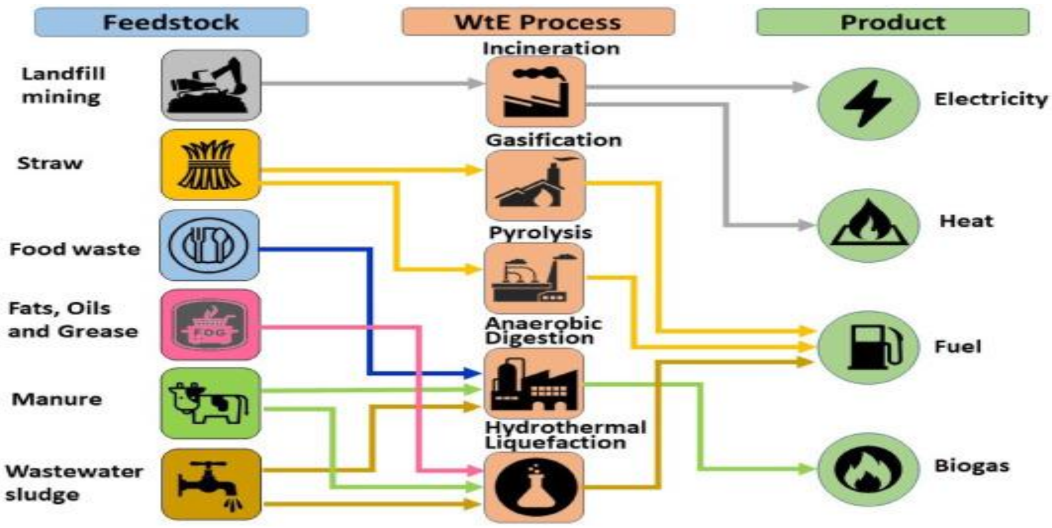
Ideally, RDF fuel contains metals, glass, and modern automation and control systems that ensure equipment operation and constant monitoring of the composition of combustion products.

According to CEWEP, between 1990 and 2000, dioxin emissions from waste treatment plants in Germany fell from 500 g to less than 0.5 g per year, while the amount of thermally treated waste more than doubled over the same period.

1.7. Waste-energy technologies

Waste-to-Energy Technologies provides a brief overview of available technologies. Each mentioned technology has its own advantages, disadvantages and areas of application. These technologies are used to significantly reduce the discharge of waste to open areas, such as thermal treatment of domestic or industrial waste and sludge, medical or industrial hazardous waste. This generated energy output is seen as a new source of income with economic benefits for the local community and environmental benefits in cleaner air, water and soil.

Waste-to-energy projects are extremely complex and expensive to build. Most investors are driven by economic interestsfinancial incentives, renewable identification numbers, tax credits, etc. with. In addition to other economic streams, waste-to-energy projects typically require high fees. In the picture 1.5. waste types, process and products are shown. It is the money that the garbage hauler has to pay to dispose of the garbagein the facility (Dinis-Carvalho, J., Moreira, F., Bragança, S., Costa, E., Alves, A., & Sousa, R. (2015)).



Picture 1.5. Types and sources of waste

Source: https://stock.adobe.com/search/images?k=%22waste%20types%22

- **Liquefied Bed Technology.**

Liquefied bed is one of the main technologies for converting waste to energy. There arestatic or circulating types of bed. The technology is mainly used for sludge or solid waste treatment. It has high processing efficiency and low residual values. Fluidized bed technology always involves energy recovery and flue gas cleaning. The pollution level of flue gases is much lower than the legal requirements.

- **RotaryKiln.**

It is used in the processing of hazardous, medical, biological and industrial waste. Higher temperatures allow the complete destruction of viruses and microbes to be controlled, while low oxygen uptake ensures low emission values.

Rotary kilns are also used in the cement industry. The scarcity and depletion of fossil fuels as well as the management of gaseous emissions and fine particles in the atmosphere is one of the main real problems facing rotary kilns, especially those involved in cement production.

- **Gasification.**

It is also a popular technology with a long history in the market. However, it is not as widely used as the grilling process due to various problems such as oxidation of hydrocarbons, high CO2 production, formation of pollutants during gasification, and low calorific value of the produced synthesis gas.

The advantage of this process is that it doesn’t release harmful gases.

- **Plasma Arc Gasification**

Technologists use plasma arc gasification to process and dispose of a special group of waste: a very dangerous and radioactive process. It is very expensive, consumes a lot of energy for the process and presents several problems. The low level of net energy is much higher than energy efficiency. A high temperature of 9600°C is good for hazardous waste processing, but poses management problems.

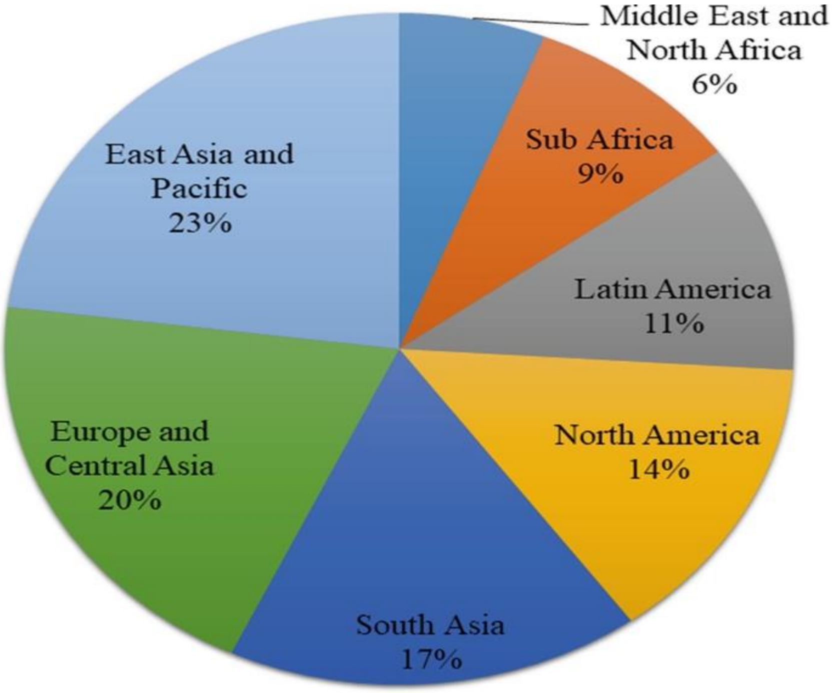
Plasma gasification uses a plasma torch at an extremely high temperature of approximately 5000°C to 7000°C in a reactor to transform the feedstock into a reactor. As a result of the plasma burning of syngas, the breakdown of molecules and the change in chemical composition is also called plasma pyrolysis.

. However, compared to dioxins produced in traditional incineration plants, they are much less. Needless to say, future sustainable waste management technologies are headed in this direction because it is both efficient and less polluting.

