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# Utilization of Industrial Machine Waste Heat for Co-Generation Systems

**Mochamad Saleh**
Fakultas Teknik Mesin Universitas Sunan Giri Surabaya

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**ABSTRACT**

Waste heat generated from industrial machinery operations represents a significant yet underutilized energy resource, particularly in developing countries like Indonesia. This thermal energy, if properly harnessed, holds considerable potential for conversion into useful energy through the implementation of co-generation systems. Co-generation refers to the simultaneous production of electricity and heat from a single fuel source. Utilizing this system not only enhances overall energy efficiency but also contributes to reducing greenhouse gas emissions and lowering industrial operating costs. This study explores the potential use of industrial waste heat in Indonesia and assesses the feasibility of applying co-generation systems using locally adapted technologies aligned with national industrial conditions. The research methodology includes a combination of literature review, field observation, and interviews with industry practitioners. Findings reveal that co-generation systems can reduce primary energy consumption by up to 30% and improve thermal efficiency to over 70%. Moreover, this approach offers economic benefits by lowering energy expenses and enhancing industrial productivity. In conclusion, harnessing waste heat through co-generation presents a strategic pathway toward improving national energy efficiency and promoting industrial sustainability. Successful implementation will require strong policy support, fiscal incentives, technological innovation, and the development of skilled human resources.

***Corresponding Author:***

**Mochamad Saleh**

Fakultas Teknik Mesin Universitas Sunan Giri Surabaya
moch.sholeh70@gmail.com

## INTRODUCTION

Indonesia, as a developing nation, has experienced significant industrial growth over the past two decades. This rapid expansion in industrial activity has had a direct impact on national energy consumption. According to data from the Ministry of Energy and Mineral Resources (MEMR), the industrial sector accounted for approximately 37% of total energy consumption in 2020, making it the largest energy consuming sector in the country surpassing transportation, residential, and commercial sectors (Mulyani & Hartono, 2018). Despite this high level of energy use, energy efficiency in Indonesian industries remains relatively low. One of the primary reasons for this inefficiency is the substantial amount of energy wasted as unused heat, or what is known as waste heat (Kartika, 2018).

Waste heat refers to thermal energy produced by various industrial processes such as from engines, boilers, turbines, and chemical reactions that is typically discharged into the environment through chimneys, cooling pipes, or equipment surfaces. This heat is often overlooked as a by-product with little to no value, even though it holds substantial energy potential. The temperature of industrial waste heat can range from 150°C to over 500°C, depending on the type of industry and the processes involved. If managed with appropriate systems, this thermal energy can be reclaimed and converted into usable energy forms, such as electricity or process heat (Ulimaz, 2021).

One promising approach to recover this energy is the implementation of co-generation systems, also known as Combined Heat and Power (CHP) systems. Co-generation enables the simultaneous production of both electricity and useful thermal energy from a single fuel source. This recovered heat can be reused for various industrial needs, including heating, drying, or even cooling through technologies like absorption chillers. Not only does this improve energy utilization, but it also reduces primary energy demand and mitigates greenhouse gas emissions (Ramlan, 2004).

In conventional power generation systems, energy efficiency typically ranges between 30% and 45%, with the remainder lost as waste heat. In contrast, co generation systems can achieve total energy efficiencies exceeding 80% by repurposing the heat for other industrial applications. This significant improvement in performance positions co-generation as a strategic technology for advancing national energy efficiency goals (Gani et al., 2017).

Advanced economies have already adopted co-generation extensively. In Europe, for instance, this system forms a core element of energy efficiency and carbon reduction strategies. