International Journal of Science and Research Archive

eISSN: 2582-8185

Cross Ref DOI: 10.30574/ijsra

Journal homepage: https://ijsra.net/

(Review Article)

Check for updates

Solid waste incineration in the context of climate change mitigation: A renewable energy perspective

Mohammed Ali A. Shaban *

Civil Engineering Department, College of Engineering, Al-Nahrain University, Baghdad, Iraq.

International Journal of Science and Research Archive, 2025, 14(02), 1383-1393

Publication history: Received on 09 January 2025; revised on 18 February 2025; accepted on 21 February 2025

Article DOI: https://doi.org/10.30574/ijsra.2025.14.2.0501

Abstract

Given the benefits of solid waste incineration (SWI)—it is a waste management practice as an energy recovery approach, as a diversion to landfills, and as a reduction in greenhouse gas (GHG) emissions to mitigate climate change—it has become a very important approach. A second, though less often mentioned, solution is incineration. Given its use as a last resort over past decades, the idea of promoting it is met with alarm, and yet incineration must be reconsidered, especially if designed with scale and renewability in mind. This paper gives a review of SWI technologies and their environmental aspects, energy efficiency, and reduction of carbon footprint in waste disposal. This paper presents assessments of how SWI can be considered renewable energy through an assessment of state-of-the-art developments in WTE incineration, including flue gas treatment, plasma gasification, and carbon capture integration. The possibility of SWI in conjunction with district heating systems and industrial applications is examined in order to assess the possibility of maximizing the amount of energy recovered while minimizing the level of environmental impact. Financial viability, investment cost, operational expense, and corresponding government incentives are also discussed as economic, policy, and societal challenges to the implementation of SWI. Stiff regulatory frameworks and changing waste management policies that lead to strict frameworks, the examination of their effects on public perception and public concerns for emission and health risk and for transparency of emission sources, public engagement, and environmental monitoring improvement, create an impact on the potential future SWI growth. It has been found that although SWI provides apparent landfill replacement potential, various stringent emissions control, public acceptance, and feasibility are also strong requirements before the SWI technique can be scaled. Therefore, improved SWI sustainability is contingent upon the future development of incineration technology (i.e., hybrid WTE, advanced APC methods, and digital optimization with artificial intelligence). The current global waste management approaches are moving towards the circular economy principles, and SWI will assist in adding recycled and composted products while also strengthening the sustainability and reliability of the energy infrastructure.

Keywords: Circular Economy; Carbon Emissions Mitigation; Renewable Energy Recovery; Greenhouse Gas Reduction; Waste-to-Energy (WTE); Sustainable Waste Management

1. Introduction

This exponential increase in the rate of solid waste generation has been global, and it is estimated that solid waste generation from municipal solid waste will reach a rate of 3.40 million tons annually by 2050 [1]. Nowadays, MSW generation is constantly increasing around the world, and we need a sustainable waste management solution. Waste generation is projected to continue rising during this period (Fig. 1), and the waste crisis will continue to escalate and may even have environmental implications.

* Corresponding author: Mohammed Ali A. Shaban

In Figure 1, we can see how there will be almost double the amount of waste generated by the mentioned next three decades. There is a need to put solid waste incineration (SWI) strategies in place as ways to deal with waste to control how enormous the expansions of landfills will become to allow the amount of methane emissions and speed up climate change.

