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Investigation into the Development of Waste to Energy as an Alternative Energy Source

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Abstract--**Pakistan, a developing nation, is facing a critical crisis regarding its fossil fuel resources and the production of electrical energy. The country's electricity demand has reached approximately 29,000 MW, while the generation capacity is only 22,000 MW. This significant gap between generation and demand has led to load-shedding. To address this issue, we are considering the development of waste-to-energy plants, which are waste management facilities that utilize combustion to generate electricity. Instead of relying on traditional fossil fuels like coal, oil, or natural gas, waste-to-energy plants use trash as a fuel source. By burning this fuel, heat is produced, which heats water to generate steam that drives a turbine, ultimately creating electricity. While waste-to-energy is often portrayed as a viable method for extracting energy from available resources, it does pose challenges to the circular economy. This approach generates toxic waste, contributes to air pollution, and exacerbates climate change. These plants emit chemicals such as mercury and dioxins, which pose risks to human and environmental health. To address these concerns, we aim to investigate the development of waste-to-energy as an alternative energy source while prioritizing creating a healthy environment. As part of this effort, we intend to implement a sensor network to detect the heat generated during incineration and monitor the emission of pollutants. Our overarching goal is to generate electricity while recycling waste materials as much as possible, thus promoting a sustainable and eco-friendly approach.**

Index Terms—Waste to energy, electricity, sensor network.

I.INTRODUCTION

Population growth and urbanization have led to a significant rise in waste production, posing substantial environmental and health hazards. Effective waste management has become a global challenge, impeding sustainable development, economic progress, and societal well-being. Developing countries, in particular, need more support in implementing engineered solutions for waste disposal due to negative economic regulations, lack of political commitment, and technical and operational constraints. 2 The primary approaches to addressing waste in developing countries include open dumping, incineration, and waste picking [1-5]. However, these methods have detrimental consequences. Open dumping contributes to the contamination of the surrounding environment with heavy metals, degrades the area's aesthetic appeal, leads to air pollution through the release of odors and greenhouse gases, spreads diseases, and pollutes surface and groundwater. Incineration through open burning emits harmful pollutants like carbon monoxide and nitrogen oxides. Waste picking poses significant health risks for the individuals involved. Overall, the issue of waste management in developing countries necessitates urgent attention and the exploration of alternative solutions to minimize environmental and health impacts while promoting sustainable development. Solid waste collection is a significant challenge in Pakistan, with only approximately 60% of waste being effectively gathered [6-10]. This leads to the accumulation of uncollected rubbish on the streets.

Karachi, the country's largest city, with a population exceeding 20 million, produces over 14,000 tons of solid waste daily. However, waste management practices in Pakistan suffer from various issues, including a need for a trained workforce, unreliable data, and inadequate administration. Municipalities primarily govern solid waste collection, and private waste pickers charge households a monthly fee ranging from $0.71 to USD 19 for door-to-door waste collection services [11-16]. Homeowners and waste pickers segregate recyclable materials such as metal and plastic, then sold for income generation. Non-recyclable waste is typically transported to the town municipal administration-assigned large containers and subsequently taken to landfills. Unfortunately, three unauthorized dumping in other locations throughout Karachi is also frequently reported. The prevailing situation underscores the urgent need for improved waste management practices in Pakistan, including enhancing collection systems, addressing the shortage of trained personnel, establishing reliable data management systems, and implementing better administrative measures [17-25].

II.MODERN DAY METHODS

Modern APC systems encompass both combustion control and post-combustion control techniques to minimize the formation of conventional and trace contaminants and enhance the quality of flue gas emitted from the stack. Combustion control methods 18 now incorporate heat release sensors within the furnace to precisely adjust the air supply and ensure optimal combustion, which is crucial for achieving nearly complete burnout of flue gases. Another approach involves the recirculation of flue gases, resulting in a thermal capacity increase of approximately 1-3%, a 20-40%

reduction in NOx emissions, and the suppression of dioxin generation, thereby facilitating the subsequent treatment of flue gases [26-29].

A. Integration of Environmental Sustainability

Environmental sustainability has gained increasing prominence in waste-to-energy incineration plants in recent years. Advanced emission control technologies have been adopted to minimize further air pollutants, including nitrogen oxides, sulphur dioxide, and heavy metals. Selective catalytic reduction (SCR) systems and activated carbon injection are employed to meet stringent emission standards. Furthermore, efforts are being made to integrate waste-to-energy facilities with other sustainable waste management practices, such as recycling and composting, to establish a more comprehensive and environmentally friendly waste management system [30,31].

B. Technological Advancements and Efficiency

Improvements Technological advancements have been pivotal in developing waste-to-energy (WTE) incineration plants, improving efficiency and performance. Modern designs utilize moving grates or fluidized bed incinerators, enabling better waste mixing and more thorough combustion. As a result, these advancements contribute to higher energy generation and reduced emissions. Additionally, integrating automation and control systems in plant operations optimizes performance, enhances overall reliability, and increases efficiency.

C. Waste Segregation and Pre-treatment

To align with evolving waste management practices and the growing emphasis on recycling, WTE incineration plants have embraced waste segregation and pre-treatment processes. These processes remove recyclable materials and hazardous substances from the waste stream before incineration. Various techniques, including manual sorting, mechanical sorting, and magnetic separation, are employed to segregate the waste effectively. These strategies can recover valuable resources while hazardous waste is diverted to appropriate treatment facilities. 19 This approach aligns WTE incineration plants with the principles of a circular economy, maximizing resource recovery and minimizing environmental impacts.

C. *Co-generation and Combined Heat and Power (CHP)*

Applications An important trend in the progression of waste-to-energy incineration plants is the implementation of co-generation or combined heat and power (CHP) applications. These plants generate electricity and utilize the waste heat produced during the combustion process to generate steam or hot water. This recovered heat can be effectively utilized for various purposes, such as industrial processes, space heating, or district heating systems. By incorporating CHP applications, waste-to-energy plants significantly enhance their overall energy efficiency, making them a more sustainable and appealing choice.

D. Public Perception and Community Engagement

The history and advancement of waste-to-energy incineration plants have encountered challenges regarding public perception and community engagement. The concerns surrounding air pollution, potential health impacts, and the siting of waste-to-energy plants have prompted increased efforts in transparent communication, public participation, and community involvement. Education and awareness initiatives have been initiated to promote a better understanding of the technology and its environmental benefits. These endeavours address public concerns, foster trust, and ensure community acceptance of waste-to-energy facilities [32, 33].

III.PAKISTAN'S PERSPECTIVE

The Government of Punjab has initiated the establishment of a Waste-to-Energy power plant in Lahore City, the capital of Punjab. This project uses municipal solid waste (MSW) as a partially renewable fuel to generate electricity for the city's grid. It will be the first waste-to-energy facility of its kind in Lahore. The technology employed for this plant will involve controlled combustion, either using a circulating fluidized bed (CFB) or a moving grate (MG) system. The primary objective of this initiative is to address the issue of MSW disposal in an environmentally friendly manner by converting it into electricity through a state-of-the-art power plant. The Lahore Waste Management Company (LWMC), a specialized entity established to collect, process, and dispose of MSW, will 20 oversee and manage the project. The LWMC also produces electricity, heat, and recyclable materials. The proposed location for the facility is an empty lot adjacent to the Lakhodair Landfill, which covers an area of 125 acres. This strategic placement ensures proximity to the waste source while facilitating efficient waste management and energy generation [34-37].

Project total cost	14 billion Pak Rupees ($140 million)
Land area	25 acres (101,000 square meters)
MSW processing capacity	2,000 tons per day (TPD); 600,000 tons/year
Power generation capacity	35 MW
Water requirement	36.3 TPD for steam generation
Source of water	Reprocessed and municipal supply

Table 1

Salient features of Lahore WTE plant [7]

IV.EXPERIMENTAL WORK

Our electricity generation process utilizes waste directly collected from households, commonly called door-to-door waste. For this project, we will focus on utilizing combustible materials such as paper and cardboard waste, which emit energy when burned. The key components employed in this technology include a waste heat structure or a base stand metal box for generating electricity, a Peltier module, a heat sink, a boost module, an open circuit, a battery, and a buck. The module, a capacitor bank, an Arduino Uno microcontroller, an LCD, sensors, LEDs, and a filter. With the increasing energy demands, particularly in developing nations like Pakistan, it is crucial to identify various sources that can be effectively utilized for power production (see Fig.1).