- **Pyrolysis**

The application of the pyrolysis process to waste has started relatively recently. The technology has many advantages, such as minimal oxidation of waste, no production of pollutants, high level of synthetic gas production, and clean gas production. It seems to be the most ecologically clean, simple and modular modern technology of waste disposal. The only problem is that since it is a new technology, it is not well known in the market.

WTEI pays special attention to this technology and tries to apply it in every new project. In the picture 1.6. regions with the most WtE technologies are shown. WTEI has an agreement with the owner to market and sell this patented pyrolysis technology in various regions of the world, including Europe.



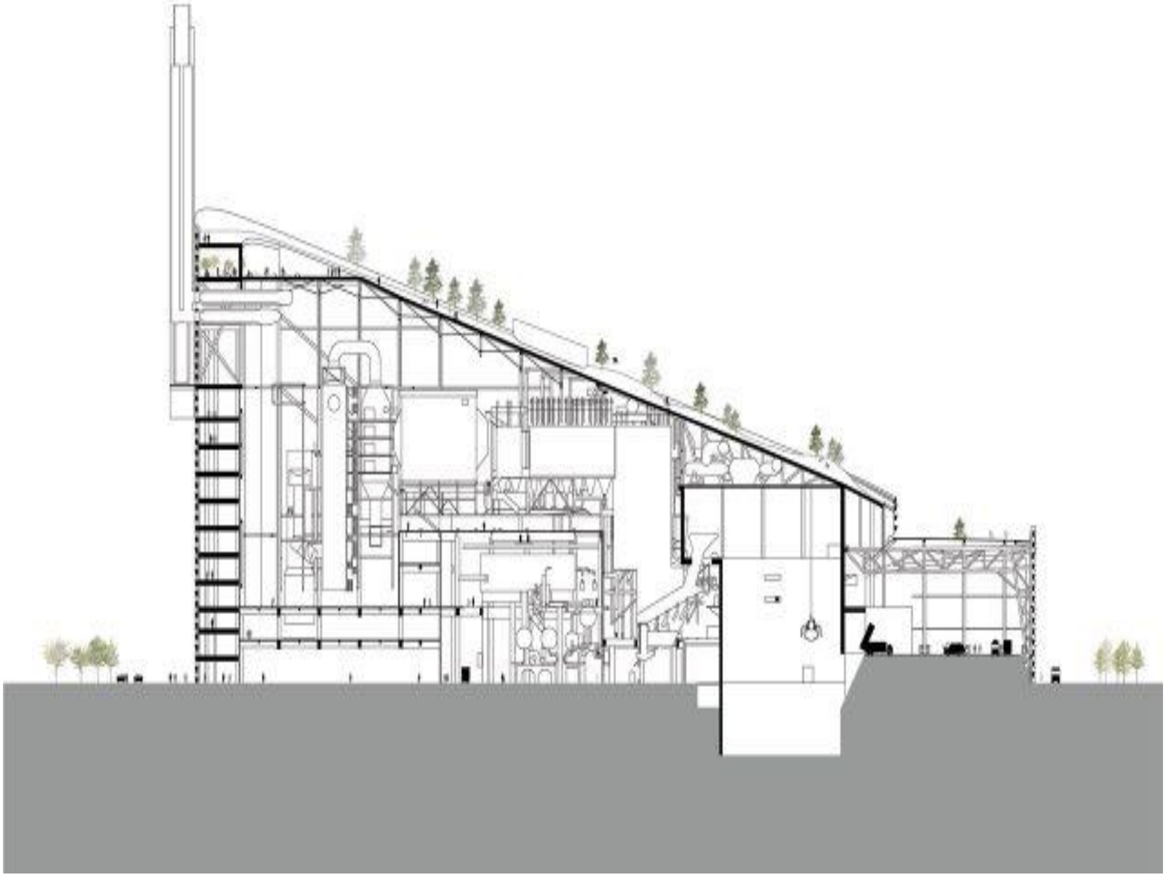
Picture 1.6. Most WtE technology using regions

Source: https://link.springer.com/chapter/10.1007/698_2020_611

Currently, 1.3 billion tons of Solid Household Waste are generated in the world every year. By 2025, the world may produce 2.2 billion tons of Solid Household Waste per year. Such a prediction forces us to consider and develop alternatives to solve future waste management problems.

The solution to this problem is to divert waste from landfills to energy production, improving waste-to-energy technologies that will help facilitate waste management programs. Unfortunately, waste-to-energy practices are underutilized and therefore most of the world still uses landfills as the primary disposal method.

Perhaps the two most prominent countries that have played a major role in sustainable waste management infrastructure by incorporating waste-to-energy technologies are Sweden and Denmark. Sweden recycles more than 99% of MSW, 50.3% of all household waste is incinerated for energy recovery and 16% is used in. Similarly, Denmark has adopted the idea of "hedonistic sustainability. In the picture 1.7. Denmark’s WtE plant is shown. Here, infrastructure that contributes to building an ecologically and socially responsible society becomes a dynamic and usable public space. As an example, Copenhagen's recent projects include a ski slope and an incinerator that functions as a WTE education center for citizens. Only 3% of Copenhagen's garbage is thrown away. 54% is sent to incineration plants and used there to generate heat and electricity.97% of all urban residents receive their energy as excess heat produced by waste incineration plants(Casti, T. (2020)).



Picture 1.7. WtE plant in Denmark.

Source: https://www.architectural-review.com/buildings/amager-bakke-waste-to-energy-plant-in-copenhagen-denmark-by-big-and-sla

Supplementing this academic review is a quantitative analysis, wherein we scrutinize data concerning energy output, waste diversion rates, and other pertinent metrics. Early observations underscore variations in energy generation and disposal methods, contributing to initial comparative insights.

Concurrently, qualitative dimensions emerge from our comparative case studies, involving interviews with policymakers, industry experts, and stakeholders. Early findings suggest that the success or challenges faced by each country extend beyond technological choices, encompassing socio-economic factors, political will, and community engagement.

II CHAPTER. WASTE TO ENERGY POLICY IN AZERBAIJAN

2.1. Renewable energy policy in Azerbaijan

Azerbaijan is also going to be among the leading countries in terms of renewable energy sources. That’s because its land energy generation is 135 GW, and sea is 155 GW, About 3000 MW of wind energy, 23000 MW of solar energy, 380 MW of bioenergy potential.

Appropriate a lot of laws and invests accepted in our country for the developing the renewable energy, legislation in this area, as well as improvement of the environment.The total electricity production capacity of Azerbaijan is estimated as 8320.8 MW. The capacity of renewable energy power plants, including large HPPs, is 1687.8 MW, which is 20.3% of the total capacity.

Water power 1301.8 MW (35 stations, 24 of which are HEPS), wind power 66.4 MW (8 stations, 3 hybrid), bioenergy power 37.7 MW (2 stations, 1 hybrid), solar power capacity 281.9 MW (13 stations, 3 of them hybrid).Two hybrid power plants (Gobustan) operate on the basis of 2.85 MW wind, 3.8 MW solar and 0.7 MW bioenergy. TPPs with a total capacity of 39 MW have been put into operation in Nakhchivan MR. Excluding large hydropower plants, the installed capacity of renewable energy sources was 529.3 MW in 2023, accounting for 6.4% of the total electricity generation capacity.