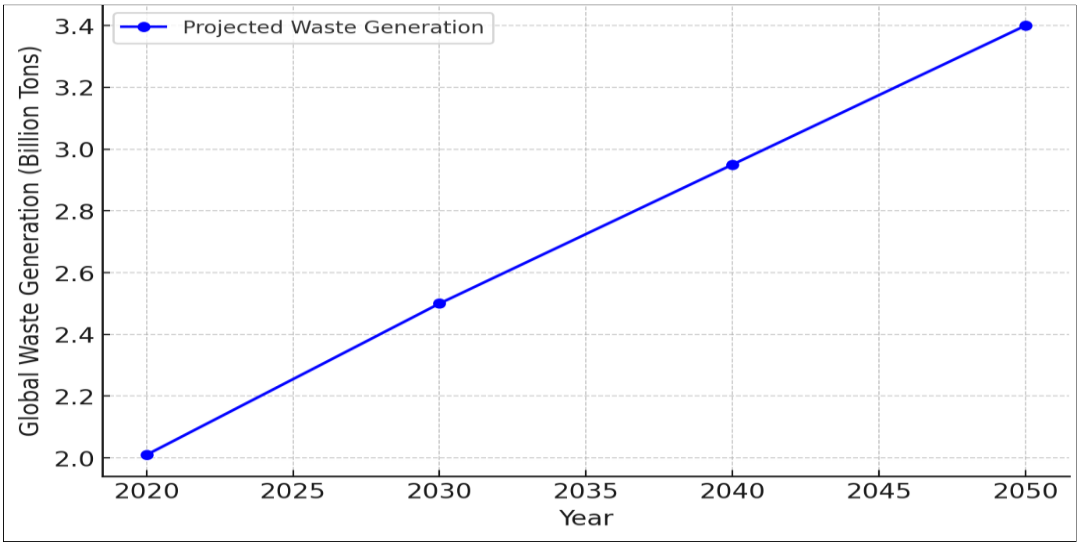

Figure 1 Global Waste Generation Trends

Landfilling of waste is no longer an acceptable option because of limited land availability, the high cost of waste disposal, and the environmental impact of methane emissions, a potent greenhouse gas (GHG) [2]. This has made the importance of incineration an alternative to these challenges through the thermochemical solid waste incineration (SWI) process that decreases the waste volume and at the same time produces energy with minimal waste left [5]. Using sophisticated advanced combustion techniques to improve energy recovery, minimize noxious gaseous emissions, or provide safe, environmentally sound solutions to problems of solid waste disposal, modern waste-to-energy (WTE) plants have magnified local and public fears surrounding solid waste disposal. Advances in SWI technology have led to more efficient and environmentally friendly systems, such as plasma gasification, which operates at temperatures above 5,000 °C to break down waste into syngas, significantly reducing GHG emissions and producing vitrified slag that can be repurposed for construction applications [8]. Furthermore, integrating SWI with carbon capture and storage (CCS) technologies has shown promising potential in mitigating CO_2 emissions, making WTE plants a viable contributor to climate change mitigation strategies [9] [10]. Furthermore, the SWI with CCS is in fact capable of achieving net negative emissions [11], which makes it an appealing tool for waste management. However, other countries such as Sweden and Denmark managed to improve the energy efficiency of their national grids by implementing SWI in the national grids by utilizing energy from incineration to supplement district heating to increase overall energy efficiency [12] [13], and SWI gives economic opportunity as it reduces this dependency on fossil fuels and creates jobs in waste management and energy [14]. However, for PPC systems, public concerns and issues regarding air pollutants, dioxins, and particles of course less than 2.5 micrometers in size (fine particulates) are still major obstacles to deployment [15][16]. For instance, it is possible to cope with these concerns by using advanced flue gas treatment systems to remove harmful pollutants before they are emitted into the atmosphere [17]. From a policy point of view, governments are increasingly recognizing the importance of SWI in terms of the circular economy and minimizing landfill dependency. Regulations, such as the European Union's Waste Framework Directive, that require at least 65% of municipal waste to be recycled or recovered are also called up by recycling and composting efforts [18] [19], and SWI is also a complementary solution to these.

At the regional level, similar financial incentives like carbon pricing or renewable energy credits have been implemented as well to stimulate WTE investment in the infrastructure [20], while SWI still needs to evolve to the extent that it meets global sustainability target performance. The rate of energy conversion can still be increased, the environmental impact from the waste feedstock can be reduced by segregating waste feedstock, and the efficiency of waste feedstock segregation enhanced and IT-enabled optimization developed for future research. Second, policymakers, industry stakeholders, and environmental groups will all be key to developing a responsive SWI strategy that balances the benefits and meets the public's reservations [23]. Advanced emission control technologies would be incorporated and optimized for energy recovery to best mitigate climate change and reduce resource efficiency (e.g. [24] [25] [26] [27]) would benefit SWI greatly.

2. Waste-to-Energy Technology: Process and Advancements

2.1. Principles of Solid Waste Incineration

SWI involves the controlled combustion of waste materials at temperatures exceeding **850°C**, effectively reducing waste volume by **70-90%** while generating steam for electricity production [13]. This process converts organic and inorganic waste components into ash, heat, and flue gases, which are further processed to recover energy and minimize environmental impacts.

The combustion process consists of four key stages:

- **Drying:** Moisture content in the waste is evaporated due to the high temperatures, which increases the calorific value of the waste material and improves combustion efficiency.
- **Pyrolysis:** Organic materials decompose in an oxygen-deficient environment, forming volatile gases, char, and small amounts of tar. Pyrolysis is a critical step that determines the energy output and emissions characteristics of the incineration process.
- **Combustion:** Oxidation of volatile gases and char produces significant amounts of heat, which is transferred to boiler systems to generate steam. The steam drives turbines for electricity generation or is used in district heating applications. Advanced control systems optimize combustion efficiency while minimizing harmful byproducts.
- **Flue Gas Treatment:** Harmful emissions such as dioxins, furans, sulfur oxides (SOx), nitrogen oxides (NOx), and particulate matter are captured and neutralized using sophisticated gas treatment technologies, including selective catalytic reduction (SCR), electrostatic precipitators, and activated carbon filtration [14][15].

The SWI process consists of four major stages, each playing a crucial role in waste conversion and energy recovery. Figure 2 presents a schematic representation of the waste-to-energy incineration process, including drying, pyrolysis, combustion, and flue gas treatment

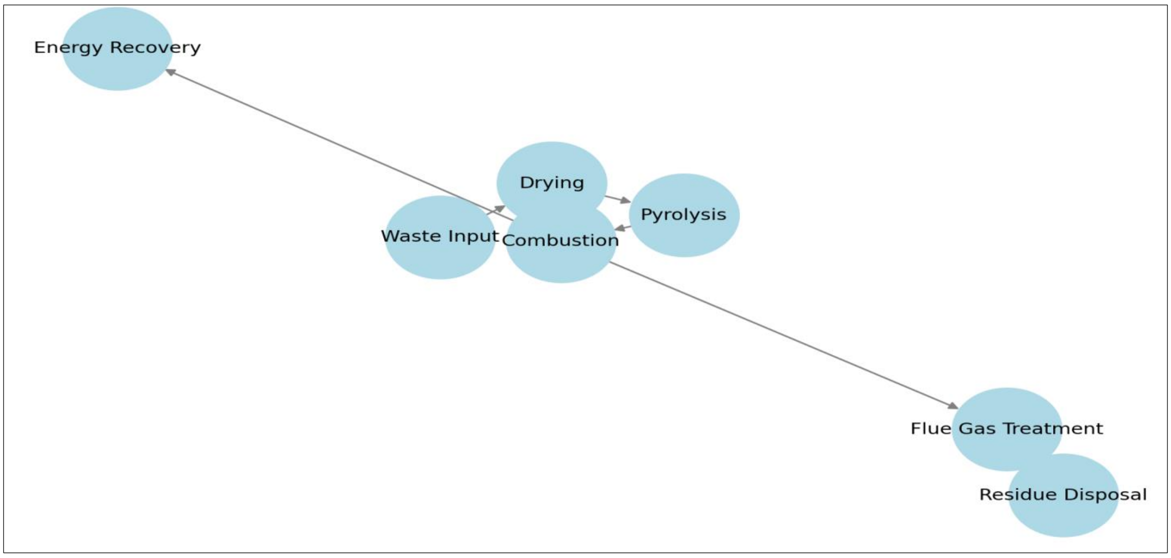

Figure 2 Solid Waste Incineration Process Flowchart

This diagram illustrates the transformation of waste into usable energy and highlights the critical importance of flue gas treatment in reducing harmful emissions. Advanced incineration technologies aim to optimize each stage for maximum energy recovery and environmental safety

Modern SWI systems incorporate energy recovery enhancements, such as heat exchangers, waste heat boilers, and steam turbines, to maximize the efficiency of power generation. The integration of flue gas recirculation (FGR) further improves thermal efficiency and lowers pollutant emissions by maintaining optimal combustion temperatures.

2.2. Plasma Gasification: A High-Efficiency Approach

Plasma gasification is a next-generation WTE technology that enhances the efficiency and sustainability of waste conversion. Unlike conventional incineration, which combusts waste directly, plasma gasification relies on high-temperature plasma arcs to break down waste at the molecular level, yielding syngas (a mixture of H_2, CO, and CH_4) that can be utilized as a fuel source for power generation or converted into biofuels and synthetic chemicals [20].

2.2.1. Key advantages of plasma gasification include:

- **Extreme High-Temperature Processing**: Plasma torches operate at 5,000–10,000°C, ensuring complete decomposition of waste into basic molecular components, minimizing residual ash formation, and preventing the release of hazardous byproducts [21].
- **Production of Vitrified Slag**: Unlike conventional incineration, which produces fly ash and bottom ash requiring further disposal, plasma gasification produces vitrified slag—a non-toxic, glass-like material suitable for construction aggregates and road surfacing applications [22].
- **Enhanced Energy Recovery Efficiency**: Plasma gasification achieves nearly 90% energy efficiency, significantly surpassing the energy recovery rates of conventional SWI, which range between 20-30% [23].

Plasma gasification offers significantly higher energy efficiency compared to conventional incineration, primarily due to its ability to break down waste at temperatures exceeding 5,000°C. Figure 3 compares the energy recovery efficiency of traditional incineration and plasma gasification technologies

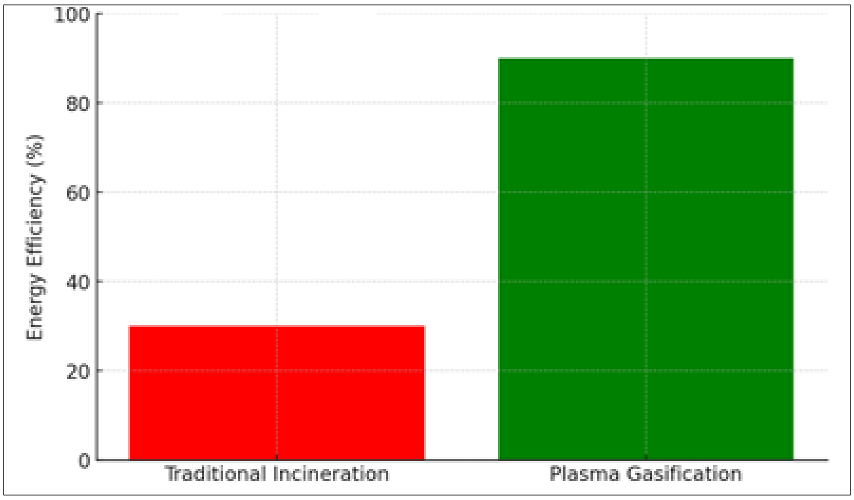

Figure 3 Comparison of Energy Efficiency between Traditional Incineration and Plasma Gasification

As shown in Figure 3, plasma gasification not only achieves higher energy recovery but also produces cleaner byproducts, such as vitrified slag, which can be repurposed for construction applications. This efficiency improvement makes plasma gasification a promising future alternative for waste-to-energy conversion.

2.2.2. Syngas Utilization and Energy Generation

The synthesis gas (**syngas**) generated from plasma gasification can be processed in multiple ways to maximize energy recovery:

- Combustion in Gas Turbines: The syngas is directly combusted in gas turbines or internal combustion engines to generate electricity with high efficiency.
- Conversion to Hydrogen Fuel: Hydrogen extracted from syngas can be utilized in fuel cells, offering a clean and sustainable energy alternative.
- Methanol and Synthetic Fuels Production: Syngas serves as a precursor for methanol synthesis, enabling its use as an industrial feedstock or transportation fuel.

2.2.3. Carbon Capture and Negative Emissions Potential

Studies indicate that plasma gasification integrated with carbon capture and storage (CCS) can achieve net-negative emissions, making it a viable carbon-neutral or even carbon-negative waste treatment technology [24][25]. This is achieved through:

- **Pre-Combustion CO_2 Capture**: Carbon dioxide is separated from syngas before energy conversion, allowing for permanent sequestration or utilization in industrial processes.
- **Biochar Production**: Some plasma gasification systems allow for biochar generation, which can be utilized as a carbon sink in agricultural applications.
- **Geological Sequestration**: Captured CO_2 can be stored underground in depleted oil fields or saline aquifers, preventing its release into the atmosphere.

Recent case studies in Japan and the United States demonstrate the feasibility of combining plasma gasification with CCS, yielding carbon-negative energy solutions while effectively managing municipal solid waste [26].

2.3. Future Advancements in WTE Technologies

Looking ahead, the next generation of WTE technologies is expected to focus on:

- **Hybrid Waste Processing**: Combining anaerobic digestion, mechanical-biological treatment (MBT), and incineration to improve energy yield and minimize emissions [27].
- **AI-Optimized Waste Sorting**: Using machine learning and AI-driven robotics to enhance waste segregation efficiency, ensuring that only non-recyclable materials are incinerated [1].
- **Decentralized Micro-WTE Plants**: Smaller-scale, modular WTE plants capable of serving urban and remote areas, reducing waste transportation emissions and increasing local energy independence [2].
- **Waste-to-Hydrogen Technologies**: Expanding hydrogen production from WTE to support the transition toward low-carbon transportation and industrial decarbonization [3].

With continued innovation and policy support, plasma gasification and advanced SWI systems are poised to play a pivotal role in global waste management strategies, renewable energy production, and climate change mitigation efforts [5][6][7][8][9][10].

3. Climate Change Mitigation Potential

3.1. Reducing Greenhouse Gas Emissions

Solid Waste Incineration (SWI) plays a crucial role in mitigating climate change by significantly reducing greenhouse gas (GHG) emissions associated with waste disposal and energy production. The primary ways in which SWI contributes to GHG reduction include:

- **Landfill Diversion:** SWI provides one of the major environmental benefits of diverting waste from landfills, which are a major source of CH_4 emissions. Methane, which is a greenhouse gas with a 25 times greater global warming potential than carbon dioxide (CO2) over a 100-year period, is also present in the domestic range of methane and flourishes in wastewater that is pumped into the ground for waste disposal. SWI incinerates municipal solid waste (MSW) rather than landfilling it and thus greatly reduces methane emissions, resulting in roughly 16% of global anthropogenic methane emissions. It was also demonstrated that 70–90% of landfill dependence can be reduced through advanced waste-to-energy (WTE) facilities and methane emissions from organic waste decay [11].
- **Displacement of Fossil Fuels:** By generating electricity and thermal energy, SWI replaces fossil fuel-based power sources such as coal and natural gas. As it turns out, the reduction of CO_2 and SO_2 releases per megawatt-hour (MWh) of generated electricity is substantial, as WTE plants release less of these pollutants per MWh than conventional fossil fuel plants do [11]. Where [13] SWI has been adopted widely—as was the case in Germany and Sweden—WTE plants have enabled 40–50% of CO2 emissions from the power sector to be displaced from coal-fired electricity generation.
- **Integration with Carbon Sequestration:** Recent studies demonstrate that the integration of SWI with carbon capture and storage (CCS) technologies leads to net negative emissions. This is because waste materials have high amounts of biogenic carbon, from which CO_2 produced during incineration can be captured and stored

permanently [14]. Advanced CCS in WTE plants have realized CO_2 reduction potential of 500 to 800 kg per ton process and are viable for carbon neutral or carbon negative electricity generation [15].

- **Reduction of Transportation Emissions:** By reducing the volume of waste transported to distant landfills, SWI lowers emissions associated with waste collection, hauling, and disposal. A single modern WTE facility can process waste equivalent to what would require 100,000 truck trips to landfills annually, leading to a 15-20% decrease in transportation-related CO_2 emissions [16].

One of the most significant advantages of SWI is its potential to reduce greenhouse gas emissions by diverting waste from landfills and replacing fossil fuel-based electricity generation. Figure 4 presents a comparative analysis of methane and CO_2 emissions from landfills, traditional fossil fuel power plants, and waste-to-energy incineration

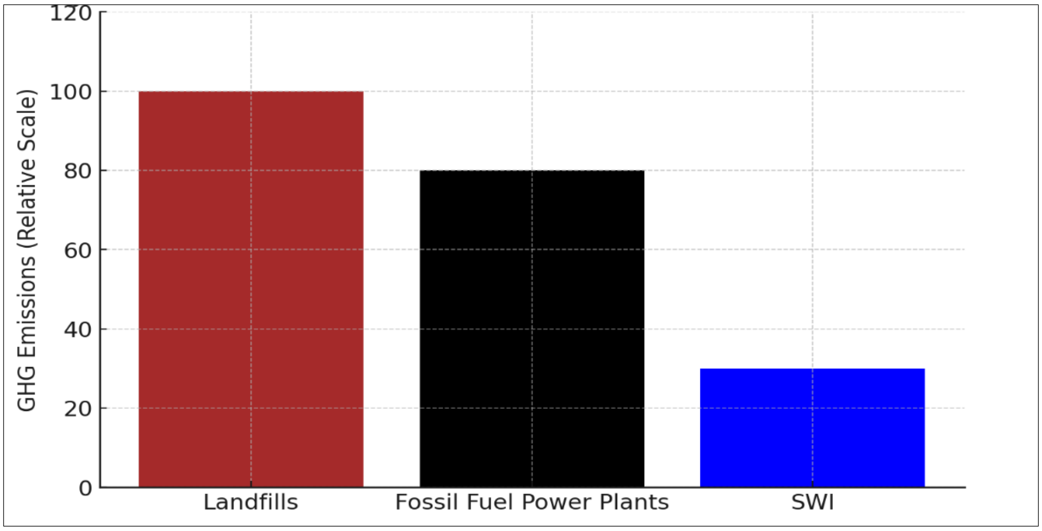

Figure 4 Greenhouse Gas Emissions Reduction Potential of SWI

From the data in Figure 4, it is evident that SWI significantly reduces methane emissions by eliminating organic waste decomposition in landfills. Additionally, when integrated with carbon capture and storage (CCS) technologies, SWI can further reduce its carbon footprint, making it a sustainable alternative for waste management and energy production.