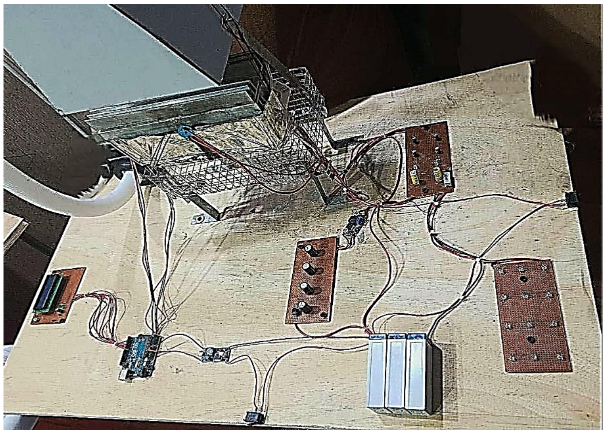

Figure 1. WTE visualization

This system proves to be an exceptionally valuable method for generating power. An important advantage of this project is its sole dependence on waste as a fuel source, eliminating the need for other energy sources. The setup for this system is straightforward and compact, requiring only a limited number of components for operation. Moreover, the components used in this project possess specific operational specifications (see Table 2).

V. METHODOLOGY

There are two pushbuttons in this project. One is attached to the Arduino circuit, while the other is placed on the output circuit (LEDs). Initially, we will burn the waste in the waste heat structure, i.e., the zaar box. According to our available sensors, we use cardboard or paper for combustion purposes. After combustion, heat will be emitted and advance toward the Peltier module placed above. The heat sink is placed in the chimney to remove excess heat. We have used three Peltier modules (TEC 12706) in series. Two rods, hot and cold, surround this Peltier module. The potential difference between this hot and cold side indicates the maximum output. An increase in potential difference will increase output. The output of the Peltier module is LED, which shows the generation of 30 power. A capacitor bank is attached for the storing of charge. The output of the Peltier module is also connected to the boost module (XL6009) to charge the battery. Three batteries of 4V are attached in series which

will accumulate a voltage of up to 12V. After the battery, a buck module (LM2596) is placed to convert 12V to 5V of Arduino Uno. This Arduino Uno will control the LCD and sensors attached to it. Two sensors, MQ4 and MQ135, are secured in the network. These sensors are placed on top of the chimney to sense the toxic gases before filtering them out. A drain pipe is placed above the chimney, providing a path to hot gases toward the filter attached at the end of the pipe (see Fig. 2).

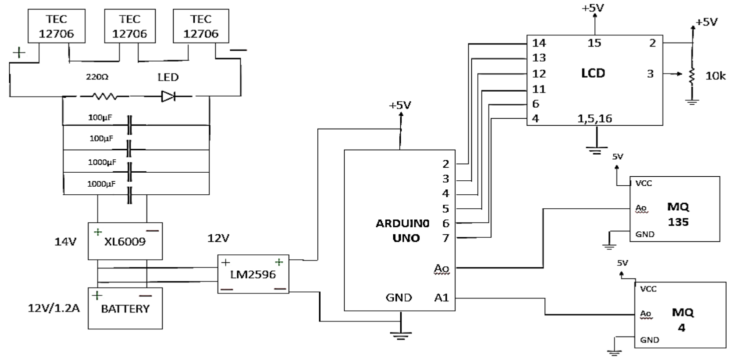

Figure 2. Circuit Diagram of hardware implementation

VI. RESULTS

Sensors MQ4 and MQ135 detect toxic gases in chimneys filtered through a drain pipe, ensuring hot gases reach the filter.

MQ4	MQ135
31.24	2.44
33.04	3.17
31.86	3.34
30.86	3.30
29.46	2.97

Table 2 Values of Sensors.

VII. CONCLUSION

So, waste-to-energy plants have the potential to make a substantial impact on waste management and the production of renewable energy. When integrated into a comprehensive waste management approach and equipped with advanced emission control technologies, these plants provide a sustainable solution that diminishes waste, generates energy, and contributes to environmental objectives. Nonetheless, it is crucial to undertake careful planning, engage with the community, and adhere to environmental regulations to ensure such facilities' successful and responsible operation. In conclusion, we designed a sensor network to detect the emission of toxic gases using MQ series sensors and filtered out these gases using a filter.

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