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SUSTAINABILITY EVALUATION OF WASTE-TO-ENERGY POWER PLANTS IN SOLO CITY, INDONESIA

Muhammad Sukron[1]*, Mudiyati Rahmatunnisa[2], Sunardi[3], Cipta Endyana[4]

[1]Environmental Science, Padjadjaran University, 40132 Bandung, Indonesia
[2]Padjadjaran University, 40132 Bandung, Indonesia
[3]Department of Biology, Padjadjaran University, 40132 Bandung, Indonesia
[4]Department of Geological Engineering, Padjadjaran University, 40132 Bandung, Indonesia

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Corresponding Author: Muhammad Sukron (msukron26@gmail.com)

ABSTRACT

This study evaluates the implementation of Presidential Regulation No. 35 of 2018 on Waste-to-Energy (WtE) power plants in Indonesia using the Context, Input, Process, Product (CIPP) framework. The regulation aims to address municipal solid waste accumulation and the need for renewable energy. However, progress is limited, with only two of the twelve targeted facilities operational. Main obstacles include poor technological compatibility with local waste, absence of systematic waste sorting, limited fiscal commitment from local governments, and weak private sector engagement. The study employs a multi-perspective approach combining regulatory review, technical assessment, and stakeholder analysis to assess policy performance. Results show a significant gap between policy objectives and outcomes, largely due to institutional fragmentation and weak coordination. The findings highlight the necessity for stronger governance mechanisms, localized technology adaptation, and enhanced financial and regulatory incentives to achieve the regulation's goals. This research contributes to environmental policy evaluation in developing countries, particularly in linking waste management with energy transition strategies.

KEYWORDS: waste-to-energy, power plants, Indonesian regulation, evaluation model, renewable energy

1 INTRODUCTION

The increasing population and urbanization have directly led to the rising volume of waste, particularly in large cities (Hoornweg & Bhada-Tata, 2012). When not properly managed, waste leads to environmental pollution such as air pollution, flooding, and a reduction in the quality of life. The government of Indonesia has addressed this by issuing policies on waste management that address not only technical aspects but also people's awareness in order to attain sustainable waste management.

One of the significant regulations is Law Number 18 of 2008, which prescribes the stages of waste management—from collection and sorting to final processing. In practice, the system faces a number of issues, such as overcapacity of landfills, environmental pollution, and the quest for new landfill sites. To address these kinds of problems, the government introduced Presidential Regulation Number 35 of 2018 to accelerate the development of Waste-to-Energy (WtE) power plants in Indonesia, named **PLTSa** (*Pembangkit Listrik Tenaga Sampah*) with green technology, which integrates waste reduction and renewable energy production.

Though introduced in 2018, the regulation has been enacted very slowly. Out of 12 PLTSa sites that were targeted, only two are already in operation: PLTSa Benowo in Surabaya and PLTSa Putri Cempo in Solo. The key constraints include the lack of sorting of waste at the source, difficulty in selecting the right technology (Rani & Kumar, 2020), the lack of contribution of the local budget (Jin & Ma, 2019), insufficient human resources, and the lack of incentives to private developers. In addition, the execution of Power Purchase Agreements (PJBL) (Pan & Duan, 2015) with the state electricity company is hindered by the more expensive production compared to coal-based power.

Beyond the technical issues, the policy has been contentious in terms of its fundamental intention (Park & Lee, 2013)—whether it is less about generating electricity or more about resolving the waste crisis. Although the regulation gives precedence to the management of waste (Tan & Hashim, 2015), its real impact in reducing landfill rubbish on the ground remains limited. There are also worries about health risks, environmental impact (Dong & Tang, 2020), and burden imposition on local societies. Other countries, like Japan, have developed significantly in WtE technology (Zhou & Chen, 2021), especially through gasification processes, which are more efficient and leave fewer residues than conventional incineration.

Because of the slow progress and complex problems, it is necessary to evaluate the effectiveness of Presidential Regulation No. 35/2018. The chosen model for this evaluation is Daniel Stufflebeam's CIPP (Y. Zhang & Huang, 2019) model (Context, Input, Process, Product) that is famous for being comprehensive. The model not only assesses outcomes but also provides helpful information for decision-making, with the aim of improving the policy. Such an evaluation ultimately helps achieve the national target of 25% renewable energy by 2025, as well as institute more effective and sustainable measures for waste management.

The increasing global demand for energy and the rapid growth of municipal solid waste have created significant environmental and economic challenges for modern societies. Waste-to-energy (WtE) technology has emerged as a promising solution that simultaneously addresses waste management and energy generation. By converting waste materials into usable forms of energy such as electricity, heat, or fuel, WtE systems contribute to resource efficiency and environmental protection. These technologies are increasingly promoted as part of sustainable energy transitions and circular resource management strategies. In particular, WtE initiatives support the objectives of the United Nations Sustainable Development Goals (SDGs), especially those related to clean energy, sustainable cities, and responsible consumption.

Despite the growing interest in WtE technologies, existing literature reveals several important research gaps regarding the comprehensive sustainability evaluation of WtE power generation systems.

2 MATERIALS AND METHODS

2.1 Hypothesis

Based on the background and problem identification in Chapter 1 and the theoretical considerations in Chapter 2, the conclusions that can be made are as following the implementation of Presidential Regulation No. 35 of 2018 is not yet optimal, development of Waste-to-Energy facilities can improve environmental quality and public health, construction of power plant helps to produce renewable energy and has positive environmental effects, Technology for waste-to-Energy power plant is not yet suitable for the conditions of waste in Indonesia.

2.2 Regulation Evaluation Concept

Regulatory analysis is a necessary step to determine if a regulation or policy achieves its anticipated objectives in practice. If not tested, an optimally designed rule may read well on paper but have minimal impact on the actual world. The analysis is conducted with various approaches such as compliance analysis and socio-economic impact assessment (Radaelli & De Francesco, 2010). Research by Kirkpatrick and Parker (2004) shows that evaluations done after implementation tend to expose gaps between anticipated results and actual achievements, depicted by ineffective environmental policy because of weak enforcement. Evaluation, in this way, does not merely act as a monitoring tool but also as a means of guaranteeing ongoing policy improvement. (Kirkpatrick & Parker, 2004)

Along with quantifying compliance, regulatory analysis needs to assess efficiency and unwanted impacts. Hahn and Tetlock (2008) argue that many regulations place undue administrative burdens that are not proportionate to the benefits derived. (Hahn & Tetlock, 2008)Cost-benefit analysis (CBA) is a critical tool in determining whether regulation's benefits outweigh its cost implications (Sunstein, 2014). Research by (Wiener et al., 2011) found that overly restrictive financial regulations stifle innovation, while participatory evaluations involving stakeholders can help identify problems early on (Baldwin et al., 2012). Evidence-based approaches guarantee that regulations possess not merely theoretical but also practical applicability and flexibility.

One of the most important issues in regulatory evaluation is data availability and objective evaluation. Note that the government does not have performance data due to weak monitoring systems. This has, however, been altered by the increase in big data and AI (Papangelou & Vasilakos, 2021), which enables real-time monitoring of policies. Additionally, cite comparison with similar legislation in other countries as a source of broader insight. Through rigorous methodologies, regulation review is transformed into a strategy of governance for improved governance and ensuring policies truly benefit society.

2.3 Evaluation Model

Based on several evaluation models as materials applied in policy studies in waste-to-energy power plant technical evaluation research in Indonesia. The author recapitulates them in the comparative analysis table below.