3.2. Energy Recovery and Circular Economy Integration

SWI not only mitigates climate change through emissions reduction but also plays a key role in advancing the principles of a **circular economy** by maximizing energy recovery and resource efficiency.

- **Waste-to-Energy Efficiency:** Modern WTE plants achieve energy conversion efficiencies of 20-30% in electricity generation, with combined heat and power (CHP) systems increasing total energy efficiency to 80-90% [4][1[17]. This efficiency makes SWI a highly effective alternative to landfill gas recovery systems, which typically capture only 40-60% of landfill methane emissions for energy use [18].
- **Integration with District Heating Systems:** Countries such as Sweden, Denmark, and the Netherlands have successfully integrated SWI into their national energy frameworks, using excess heat from incineration for district heating networks. Sweden, for example, incinerates 50% of its MSW, with a significant portion of the recovered heat being used to warm buildings in urban centers during winter months [19]. This approach reduces reliance on fossil fuels for heating, cutting CO_2 emissions and increasing energy security [20].
- **Material Recovery from Incineration Ash:** Innovations in SWI technology have enabled the recycling of incineration byproducts, such as bottom ash and fly ash, into useful materials. Modern facilities recover metals (iron, aluminum, and copper) from incineration ash, which are then reintroduced into manufacturing processes. Additionally, treated fly ash can be used in cement production and road construction, further enhancing resource recovery and minimizing landfill waste [21].
- **Biofuel and Hydrogen Production:** Advanced SWI plants are now exploring the potential of hydrogen production from syngas, a byproduct of waste gasification. Hydrogen extracted from WTE processes can be used as a clean fuel for transportation and industrial applications, supporting the shift toward decarbonized energy systems [22].

- **Alignment with Circular Economy Policies:** The European Union's Waste Framework Directive has set ambitious targets for waste recovery and recycling, positioning SWI as a complementary solution to recycling efforts. Under this directive, at least 65% of municipal waste must be recycled or recovered, reinforcing SWI's role in closing the material loop and minimizing landfill dependency [23].

The integration of SWI into a circular economy model enhances material and energy recovery, reducing reliance on virgin resources. Figure 5 illustrates how SWI fits into the circular economy framework by converting waste into energy while enabling the recovery of valuable materials.

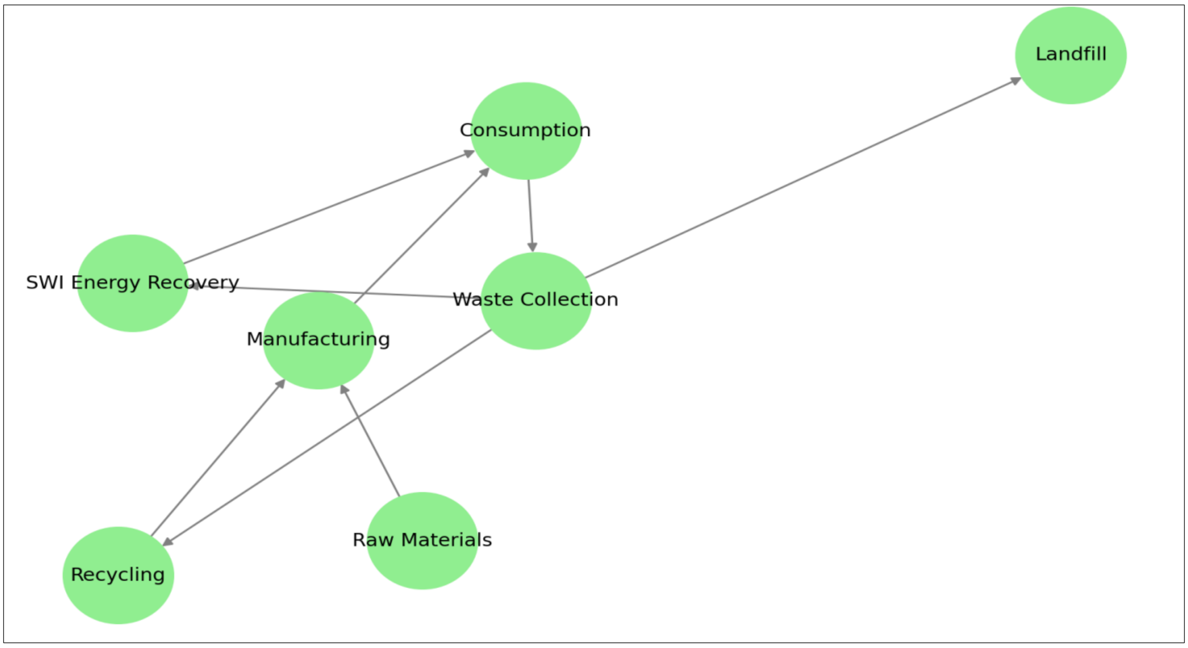

Figure 5 Circular Economy Model Integrating SWI

This model demonstrates how SWI can complement recycling and composting efforts, ensuring a closed-loop waste management system. By optimizing the recovery of energy and secondary raw materials, SWI contributes to a more sustainable and resource-efficient economy

3.3. Future Innovations in SWI for Climate Change Mitigation

To further enhance SWI's contribution to climate change mitigation, researchers and policymakers are focusing on several key innovations:

- **Future WTE plants will be hybrid waste processing** :anaerobic digestion, pyrolysis, and incineration integrated to achieve the best waste processing efficiency and reduce residual waste. The net energy output can be improved, and the emission is further reduced by this multistage approach [17].
- **Artificial waste sorting using Artificial Intelligence (AI):** Artificial intelligence (AI) is being used in the development of AI-driven automated waste sorting in order to enhance the recycling rates and ensure only those materials that are not recyclable are incinerated in order to improve SWI's sustainability and limit the environmental impact [18].
- **New Adsorption and Membrane-Based CO_2 Capture Technologies**: Specially Designed for WTE Plants Offered Significant Improvement in the Carbon Sequestration Efficiency and Reduced Overall Emissions [19].
- **Modular, Smaller Scale Micro-WTE Plants for Community WTE**: designed smaller scale, modular WTE facilities for urban and rural community service to reduce transportation emissions and increase community energy independence [20].