Bioenergy in Azerbaijan involves utilizing organic materials like biomass, biogas, and biofuels for renewable energy production. The country's abundant biomass resources, including agricultural and forestry residues, along with organic waste from various sectors, present ample opportunities for bioenergy generation. Processes such as combustion, gasification, and anaerobic digestion can convert these biomass feedstocks into usable energy forms.

Biogas production through anaerobic digestion offers a sustainable energy source primarily composed of methane and carbon dioxide. This biogas can be used for electricity generation, heating, and cooking, providing an environmentally friendly alternative to traditional fossil fuels.

Waste-to-energy technologies enable the conversion of organic waste into heat, electricity, or biogas, thereby managing waste while simultaneously generating renewable energy. This approach contributes to environmental protection and enhances energy security by reducing reliance on non-renewable energy sources.

Azerbaijan also has potential for biofuel production, including biodiesel and bioethanol, derived from agricultural crops, algae, and waste oils. These biofuels can be blended with conventional fuels or used independently, reducing greenhouse gas emissions and promoting energy independence.

Supportive policies, such as feed-in tariffs and tax incentives, can encourage investment in bioenergy projects and infrastructure. Research institutions and universities play a vital role in advancing bioenergy technologies, improving efficiency, and exploring new feedstock sources through collaborative efforts with international partners.

Environmental benefits of bioenergy include reducing greenhouse gas emissions, mitigating air pollution, and promoting sustainable land use practices. By harnessing renewable organic resources, Azerbaijan can contribute to climate change mitigation and environmental sustainability goals.

In 2023, the production of electric power in SPPs was 1757.2 million kilowatt hours, compared to other sources, it was close to 359 million kilowatt hours. 56.6 million kilowatt-hours of electricity were produced in CHPs, 79.4 million kilowatt-hours in thermal power plants, and 220 million kilowatt-hours in the waste incineration plant. Electricity produced from renewable energy sources was 7% of the total production. Since 2020, cooperation on renewable energy projects has started with Masdar, BP, Fortescue Future Industries, China Gezhouba Group Overseas Investment and other companies.

On October 26, 2023, the foundation of the 230 MW Garadagh Solar Power Plant was established in cooperation with Masdar, the largest solar power plant in the

Caspian. The station is expected to save 110 million cubic meters of natural gas by producing 500 million kilowatt-hours of electricity per year. In the picture 2.1. “Inciner8” is shown. About 570,000 solar panels have been installed in the power plant covering an area of 550 hectares. In order to connect this station to the grid, a 330-kilovolt substation has also started operating.

Picture 2.1.Inciner8

Source: https://www.inciner8.com/general-waste/waste-to-energy?utm_source=googleads&utm_content=cid|20954368526|gid|154719397901|kwid|dsa-19959388920&utm_source=goog

Within the framework of the opening of the Garadagh Solar Power Station, three investment agreements on green energy projects with a total capacity of 1000 MW were signed between the government of Azerbaijan and the UAE company "Masdar". It is planned to implement YES and 240 MW HPP in Absheron-Garadagh region.

Construction of the 240 MW Khizi-Absheron Wind Power Plant is also planned in cooperation with ACWA Power of Saudi Arabia. Within 2 years from March 2020, 7 measurement-observation stations were built at an altitude of 100 m, and topographic and preliminary geodetic works were carried out.

Waste-to-energy initiatives in Azerbaijan encompass various strategies aimed at extracting energy from waste materials while simultaneously addressing waste management challenges. These methods primarily include landfill gas capture, biogas production through anaerobic digestion, and potentially waste incineration for energy generation.

Landfill gas capture involves the collection and utilization of methane gas emitted during the decomposition of organic waste in landfills. This methane, a potent greenhouse gas, can be harnessed as a renewable energy source for electricity generation or heat production. By capturing methane, not only is a significant greenhouse gas mitigated, but valuable energy is also recovered from what would otherwise be a waste byproduct.

Biogas production via anaerobic digestion is another prominent approach. This process involves the breakdown of organic waste in the reduce of oxygen, resulting in the release of biogas composed primarily of methane and carbon dioxide. Biogas can be utilized in various applications, including electricity and heat generation, as well as fuel for transportation. Anaerobic digestion not only provides an energy source but also contributes to waste reduction and odor control in waste management facilities(Abbasov, E. 2015).

Waste incineration, while less common and often contentious due to environmental concerns, remains a potential method for energy recovery from waste in Azerbaijan. The heat generated can be used to produce steam. However, this method requires stringent pollution control measures to minimize air emissions and ensure environmental safety.

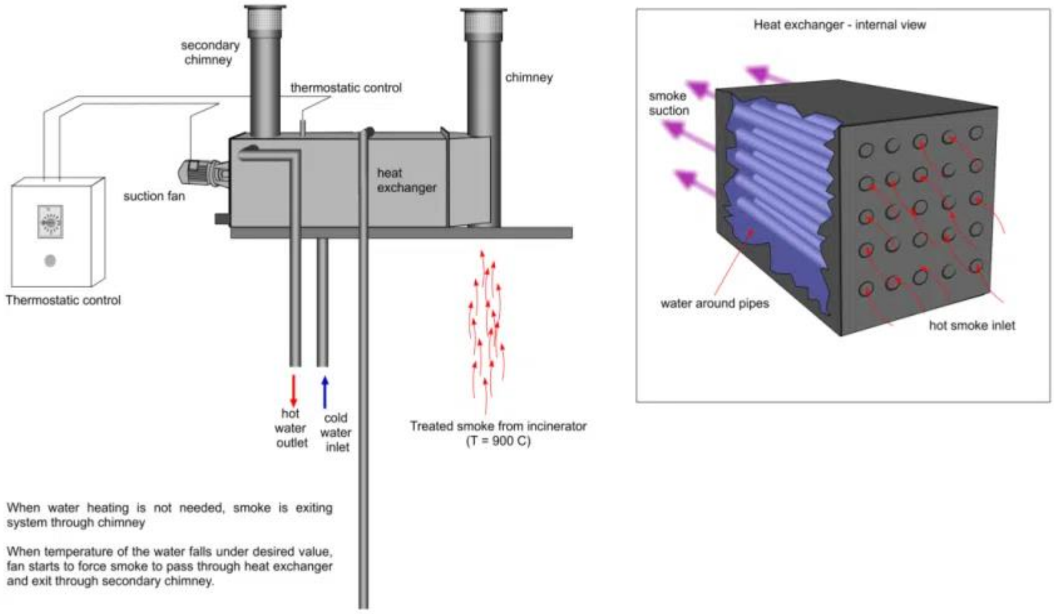
The successful implementation of waste-to-energy projects in Azerbaijan hinges on several factors, including supportive government policies, regulatory frameworks, and investment in infrastructure. It is crucial to develop comprehensive waste management strategies that prioritize sustainability and environmental stewardship. This involves minimizing the environmental footprint of waste-to-energy processes, including controlling air and water pollution, managing ash disposal, and mitigating greenhouse gas emissions.

In conclusion, waste-to-energy initiatives in Azerbaijan present opportunities to address both waste management and energy needs. By employing a combination of landfill gas capture, biogas production, and potentially waste incineration, Azerbaijan can harness the energy potential of waste while promoting environmental sustainability and resource efficiency.

At the same time, the project supports attracting investors to relevant marine projects, establishing partnerships with the private sector, and making necessary investments. Effective use of this phased potential is expected to create opportunities that add value to the country's economy, along with new jobs.

Within the Baku Energy Week held in Shusha on June 4, 2022, between the Ministry of Energy and the UAE company Masdar regarding the assessment, development and implementation of 1 GW utility-scale projects for onshore solar and wind energy in the Republic of Azerbaijan.

In summary, Azerbaijan's bioenergy sector holds significant potential for sustainable energy production, waste management, and economic development. Strategic policy measures, investments in research and infrastructure, and collaborative partnerships will be crucial in unlocking the full potential of bioenergy to meet the country's energy needs while advancing environmental and socioeconomic objectives.



Picture

2.2.Waste-to-Energy Incinerator Work

Source:https://www.inciner8.com/general-waste/waste-to-energy?utm_source=googleads&utm_content=cid|20954368526|gid|154719397901|kwid|dsa-19959388920&utm_source=goog

Let's present the basic scheme of operation of a waste incineration plant for processing waste into energy (picture 2.2). A new technology incinerator is a plant that burns waste to generate electricity and heat. The key component of this system is alarge heat exchanger. The heat exchanger is located on the smokestack. Here, hot gases pass through tubes, capturing energy from the waste. Water surrounds these tubes and absorbs heat from the hot gases.

The amount of heat exchange depends on several factors:

1. the type of material being burned
2. the temperature of the gases
3. the volume of smoke emitted.

On average, an incinerator such as an I8-250 or I8-500 can generate about 200 kWh of energy. If you increase the water flow, the outlet temperature will be lower, and if you decrease the water flow in the system, the outlet temperature will be higher.

When heating water from 16 to 60 degrees Celsius, for example, we need (60 - 16) x 0.00116 = 0.05104 kWh for each liter of water. This demonstrates the potential of such a waste-to-energy system.However, the actual performance will be about 60-70% of the theoretical maximum due to heat losses.A special pump determines the water flow in the heat exchanger.

2.2. WtE plants in Azerbaijan

Many measures have been implemented based on the design, construction and repair of Azerbaijani power plants. As a result of these measures, effective and reliable power plants have been put into operation in order to protect the environment and ensure energy transportation to registered areas.Examples of these energy plants are wind, solar, bioenergy and waste energy plants. Waste energy plants are among the most promising and desirable projects for Azerbaijan. Such stations include Balakhani Waste Treatment Plant. This waste energy plant was built according to the order of the President of the Republic of Azerbaijan IlhamAliyev and has the capacity to process about 100 tons of waste every year.However, given the growing population, the need for larger and more waste-to-energy plants in the next 5-10 years is inevitable.Basically, it is necessary to closely study the importance of the power plants planned to be built in our territories freed from occupation and their working principles, and to learn specific details from the countries that are leaders in this field.

2.3.The solid waste management project

The ongoing initiative known as the "Integrated Solid Waste Management" Project is a significant collaborative effort between the World Bank and the Republic of Azerbaijan under the broader umbrella of the "Absheron Ecological Rehabilitation Program.

The genesis of this project traces back to May 20, 2009, marked by the signing of a pivotal loan agreement between Azerbaijan's Minister of Economic Development and the World Bank's representative in Azerbaijan. Since then, concerted efforts have been channeled into five distinct components, each strategically tailored to tackle various facets of the solid waste management landscape.

Beginning with institutional reform and project management, the project endeavors to bolster administrative capacities, foster strategic planning initiatives, and establish and bolster the operational efficiency of "TamizShahar" JSC, the designated waste management entity (Delucchi, M., and Jacobson, M, 2013).

The rehabilitation and management of the Balakhany landfill constitute another crucial facet of this endeavor. Here, a multifaceted approach is adopted, encompassing environmental impact control, landfill efficiency enhancement, and the infusion of state-of-the-art equipment and technologies such as weigh bridges and bulldozers. Furthermore, preparatory groundwork is underway for the eventual cessation of Balakhany landfill operations, with simultaneous preparations for the establishment of modern, environmentally sustainable alternatives.

Beyond Balakhany, efforts extend to the closure and effective management of other landfills scattered across Baku. This necessitates the meticulous closure and decontamination of unofficial landfills, coupled with upgrades to existing landfill management practices to align with modern standards of environmental stewardship.

A cornerstone of this initiative lies in the provision of cutting-edge equipment for waste collection, with a particular focus on expanding service coverage and enhancing operational efficiency in underserved areas. This entails the procurement of a fleet of lorries and waste trucks to bolster service quality and extend the reach of waste collection services.

Lastly, a critical aspect of the project entails technical groundwork for future investments. This encompasses the execution of comprehensive feasibility studies and rigorous environmental impact assessments, laying the groundwork for the design and establishment of novel landfill facilities and transfer stations. Such preparatory measures are envisioned to optimize waste collection systems and ensure the long-term sustainability and efficacy of waste management endeavors.

In aggregate, these concerted measures are poised to herald a transformative paradigm shift in Azerbaijan's solid waste management landscape, heralding a future marked by enhanced environmental sustainability, improved public health outcomes, and heightened resilience against the perils of indiscriminate waste disposal. With a projected budget totaling $41.5 million over a span of five years, this ambitious undertaking stands as a testament to the unwavering commitment of both the World Bank and the Azerbaijan Government towards fostering a greener, more sustainable future for generations to come.

2.4. The Balakhani project

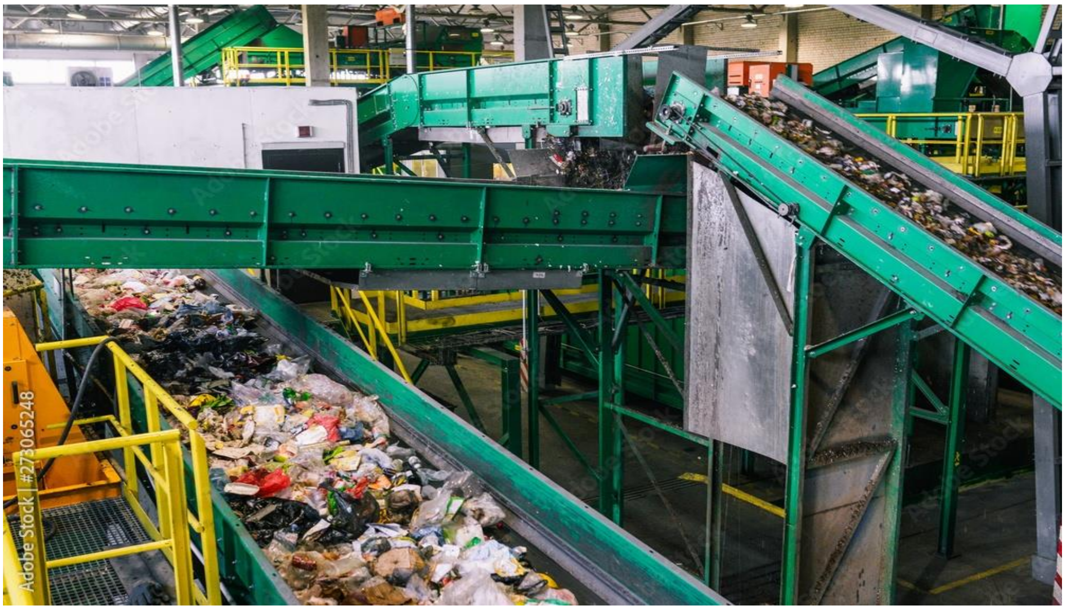
The Balakhani landfill, founded in 1963, has created a threat to human health and the environment.Waste was simply thrown away a landfill that causes methane emissions from anaerobic waste processing. One of the first work of the Clean City.

Since October 2009, it has been done to improve the management of the site, which has approximately 3 million m³ solid household waste is collected every year. This includes waste covering and leveling works as well as defining operational zones. The current tailings depth of the waste disposal site is approximately 20 m. It could beif necessary, it is increased to 40 m. Energy is mainly produced by fossil fuel power station. It produces CO2emissions from burning fossil fuels. This is expected to continue in the absence of project activitythus, the initial scenario is the same as the scenario before the implementation of the project.

The project involves the incineration of waste that would otherwise be collected. Production of electricity from waste heat is in Balakhani waste area.As an additional service, electricity will be exported to the national grid.

An alternative solution to waste reduction was requested by the Cabinet of Ministers dependence on the Balakhani landfill health and environmental hazard risks that the incineration plant will produce approximately 500,000 tons of waste

it makes up more than half of the expected waste in the Baku region every year. It is an incineration plant highly efficient. The plant strictly adheres to environmental protection and safety standards. In the picture 2.3. Balakhani Waste Management Project is shown. Factory key the equipment includes grid-type combustors, each with heat recovery boilers, and a 39.5 MW condenser turbogenerator to be driven by steam from all boilers. More equipment includes feeders, flue gas filtration and treatment, electrical substation and control equipment. The plant is conceptualized as two separate waste lines with the addition of a third consisting of a furnace, a boiler and a suitable turbogenerator are required. Each waste line is capable burns about 250,000 tons of waste per year (Hulgaard T. &Vehlow J. 2011).



Picture 2.3. The Balakhani project

Source: https://tamizshahar.az/en/projects/1

This enterprise with an annual production capacity of 200,000 tons, built for the purpose of developing the domestic waste separation and recycling business in the country, has been operating in trial mode since August. It became fully operational on December 19, 2012.

The material recovery facility was designed by "Aztech Project Construction" LLC. The contractor is "M-Naf" company, and the supplier is "Adelmann" company.

As a result of sorting, paper, glass, plastic, non-ferrous metal, iron and other recyclable materials are separated, and as a result, the total volume of waste is reduced, a cheap raw material market is formed, and the basis for the creation of a recycling industry is created. is created in the country, energy is saved, the negative impact on the environment is reduced. In addition, hazardous waste such as batteries, accumulators and e-waste are separated from general waste and sent to appropriate locations.

2.5. The sustainable development of waste energy in Azerbaijan

The Presidential Decree of Azerbaijan dated November 29 regarding the formulation of the Concept "Azerbaijan 2020: a vision of the future" by 2020 plays a major role in adoption of sustainable development principles. Currently, more than 60 state programs pertaining to social and environmental concerns are implemented in the country, where Azerbaijan formulates comprehensive strategies for development, sustainability, and environmental protection across the entire economy as well as within specific sectors.

The primary links between the green economy and the implementation of sustainable consumption and production policy are confirmed in the "Azerbaijan-2020: vision of the future" Development Plan. The concept's long-term objectives encompass creating an economic model founded on efficient state regulation and market dynamics, ensuring sustainable socio-economic growth, enhancing the economic structure—particularly in transit and logistics—achieving balanced regional development, and safeguarding the environment. (Safaroff Agency, 2024)).

Management of natural resources in Azerbaijan is conducted based on basis of permits, including permits for the specialized use of water resources. Diligent efforts aligned with the timely adoption of international standards encourages the country's participation in the international market, as well as reducing heavier load on the environment and more efficient use of natural resources. Azerbaijan utilizes an operational permit system sanctioned by the State Ecological Expertise Department of the Ministry of Ecology and Natural Resources. Permits for significant projects adhere to internationally recognized methodologies and procedures for environmental impact assessment. Presently, environmental standards are under development for products and services manufactured and traded in the Azerbaijani market. The foundation for creating these standards is to bolster the establishment of environmental criteria for goods and services within the framework of the European Union directives, as well as the United Nations Development Program.

Picture 2.4. Future goals in Azerbaijan for WtE

Source: https://www.undp.org/azerbaijan/press-releases/undp-government-hold-first-public-private-sector-dialogue-sustainable-development-goals

It is being considered whether to implement incentives to encourage the introduction of new technologies with the goal of enhancing and bolstering Azerbaijan's environmental quality and drawing in both domestic and foreign investment (picture 2.4). The state tries to attract attention for international technical assistance to increase the technological capabilities of the national economy and ecological principles. Based on sustainable regional development for 2014-2018, technical maintenance has been prepared taking into account the requirements related to the production and operation of environmentally friendly products in Azerbaijan. At the same time, financial support mechanisms are being developed for organizations producing organic products.

Azerbaijan established an industrial base to refine Caspian oil for Soviet consumption. During the Soviet era, the union completely lost compatibility with industrial supply, and the agreements fell apart. (Robbani, A. ,2024)). As a result, the reduction of industrial waste. The improvement of atmospheric air quality in the Baku-Sumgait area, however, left the massive old pollution problem unresolved. While not on the same scale, the issue of closed industrial facilities and their waste can be found throughout much of Azerbaijan. Pilot-scale repairs have been made thus far, but nothing has changed significantly. Rather, the environment the indicators of the oil production sector have improveddirect investments from the Economic Cooperation Organization and developing countries.

Like other energy sources Azerbaijan, which exports to countries of the former Soviet Union, uses its own energy and is relatively inefficient. generating electricity with heavy oil by burning gases between generation and general energy-using equipment inefficiencies are the main factors. Air pollution in Azerbaijan has decreased significantly Industrial contraction since 1991 is largely responsible.