Table 1: Evaluation Models Comparison

Model	Key Focus	Strengths	Limitations	Application Study
CIPP (Stufflebeam)	Context, Input, Process, Product	Holistic, adaptable to various stages	Time-consuming for large-scale programs	Zhang et al. (2021) in *Evaluation and Program Planning*
CSE-UCLA	Five-level evaluation	Systematic progression from formative to summative	Less flexible for emergent outcomes	Alkin (2013) in *American Journal of Evaluation*
Brinkerhoff	Success Case Method	Identifies what works in real conditions	May miss systemic failures	Brinkerhoff (2005) in *Performance Improvement*
Stake's Countenance	Antecedents-Transactions-Outcomes	Rich qualitative data collection	Subjective interpretation risks	Forss et al. (2011) in *Evaluation*
Wollmann	Policy cycle alignment	Integrates with governance processes	Eurocentric bias	Wollmann (2017) in *Local Government Studies*
Dunn's Policy Analysis	Argumentative approach	Emphasizes stakeholder discourse	Requires high participant engagement	Dunn (2018) in *Policy Studies Journal*
Lester & Stewart	Policy implementation focus	Practical for administrative assessment	Narrow operational scope	Lester et al. (2019) in *Public Administration Review*
House's Deliberative	Social justice orientation	Addresses equity concerns	Politically challenging to implement	House (2015) in *Journal of MultiDisciplinary Evaluation*
Anderson's Logical Framework	Causal chain analysis	Clear cause-effect visualization	Oversimplifies complex systems	Anderson (2016) in *Evaluation Journal of Australasia*
Jones' Four-Part	Needs-assessment driven	Strong diagnostic capabilities	Resource-intensive data needs	Jones et al. (2020) in *Evaluation Review*
Suchman's Scientific	Experimental design	Rigorous impact measurement	Difficult in natural policy settings	Suchman (2017) in *New Directions for Evaluation*
Howlett & Ramesh	Policy subsystem analysis	Examines actor-network dynamics	Less prescriptive for evaluators	Howlett (2020) in *Policy Sciences*

Note: Literature comparation in 2025

Comparative examination of a number of policy evaluation models (Smyth & Watzlawik, 2010) demonstrates a wide range of methodological orientations bearing unique viewpoints in assessing public policies. Experimental models, including the CIPP model and Suchman's approach, emphasize the importance of systematic impact measurement and accountability. In contrast, qualitative models explained by Stake and House place emphasis on subjectivity, stakeholder perceptions, and participatory strategies. Process-based approaches, such as Wollmann and Lester & Stewart, emphasize the dynamic dimension of policy implementation in terms of temporal phases. Systems-based approaches, as categorized by Howlett & Ramesh and Anderson, conceptualize policy in terms of a larger, interlinked system with all its complexities and relationships among various components of policy.

These models also differ in their application at the various policy cycle stages. Formative phases, such as agenda-setting and policy development, are best addressed by the CSE-UCLA model and Jones' framework, which provide introductory insight into policy context and needs determination. Implementation is comprehensively addressed by Brinkerhoff and Lester & Stewart's model, which supplies tools to monitor operational performance. In impact assessment, Dunn's and Suchman's models stand out for empirical rigor and emphasis on quantifiable outcomes. Recent revisions reflect the changing dynamics of policy contexts, particularly given the advances in digital governance and the need for integrative approaches. The CIPP model has been adapted to evaluate electronic governance projects (L. Zhang, 2021), while Forss (2021) combines Stake's qualitative model with Wollmann's policy cycle model to create a hybrid, mixed-methods model that offers in-depth insights (Forss et al., 2011).

With regard to model selection, particular criteria can lead practitioners to the most suitable framework. For accountability, the CIPP model or Suchman's evaluation model is optimal since they possess systematic, outcomes-focused approaches. For participatory evaluation, House and Stake provide good models that incorporate several stakeholder inputs. For situations requiring rapid assessments, Brinkerhoff's model is handy since it is time-efficient and flexible. Finally, in assessing policies in complex systems, the systems-based models posited by Howlett and Ramesh are most appropriate for elaborating on systemic interactions and feedback loops. In summary, the choice of a policy evaluation framework must be guided by methodological orientation, the specific stage of the policy cycle being addressed, and the level of complexity in the policy context. A properly matched framework not only increases the validity of evaluation findings but also strengthens the contribution of public policy as an effective, evidence-based tool of social change.