Equipping SWI with these advancements will enable the SWI to integrate future climate mitigation innovations that will continue to enhance effectiveness in a low-carbon and sustainable future.

4. Challenges and Policy Considerations

4.1. Environmental and Public Health Concerns

Despite its very large environmental benefits, solid waste incineration (SWI) is still experiencing major public opposition as a result of fears over air pollution, waste handling, and long-term sustainability. It involves environmental and health-related concerns, which include:

- **Toxic pollutants emissions:** SWI plants produce toxic emissions comprising dioxins, furans, and heavy metals (lead, mercury, and cadmium) that build up in the environment, constituting health risks in the long term. [21]. Modern WTE facilities already have advanced flue gas treatment systems, but they still experience public skepticism owing to the poor emission control situations in the older plant.
- **Byproduct fine particulate matter (PM2.5) and air quality:** Incineration is a major byproduct of particulate matter (PM2.5), which can lead to respiratory disease and heart disease and decrease air quality in urban areas. Exposure to PM2.5 from industrial emissions is associated with an increasing risk of asthma, lung cancer, and stroke [22] and therefore contributes to SWI sustainability as emissions control.
- However, both CO_2 and nitrous oxides (NO_x) are released from SWI, whereas methane emissions are significantly reduced relative to landfills. The problem is in the integration of carbon capture technologies to reduce residual CO_2 emissions and boost the WTE plant's sustainability [23].
- **High operational costs:** There is an increase in high operational costs for SWI facilities due to emissions control systems (such as selective catalytic reduction, activated carbon filters, and electrostatic precipitators). The WTE development is an expensive investment due to the fact that countries with low financial resources may not be able to implement the required environmental safeguards.

To fulfill these challenges, regulatory bodies and industry leadership are seeking the application of more advanced filtration systems combined with AI-based emission tracking and real-time tracking of PM2.5 pollution.

4.2. Regulatory and Economic Barriers

A high capital investment is required in SWI or waste-to-energy (WTE) facilities, which is an obstacle to its wide adoption. A large-scale WTE plant is estimated to initially cost in excess of $500 million, and expenditures for ongoing maintenance, fuel processing, and public policy compliance are projected to add further high costs. SWI infrastructure consumes high capital costs and requires governments and private investors to assess financial return on investment (ROI) before committing to it.

4.2.1. To incentivize development and attract investment, several policy measures have been introduced globally, including:

- **EU Waste Framework Directive:** This directive mandates that at least 65% of municipal waste be recycled or recovered; emphasizing waste hierarchy principles that prioritize waste reduction and material recovery before incineration [24].
- **Waste-to-Energy Subsidy in Japan:** Japan provides subsidies to WTE projects, which actually led to numerous successful projects of over 1,200 incineration plants operational. Japan has been among the leaders internationally in integrating incineration with energy production, in part because of these subsidies [25].
- **WTE Operators:** Most WTE operators received or traded carbon credit or were encouraged to decrease their dependency on fossil fuels by generating waste-derived energy[26]
- Some governments impose landfill taxes and waste disposal levies, which helps the industries and municipalities to spend on SWI as a long-term waste management solution rather than a landfill expansion [27].

While these policies have accelerated investment in SWI, further economic assessments are needed to determine long-term profitability, cost recovery mechanisms, and public-private partnerships (PPP) for financing WTE facilities.

The expansion of SWI facilities requires strong policy frameworks and financial support. Figure 6 presents a comparative analysis of different global policies and economic incentives that have successfully promoted SWI implementation.

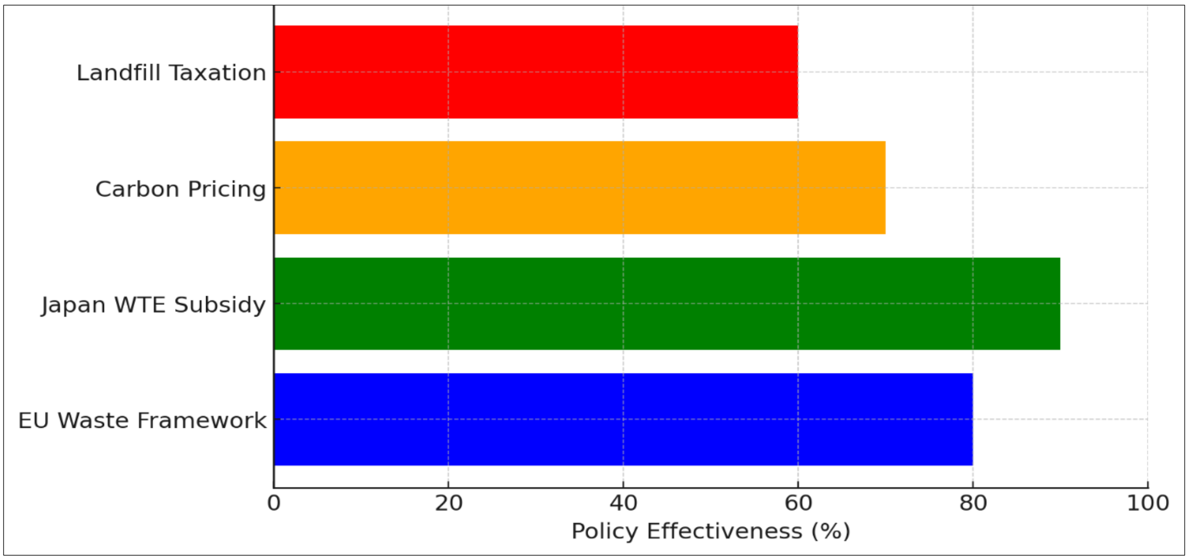

Figure 6 Economic and Policy Support for SWI

As illustrated in Figure 6, nations with well-established financial incentives, such as carbon credits, renewable energy subsidies, and landfill taxation, have achieved greater success in SWI deployment. Continued policy development and economic incentives will be crucial for expanding WTE infrastructure worldwide.