What is needed is the promotion of clean manufacturing practices and new regulations is approaching.

In 2022, Azerbaijan experienced a notable increase in waste generation, with 3,984.1 thousand tons produced, marking a 5.4% rise compared to the previous year. A significant portion of this waste, accounting for 66.7%, stemmed from solid domestic sources, while 33.3% originated from the production activities of various enterprises across the country.

Of the 2,658.3 thousand tons of solid domestic waste generated, a substantial 78.3% was transported to landfills for disposal, reflecting the prevailing waste management practices. However, a commendable 21.2% of this waste was utilized for energy production, indicating a growing inclination towards sustainable waste management approaches. Additionally, a marginal 0.5% of the domestic waste was sold within the country, possibly for recycling or other purposes, demonstrating efforts towards resource recovery and circular economy principles (Burns, T. R. (2016)).

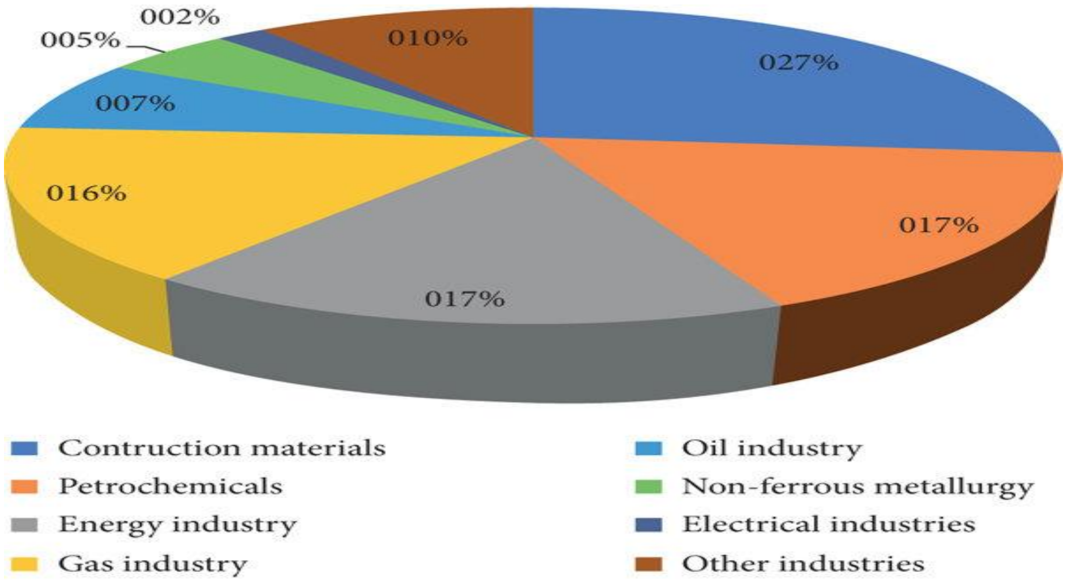
The utilization of solid domestic waste for energy production yielded positive outcomes, contributing to the generation of 205.3 million kWh of electricity, representing a 6.3% increase compared to 2021. This uptick underscores the potential of waste-to-energy technologies in meeting energy demands while concurrently addressing waste management challenges.

Moreover, in industries and other sectors, 28.5% of waste resources were repurposed as raw materials within enterprises, fostering a closed-loop approach to resource utilization. Additionally, 42.7% of waste resources were sold domestically, underscoring the economic value associated with waste materials and the potential for fostering a vibrant secondary materials market. A further 3.8% of waste resources were exported, showcasing Azerbaijan's engagement in international waste trade. However, 13.8% of waste was still directed to landfills for disposal, highlighting the need for continued efforts to optimize waste management practices and minimize landfill reliance.

The production activities of enterprises also generated hazardous waste, amounting to 337.1 thousand tons, constituting 8.5% of the total waste generated. Notably, a substantial portion of this hazardous waste, around 63.1%, originated from mining enterprises, with significant contributions from entities located in the capital city, Baku. Efforts to manage hazardous waste were evident, with 55.0 thousand tons being completely neutralized, including remnants from previous years, emphasizing the importance of effective hazardous waste management measures to mitigate environmental and public health risks.

In summary, the waste landscape in Azerbaijan in 2022 reflects a mix of challenges and opportunities, with efforts underway to enhance waste management practices, promote resource recovery, and address environmental concerns associated with waste generation and disposal. Continued focus on sustainable waste management strategies, innovation in waste-to-energy technologies, and regulatory measures to minimize hazardous waste generation will be critical for advancing Azerbaijan's waste management agenda in the coming years.

Azerbaijan is disproportionately depending on polluted transboundary rivers for its domestic requirements. The eastern section of the Kura-Aras plain faces extensive water shortages despite irrigation efforts. Mismanagement of irrigation systems has exacerbated salinity accumulation, impacting over one-third of all irrigated lands. Efforts to decrease industrial wastewater discharges have been undertaken accompanied by a decrease in industrial output were compensated by reducing municipal waste. Only 16 at most Country Environmental Analysis-Azerbaijan an important 75 cities have sewage treatment plants and most of 16 work only partially. Between 50% and 95% of the urban population is provided with drinking water. Depending on city center. After considering water quality.The effective delivery of safe drinking water falls below 50%. There is an imbalance in water usage and wastewater discharge between the primary there are losses in cities (especially Baku) and the remainder of the country, with significant disparities in infrastructure. In the picture 2.5. percentage of air pollution by industries is shown. In weak form with surface waters, it is used more often the country's underground water resources are seen as a necessity (KonstadinosAbeliotis, 2011)).



Picture 2.5. Distribution of air pollution by industries

Source: https://www.researchgate.net/figure/Distribution-of-air-pollution-by-different-industries-in-Azerbaijan_fig1_346931784

Agricultural productivity in Azerbaijan is very low. The loss of Nagorno-Karabakh increases the feeling of land scarcity in Azerbaijan. The destruction of collective farms caused widespread repercussions for cropping patterns such as pasture use and patterning maintenance of previously common infrastructure.

Overall, these changes protected livelihoods deterioration of land use, in particular in mountainous areas where perennials are replaced by annuals. Meanwhile , land reform carried out in Azerbaijan more sophisticated than all others other SOVİET country. The areas that were once pasture and forest were unaffected..However, because of reform and certain environmental issues related to land use, adjustments to the method of managing them as assets are required under the new circumstances. Changes in the approach to managing them to assets are needed in new circumstances. He remained under the forests increased pressure due to power supply disruption, gas and coal to smaller towns and haphazardly maintained pastures

This comprehensive three-year program, collaboration between Government of Azerbaijan and the Islamic Development Bank (IDB), intended to transform the way waste is managed in Baku and usher in a fresh phase of environmental warinessimproved the public health With the construction of the initial waste to energy facility in the country, Azerbaijan has established a strong precedence by demonstrating its dedication to the principles of sustainable development.