2.4 Data Collection

The four basic strategic options of a strategic matrix based on SWOT analysis are the SO (Strengths–Opportunities), the ST (Strengths–Threats), the WO (Weaknesses–Opportunities), and WT (Weaknesses–Threats), intended to coordinate internal capabilities with external conditions. The SO strategy, often descriptive of a proactive strategy, focuses on developing a company's strengths to take advantage of potential opportunities that lie within the environment. The ST strategy focuses on utilizing current strengths to anticipate and counter potential dangers, often viewed as a diversification strategy. Both strategies recognize the value of utilizing firm assets proactively to protect or gain competitive market share.

At the same time, the WT and WO strategies have a defensive or adaptive focus. The WO strategy, otherwise known as the turnaround strategy, targets eliminating internal weaknesses by exploiting overseas possibilities like new market entry or alliances. The WT strategy, on the other hand, is a defence strategy that claims to deal with internal weaknesses and external dangers concurrently. The strategy emphasizes mitigation of risk and minimization of loss, often used when a business faces serious internal constraints amidst increased external risk. These strategies allow organizations to match challenges and possibilities with resources, thus informing decision-making in the event of changes in market dynamics.

3 RESULTS

3.1 Renewable Energy

Indonesia's transition to renewable energy has been accelerated by the imperative to end climate change and gain energy security, yet offering also offers challenges as well as opportunities in the context of sustainable development. With the increasing global temperatures and the fluctuating nature of conventional energy sources, the government has set out renewable energy as a vital principle of national economic development, alongside addressing environmental concerns.

Indonesia faces a twofold problem, however, of surmounting the middle-income trap-in which GDP per capita must reach $12,616 based on the World Bank standard-and reducing its large reliance on fossil fuels, which totalled 34.8% of industrial energy consumption in 2012 (CDIEMR, 2013). From 2000 to 2012, the country witnessed a continuous growth in energy demand at a 2.9% annual growth rate, pointing to an unsustainable consumption of imported oil in the face of dwindling local production. That contradiction highlights the imperative demand for policy innovation and technological development (Schwab, 2013), where the development of renewable energy is not just environmental responsibility but also a societal transformation in nature, requiring holistic strategies that balance energy security, economic competence, and environmental sustainability to lead Indonesia to a resilient, high-income future.

Table 2: Top 10 Coal Resources and Reserves Status Per Provinces in December 2020

Provinces	Resources Total (Billion ton)	Reserves Total (Billion ton)
South Kalimantan	36.922,57	10.951,37
East Kalimantan	36.922,57	10.951,37
South Sumatera	33.941,06	8.547,88
Middle Kalimantan	3.789,97	928,11
Jambi	2.872,02	913,87
North Kalimantan	1.809,30	573,22
Aceh	1.121,25	548,48
Riau	752,20	294,80
Bengkulu	62,41	25,67
West Papua	95,57	-
Source: Ministry of Mineral Resources & Energy Republic of Indonesia (2022)		

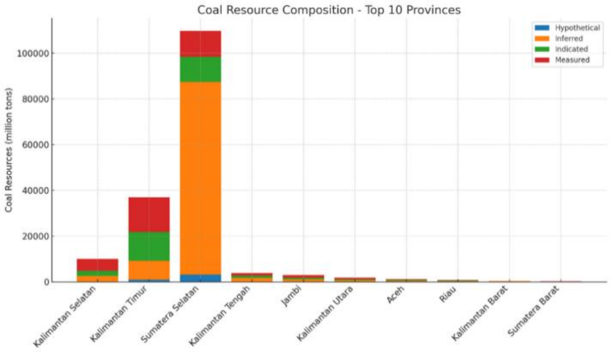

Figure 1: Total Resources and Reserves of Coal by Province in Indonesia

Waste-to-Energy Power Plants In Indonesia

Electricity serves as a promising alternative and renewable energy source to address various energy crises caused by the limitations of primary energy sources such as fuel oil, coal, and natural gas. The utilization of electrical energy offers several advantages. According to Achmad Imam Agung (2013), these benefits include: (1) relative ease of access, (2) potential for cost-free generation, (3) very low operational costs, (4) absence of waste disposal issues, (5) no contribution to global temperature rise, and (6) the ability to be sourced from renewable energies such as wind, solar, hydro, and biomass—making it resilient against fuel price fluctuations and scarcity.