5. Conclusion and Future Perspectives

Overall, these types of waste incineration together offer significant advantages of waste reduction, energy recovery, or carbon change mitigation instead of landfill disposal. But to reach its potential, much more technology development, emissions control, public policy, and equipment investment in infrastructure will be needed.

Future research and development should focus on:

- Plasma gasification systems will perform more efficiently when operated at 5,000–10,000 °C to generate complete waste decomposition and minimal waste residues. Additional expansion of this technology approach has the power to improve both energy production volume and environmental benefits.
- New and existing SWI plants must receive carbon capture technologies to decrease overall carbon emissions while increasing climate neutrality through sequestration. The next round of investments must concentrate on finding economic CCS systems that WTE operators can use.
- The integration of incineration systems with mechanical-biological treatment (MBT), anaerobic digestion, and advanced recycling methods constitutes the advanced direction for WTE technology. A mixed approach between these tactics yields the greatest material recovery results and generates the most minimized emissions.
- Artificial intelligence (AI) along with robotic sorting enables more efficient waste segregation that leads to incinerating only non-recyclable waste materials and makes the process more sustainable.
- The acceptance of SWI depends on carrying out educational initiatives combined with transparent emission reporting and inclusive community-based decisions to address public doubts regarding SWI.

SWI will be the catalyst for the coming of global waste management strategies and a more sustainable and circular economy by securing energy and climate resilience and waste reduction. As a cleaner, greener future, governments need to cooperate with industries and environmental organizations to amend their policies and the technology of clean energy from wastewater, in addition to developing environmentally conscious incineration.

References

[1] O. M. Butt et al., "Hydrogen as Potential Primary Energy Fuel for Municipal Solid Waste Incineration for a Sustainable Waste Management," in IEEE Access, vol. 10, pp. 114586-114596, 2022, doi: 10.1109/ACCESS.2022.3216706.

[2] S. Hegde, S. N, T. Pinto, S. Shukla and V. Patidar, "Optimizing Solid Waste Management: A Holistic Approach by Informed Carbon Emission Reduction," in IEEE Access, vol. 12, pp. 121659-121674, 2024, doi: 10.1109/ACCESS.2024.3443296.

[3] M. Saeed, M. Ahsan, M. H. Saeed, A. Mehmood and S. El-Morsy, "Assessment of Solid Waste Management Strategies Using an Efficient Complex Fuzzy Hypersoft Set Algorithm Based on Entropy and Similarity Measures," in IEEE Access, vol. 9, pp. 150700-150714, 2021, doi: 10.1109/ACCESS.2021.3125727.

[4] P. Pratoomma, A. Narbudowicz and S. Chalermwisutkul, "Contactless Moisture Content Sensor Based on Wheeler Cap for Waste-to-Energy Plants," in IEEE Open Journal of Antennas and Propagation, vol. 5, no. 5, pp. 1152-1165, Oct. 2024, doi: 10.1109/OJAP.2024.3437209

[5] O. Mudannayake, D. Rathnayake, J. D. Herath, D. K. Fernando and M. Fernando, "Exploring Machine Learning and Deep Learning Approaches for Multi-Step Forecasting in Municipal Solid Waste Generation," in IEEE Access, vol. 10, pp. 122570-122585, 2022, doi: 10.1109/ACCESS.2022.3221941

[6] J. Yan, Y. Teng and Z. Chen, "Optimization of Multi-energy Microgrids with Waste Process Capacity for Electricity-hydrogen Charging Services," in CSEE Journal of Power and Energy Systems, vol. 8, no. 2, pp. 380-391, March 2022, doi: 10.17775/CSEEJPES.2021.05060.

[7] E. Tereshchenko, A. Happonen, J. Porras and C. A. Vaithilingam, "Green Growth, Waste Management, and Environmental Impact Reduction Success Cases From Small and Medium Enterprises Context: A Systematic Mapping Study," in IEEE Access, vol. 11, pp. 56900-56920, 2023, doi: 10.1109/ACCESS.2023.3271972.

[8] Z. Ali, M. Ali, S. Yin and M. -S. Yang, "Novel Aczel-Alsina Power Aggregation Operators for Circular Pythagorean Fuzzy Linguistics With Application to Waste Reduction and Recycling in Green Supply Chain Management," in IEEE Access, vol. 12, pp. 151710-151727, 2024, doi: 10.1109/ACCESS.2024.3474178

[9] I. Sosunova and J. Porras, "IoT-Enabled Smart Waste Management Systems for Smart Cities: A Systematic Review," in IEEE Access, vol. 10, pp. 73326-73363, 2022, doi: 10.1109/ACCESS.2022.3188308.