The level and significance of the project was remarkable. As a result of more than 4.8 million man-hours of work modern facilities that are able to turning more than 500,000 tons of household waste into 230 GW/h of electricity per year has been created. It not only resolved a serious waste management problem, but also offered a sustainable source of energy that powered more than 50 000 households in Baku.

The project had a transformative impact that went beyond the numbers.From the time of its founding, Between 2012 and 2020, the plant processed over 3.2 million tons of household waste, greatly reducing the need for landfills.Processing and sorting 80% of Baku's household waste is an incredible accomplishment that surpasses initial targets and conforms with stringent EU environmental directives.

The achievement of the project was achieved through a strong project was successful because of a solid collaboration that brought together regional efforts and global knowledge.The cooperation between government of Azerbaijan and IDB is an example of the the cooperation needed to carry out such a revolutionary project.

IDB's participation provided Not just monetary assets,but also extensive expertise and experience in carrying out massively sustainable projects

This cooperation has played an important role in implementing advanced technology and solving problems that meet highest standards for health and the environment. The Waste to Energy Plant in Baku is proof of skills achieved through joint effort and visionary leadership. The facility, which has cutting edge emission control systems, is a global leader in waste-to-energy operations and marks a significant advancement in environmental control. These principles currently occupy a key place in Azerbaijan's development agenda.

The project has had a ripple effect, sparking a broader conversation about sustainability and waste management in Azerbaijan and beyond. The introduction of semi-automatic sorting facilities and the principle of future waste-to-energy production, the plans of these plants play a decisive role in increasing the efficiency and effectiveness of the plant. Additionally, interaction with global partners like the World Bank has created opportunities for expanded collaboration and innovation.

Baku's waste-to-energy policy is not just a project; this is one important step leading to a more sustainable and greener future(Mavropoulos, Alexandros, 2012). It serves as an example of how strategic alliances driven by a dedication to sustainability and the common good can transform obstacles into chances for social advancement and environmental revitalization. Baku's transformation from the "City of Smoke" to a shining example of green innovation offers encouragement and hope as cities all over the world struggle with related issues.

2.6. Renewable energy in Azerbaijan’s Liberated Zones

President IlhamAliyev of Azerbaijan has prioritized the economic development of newly liberated territories through the implementation of renewable energy projects.President IlhamAliyev of Azerbaijan has articulated a strategic vision for establishing a Green Energy Zone in the recently liberated territories, highlighting their ample potential for renewable energy resources.

Per the presidential decree of Azerbaijan datedMay 3, 2021 on the measures pertaining to the establishment ofrenewable energy zones in the liberated territories of the Republic of Azerbaijan, cooperation with an international consulting company has begun. A relevant concept document was prepared in cooperation with the Japanese company TEPSCO.

The concept document aims to supply the region with eco-friendly green energy by leveraging the abundant renewable energy potential in the liberated territories and devising proposals through an analysis of the feasibility of environmentally sustainable and energy-efficient green technologies.

For this purpose, energy demand models were developed using different scenarios in the liberated areas.

Production of electricity from renewable energy sources within the Green Energy Zone, energy efficiency measures, use of electric vehicles, installation of renewable energy objects (especially solar panels) on the roofs of buildings, use of solar energy-based LED lamps in lighting. measures such as the use of renewable energy technologies in the heating, cooling and hot water supply of streets and roads, the application of smart energy management, targeted management of waste energy are envisaged.

Simultaneously, during the UN Climate Change Conference in Glasgow on November 26, the Azerbaijani government announced its commitment to cutting greenhouse gas emissions by 40% from the base year by 2050 and establishing a "net zero emission" zone in the liberated areas. This, in turn, will contribute to the transformation of freed areas into renewable energy (Miliūtė J., &Staniškis, J. K., 2010). According to the preliminary observations, the favorable potential for solar energy projects in Gubadli, Zangilan, Jabrayil and Fuzuli regions is expected to be more than 7200 MW (picture 2.6). Additionally, initial assessments have identified a technical wind energy potential of 2150 MW in the mountainous regions of Lachin and Kalbajar.. In addition, the tributaries of Tartarchay, Hekari River and these rivers have great hydropower potential(Hajiyeva, N., & Karimli, A. (2021)).

Picture 2.6. Renewable energy project in Zangilan/Jabrayil zone

Source: https://area.gov.az/en/page/layiheler/yasil-enerji-zonasi/yasil

As an important component of the process of rehabilitation of the liberated territories, special importance is attached to the construction of energy infrastructure and ensuring energy security. In accordance with this goal, 4 restored hydropower plants in Lachin, Kalbajar and Sugovushanfour hydropower plants have been successfully commissioned, contributing to the restoration of 20.5 MW in power generation capacity. Concurrently, Azerbaijan is actively progressing with the construction of two additional hydroelectric power plants totaling 140 MW capacity (100 MW at Khudafarin and 40 MW at GizGalasi) along the Araz River in the Jabrayilregion.(Frost & Sullivan, 2011)).

Furthermore, on June 3, 2021, the Ministry of Energy of Azerbaijan entered into an agreement with bp to commence construction on a 240MW solar power plant in the Zangilan/Jabrayil region.

2.7. Combustion Processes and Environmental Protection

Incineration of waste is one of the many public applications of combustion.Combustion is known as an active, exothermic reaction between fuel and oxygen. Combustion applications use waste (although fossil fuels can be co-fired) and oxygen as fuel. Regardless of whether the substance being incinerated is gases, coals, woods, or gasoline, solid waste, or hazardous waste, combustion produces most of the same end products. In the combustor of a quality incinerator, temperatures are high enough to Incineration breaks down a wide range of organic and numerous inorganic molecules, facilitating interactions among the most volatile elements of the waste with oxygen atoms and nitrogen. The main reactions are those between carbon and oxygen. Moreover, hydrogen combines with chlorine found in organic compounds to generate hydrogen chloride. Additionally, various reactions generate sulfur compounds from sulfur-containing substances, nitrogen oxides from nitrogen compounds, metal oxides from certain metal compounds, and metals (National Library, Medicine, 2024).

The furnace is engineered to achieve thorough blending of combustion air with gases and vapors emitted from the burning waste. However, in the incomplete combustion parts of the furnace, the combustible components of During combustion, organic compounds are consumed, leaving behind non-combustible particles referred to as fly ash, which are carried into the flue gas.Non-burnable part of residue of the waste remains after combustion.

Achieving optimal furnace design and operation involves carefully managing combustion temperature, turbulence in the combustion gas mixture, and the residence time of gases at high temperatures. Effective combustion requires ensuring that every segment of the gas flow reaches the required temperature promptly and maintains a proper blend of fuel and oxygen

Numerous innovative design elements and operational strategies have been implemented to elevate temperatures, prolong gas residence times, and intensify turbulence within waste incinerators. These advancements aim to yield enhanced combustion efficiency and superior ash quality. They incorporate cutting-edge burner systems, preprocessing techniques like shredding and blending, and the introduction of oxygen enrichment. Additionally, meticulous monitoring and regulation of operational parameters are prioritized to ensure precise control over the entire combustion process.