The conversion of waste into electrical energy, known as Waste-to-Energy (WtE), represents an innovative approach to utilizing discarded materials as a primary energy source. Waste-to-energy is considered a sustainable solution due to the massive and continuous availability of waste. Power plants that generate electricity from waste are referred to as Waste-to-Energy Power Plants. In principle, the process of converting waste into electricity can be achieved through either direct combustion or indirect conversion methods. Figure 2 below illustrates the technological process of transforming waste into energy.

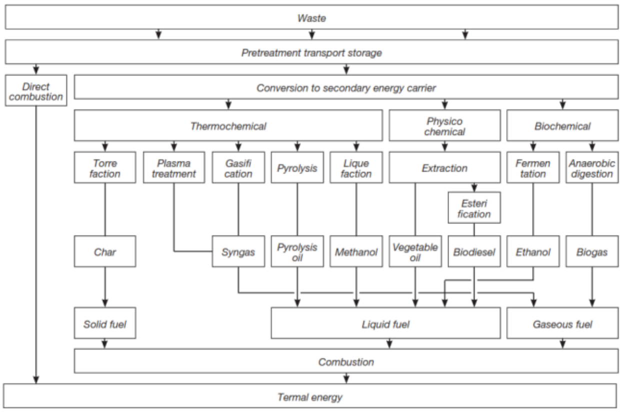

Figure 2: Process of waste-to-energy technology

Source: Kaltschmitt & Reinhardt (1997) in Bosmans & Helsen (2010)

Plastic waste poses a considerable environmental issue while also presenting itself as an encouraging prospect for energy production. The WtE processes involved in the conversion of plastic demonstrate an interesting evolution from a ubiquitous packaging material to a feedstock for electrical energy. Most plastics are derived from fossil fuels prior to being transformed into a wide variety of products that are used daily, such as shopping bags (LDPE) and food containers (PP). After these products have served their purposes, there is no need for them to be sent to landfills. If sorted carefully, some plastics can regain life through reuse, while others can go through recycling processes that physically reform or chemically break them down.

The major improvement comes from the treatment of waste not fit for recycling. Modern waste-to-energy (WtE) plants employ three advanced methods (Tchobanoglous & Kreith, 2014): burning waste at high temperatures to generate electricity and steam, subjecting the waste to controlled thermal treatment to produce synthetic gas, or allowing natural decomposition to produce biogas. Each method has unique benefits (Arafat & Jijakli, 2015; Siddiqui & Ahmad, 2021). Incineration can treat large volumes, gasification has better emission properties, and biogas production has the best results when waste has high organic content.

One of the most engaging aspects involves the development of these types of technology. Engineers are developing hybrid systems that couple recycling technology with energy recovery, especially on tough plastics that are difficult to treat. The choice of technology involves not just the generation of energy; it entails a holistic evaluation of environmental impacts, economics, and regional waste material properties. As the world shifts towards a circular economy (Silva & Prata, 2018), the facilities are evolving into sophisticated systems that mitigate waste disposal issues and, at the same time, meet our energy needs sustainably.