[10] M. I. Aceleanu, A. C. Şerban, M. -C. Suciu and T. I. Biţoiu, "The Management of Municipal Waste through Circular Economy in the Context of Smart Cities Development," in IEEE Access, vol. 7, pp. 133602-133614, 2019, doi: 10.1109/ACCESS.2019.2928999

[11] Y. Ge, Y. Wei, Q. Zhao and Y. Pei, "Energy and Exergy Analysis on a Waste Heat Recovery Module for Helicopters," in IEEE Access, vol. 9, pp. 122618-122625, 2021, doi: 10.1109/ACCESS.2021.3109738

[12] K. Tomitagawa, A. Anuntachai, S. Chotipant, O. Wongwirat and S. Kuchii, "Performance Measurement of Energy Optimal Path Finding for Waste Collection Robot Using ACO Algorithm," in IEEE Access, vol. 10, pp. 117261-117272, 2022, doi: 10.1109/ACCESS.2022.3219416

[13] D. Notosudjono, D. Suhendi, Engkos and B. D. Ramadhon, "Evaluation study of waste materials for renewable energy through 3R model in Bogor city," 2017 4th International Conference on Electrical Engineering, Computer Science and Informatics (EECSI), Yogyakarta, Indonesia, 2017, pp. 1-4, doi: 10.1109/EECSI.2017.8239144.

[14] H. Deep Singh Bhalla, "Analysis of industrial waste for energy generation with reference to Uttarakhand, India: Waste as a potential energy weapon," 2015 International Conference on Technologies for Sustainable Development (ICTSD), Mumbai, India, 2015, pp. 1-6, doi: 10.1109/ICTSD.2015.7095876.

[15] A. M. Zafar et al., "GIS-based waste-to-energy and improved solid waste management practices for waste collection in Lahore – An approach towards sustainability," 2021 6th International Conference on Renewable Energy: Generation and Applications (ICREGA), Al Ain, United Arab Emirates, 2021, pp. 82-87, doi: 10.1109/ICREGA50506.2021.9388309

[16] I. R. Rojas and L. I. Vásquez, "Energy Generation from Solid Waste. A Literature Review," 2018 Congreso Internacional de Innovación y Tendencias en Ingeniería (CONIITI), Bogota, Colombia, 2018, pp. 1-4, doi: 10.1109/CONIITI.2018.8587102.

[17] N. Othman, L. M. Sidek, N. E. A. Basri, M. N. M. Yunus and N. A. Othman, "Electronic plastic waste management in malaysia: the potential of waste to energy conversion," 2009 3rd International Conference on Energy and Environment (ICEE), Malacca, Malaysia, 2009, pp. 337-342, doi: 10.1109/ICEENVIRON.2009.5398623.

[18] B. S. Kadjo, D. Sangaré, K. M. Sako and L. Coulibaly, "Biogas production from household solid waste by anaerobic batch reactor," 2020 5th International Conference on Renewable Energies for Developing Countries (REDEC), Marrakech, Morocco, 2020, pp. 1-5, doi: 10.1109/REDEC49234.2020.9163902.

[19] M. S. Amin, K. F. Shariar, M. R. Azim and S. A. Chowdhury, "The potential of generating energy from solid waste materials in Bangladesh," 2009 1st International Conference on the Developements in Renewable Energy Technology (ICDRET), Dhaka, Bangladesh, 2009, pp. 1-6, doi: 10.1109/ICDRET.2009.5454197.

[20] R. M. Elhassan, "Potential Opportunities for Waste to Energy and Recycling in the Kingdom of Saudi Arabia," 2021 6th International Conference on Renewable Energy: Generation and Applications (ICREGA), Al Ain, United Arab Emirates, 2021, pp. 76-81, doi: 10.1109/ICREGA50506.2021.9388300.

[21] L. Mazzoni and I. Janajreh, "Plasma gasification of municipal solid waste with variable content of plastic solid waste for enhanced energy recovery," 2016 International Renewable and Sustainable Energy Conference (IRSEC), Marrakech, Morocco, 2016, pp. 907-912, doi: 10.1109/IRSEC.2016.7984049.

[22] N. Curry and P. Pillay, "Converting food waste to usable energy in the urban environment through anaerobic digestion," 2009 IEEE Electrical Power & Energy Conference (EPEC), Montreal, QC, Canada, 2009, pp. 1-4, doi: 10.1109/EPEC.2009.5420983.

[23] A. H. Khan and M. F. Khan, "Prospects of electricity generation from municipal solid waste of Dhaka city," 2009 1st International Conference on the Developements in Renewable Energy Technology (ICDRET), Dhaka, Bangladesh, 2009, pp. 1-4, doi: 10.1109/ICDRET.2009.5454206.

[24] H. Sulistyo, S. Syamsiah, D. A. Herawati and A. A. Wibawa, "Biogas production from traditional market waste to generate renewable energy," 2012 7th International Forum on Strategic Technology (IFOST), Tomsk, Russia, 2012, pp. 1-4, doi: 10.1109/IFOST.2012.6357507.

[25] O. Aga, O. K. M. Ouda and S. A. Raza, "Investigating waste to energy potential in the eastern region, Saudi Arabia," International Conference on Renewable Energies for Developing Countries 2014, Beirut, Lebanon, 2014, pp. 7-11, doi: 10.1109/REDEC.2014.7038522.

[26] A. S. Varadi, L. Strand and J. Takacs, "Clean Electrical Power Generation from Municipal Solid Waste," 2007 International Conference on Clean Electrical Power, Capri, Italy, 2007, pp. 302-305, doi: 10.1109/ICCEP.2007.384227.

[27] M. Pourali, "Application of Plasma Gasification Technology in Waste to Energy—Challenges and Opportunities," in IEEE Transactions on Sustainable Energy, vol. 1, no. 3, pp. 125-130, Oct. 2010, doi: 10.1109/TSTE.2010.2061242.