Recently, spray dryers have been adopted for managing acid gases in municipal solid waste incinerators and larger facilities handling hazardous and medical waste. In this process, atomized slurry droplets evaporate water, cooling the gas and allowing alkaline particles to react with acid gases to form dry salts. These salts and any remaining unreacted alkali are subsequently captured downstream using fabric filters or electrostatic precipitators. Additionally, dry injection scrubbers employing an anhydrous alkaline reagent have seen some use, primarily in the United States, but are less prevalent in European facilities. They typically exhibit lower emission removal efficiency compared to spray dryer absorbers. Critical considerations for both spray desiccant absorbers and dry alkali scrubbers include optimizing gas temperature in the reagent contact zone, maintaining appropriate reagent-to-acid gas ratios, ensuring uniform reagent gas distribution, and selecting the appropriate reagent type.(National Library of Medicine, 2024)).

Heavy metals in waste cannot be destroyed by burning.Those compounds with high vapor pressures transition into the vapor phase within combustion chambers and subsequently condense as flue gas cools. These metals can adsorb onto fine particles. Depending on the temperature, mercury is likely to persist in the vapor phase throughout the air pollution control phase of the incineration process, a phenomenon that may also apply to other compounds.

The prospects for waste-to-energy (WtE) around the world are very promising, and the sector has attracted increasing attention and investment in recent years. Here are some key points:

Growing demand for renewable energy sources. With growing global energy demand and pressure to reduce the use of fossil fuels, energy production from waste is becoming increasingly attractive. WtE is a sustainable energy source that can mitigate negative environmental impacts.

Increased investment and technology development. Recent years have seen increased investment in the WtE sector, fueling the development of new technologies and innovations in waste management. Technologies such as gasification, pyrolysis and biogas plants are becoming increasingly efficient and economically competitive.

Strategic importance for sustainable development. Waste-to-energy plays an important role in achieving sustainability goals such as reducing greenhouse gas emissions, improving air quality and reducing waste going to landfills.

Expansion of markets. Increased interest in WtE opens up new markets and opportunities for the development of this industry. Many countries, especially in developing regions, are looking for alternative energy sources and solutions to manage growing volumes of waste.

Support from governments and regulators. Many governments around the world recognize the importance of waste-to-energy and are implementing appropriate policies and incentives to promote the industry. This includes financial support, tax incentives, legislative measures and other tools to stimulate investment and development of WtE technologies.

Overall, the outlook for waste-to-energy around the world looks bright, and the sector will continue to play an important role in combating waste-related challenges and achieving sustainable development in the future.

Here are some key figures on the world's waste-to-energy (WtE) outlook:

Market size. According to forecasts, the global WtE market will reach significant sizes in the coming years. It is estimated that it could reach 1-2 billion by 2026.

Growth Rate: The WtE sector is witnessing steady growth with an average annual growth rate of around Y%. This growth confirms the increased interest in waste-to-energy.

Investment: Investment in WtE projects around the world is also increasing. In 2020, investments in this sector amounted to several billion US dollars, which is a record figure.

Geographical distribution: Interest in WtE is observed in many countries around the world, both in developed and developing regions. In developing countries, especially in Asia and Africa, there is growing interest in waste-to-energy recycling due to increasing waste volumes and the need for alternative energy sources.

Environmental benefits: WtE is an effective way to reduce waste, prevent pollution and reduce greenhouse gas emissions. These environmental benefits make it an attractive solution for countries facing waste management and sustainability challenges.

These figures highlight the promise of the WtE sector worldwide and its importance in addressing environmental challenges and ensuring sustainable development in the future.

CONCLUSION

Based on an analysis of world experience, the practice of countries around the world, including Azerbaijan, and having statistical data, we can talk about the prospects for the development of this energy sector.Waste disposal is vital for humanity, primarily from an environmental point of view. There are various waste disposal methods depending on their type. The work describes in detail methods for processing waste and using it as energy and fertilizers. These methods are widely used in countries with developed economies, and in those countries that are not indifferent to the fate of the planet and humanity. In our work, we carefully analyzed global experience in the waste-to-energy sector and came to the following conclusions:

The term "Waste to Energy" is used to describe various technologies that convert non-recyclable waste (plastic film, tissues and kitchen paper, foil, and soiled food packaging) into usable forms of energy including heat, fuels and electricity.WTE technologies convert non-recyclable waste into usable forms of energy. The heat from the combustion of waste generates produce electricity.

The most significant challenge to WTE technology adoption is the clean technologies for sustainable waste management and awareness that waste can be used as a source of clean and reliable energy.

1. Using the method of energy analysis to determine the performance of the system.

2. Long-Term Planning: Contribute to formulating sustainable, long-term waste management plans globally, targeting a 20% improvement in overall waste management efficiency by 2035.

3. Policy Enhancement: Identify strengths and weaknesses to refine waste-to-energy strategies and improve policies, aiming for a 20% increase in waste diversion rates by 2030.

4.Environmental and Economic Insight: Provide a comprehensive understanding of environmental and economic implications for informed decision-making, with a focus on achieving a 15% improvement in cost-effectiveness of waste-to-energy projects over the next five years.

5. Ensuring the use of resources with high efficiency and in harmony with the environment.

Converting waste disposal into energy has both positive and negative consequences:

Positive consequences:

Waste Reduction: The waste-to-energy process helps reduce the amount of waste sent to landfills or incineration. This helps reduce environmental pollution and minimize the space occupied by landfills.

Energy Generation: The waste-to-energy process produces electrical or thermal energy from waste, helping to diversify energy supplies and reduce dependence on traditional sources such as coal, oil and natural gas.

Reducing Greenhouse Gas Emissions: By burning waste and using it as fuel to produce energy, greenhouse gas emissions such as methane, which is produced by the natural decomposition of waste in landfills, can be reduced.

Negative consequences:

Air Pollution: The process of burning waste can release harmful substances and toxic gases into the atmosphere, which can negatively impact air quality and the health of surrounding people.

Waste Treatment Challenges: Some waste-to-energy technologies can be expensive and require complex infrastructure and high technical expertise. This can create problems for countries or regions with limited resources and capabilities.

Health Risks: Toxic substances and smoke may be generated from burning waste, which may pose a health hazard to people living near waste disposal facilities.

Overall, waste-to-energy conversion is a complex process that requires careful consideration of potential pros and cons, as well as effective risk management to ensure sustainability and environmental safety.

Sustainable economic development and environmental concerns are at the forefront of waste-to-energy solutions. Society must ensure that waste-to-energy facilities have the lowest possible environmental impact. We must continue our efforts to eliminate landfills.

Some of the main advantages of DLE are that is has high energy conversation with efficiency about 80% and non – emissions. Low costs make it perfect for a variety of municipalities and efficient for Azerbaijan. Waste to energy engineering will enable increased access to DLE by 2030.

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