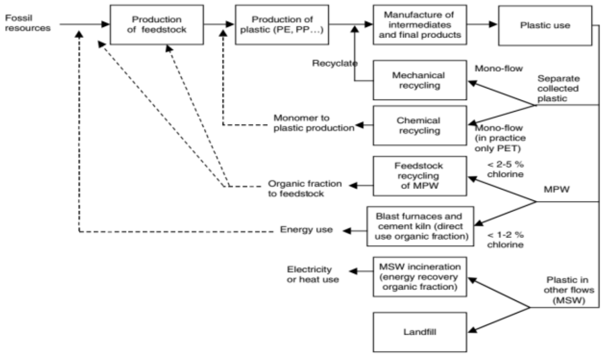

Figure 3: Plastic Waste Process Life Cycle

Source: Achilias et al. (2012)

Regulation of Waste-to-energy power plants in Indonesia

When viewed from the National Strategic Project (NPS) based on Presidential Decree No. 56 of 2018, the state financing map for investment in accelerated development is shown in Figure 3.

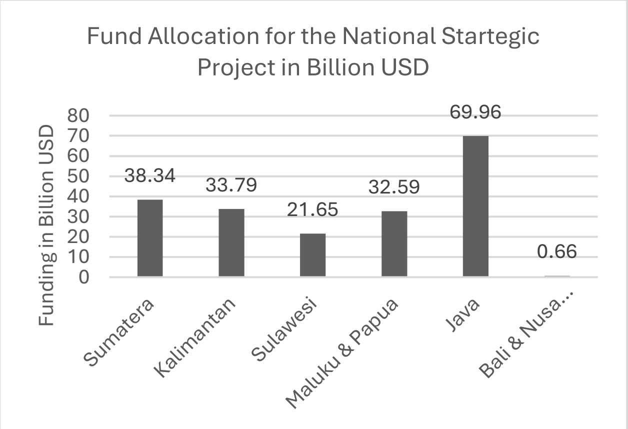

Figure 3: Fund allocation for the national strategic project

The development of Waste-to-Energy Power Plants (PLTSa) must be aligned with its downstream output - electricity generation - requiring coordination with electricity pricing regulations under Presidential Regulation (Perpres) No. 35/2018 on Accelerated Waste Processing Facility Development.

This regulation establishes two key financial mechanisms: (1) a Waste Management Service Fee (BLPS) capped at Rp500,000/ton, funded through the state budget upon proposal by the Minister of Environment and Forestry to the Finance Minister, and (2) a capacity-based electricity tariff scheme—featuring a flat rate of 13.35 US cents/kWh for plants ≤20 MW connected at any voltage level, and a sliding scale formula:

14.54 - [0.076 x WtE Plant Capacity] (1)

The formulation is for plants >20 MW, applicable only to high and medium voltage networks. This policy not only creates economic incentives (Chen & Li, 2022) for waste managers and energy producers but also strengthens the synergy between waste reduction targets (Yuan & Zuo, 2020) and renewable energy transition, demonstrating Indonesia's integrated approach to addressing environmental challenges and energy security through sustainable solutions.

4 DISCUSSION

A comprehensive evaluation of WtE plant implementation requires analysis across three critical dimensions: First, the adequacy of human resources and operational budgets must be assessed, including the availability of qualified technical personnel and sustainable funding mechanisms for plant operations and maintenance. Second, the technological infrastructure requires thorough examination - this involves identifying the specific waste processing technologies employed (whether incineration, gasification, or anaerobic digestion), their operational capacities, and supporting facilities for emissions control and energy generation.

Third, a legal review should identify favourable regulatory provisions that benefit WtE plant developers, particularly incentives under Presidential Decree 35/2018 regarding electricity pricing schemes (13.35 cents/kWh for plants ≤20MW) and waste management service fees (capped at Rp500,000/ton), along with other national and local regulations that may facilitate project development through tax incentives, simplified permitting, or public-private partnership frameworks. This tripartite assessment ensures both technical feasibility and policy alignment for successful WtE plant implementation.

5 CONCLUSION

The evaluation of the policy using the CIPP

(Context, Input, Process, Product) method has been completed, allowing for an assessment of whether the regulation has been implemented effectively. This analysis will be further supported by data gathered from community questionnaires, which capture the techno-socio-economic impacts of Presidential Decree No. 35 of 2018 on residents. Additionally, the implementation's alignment with the policy's original objectives must be examined—whether it has remained on track or deviated from its intended outcomes.

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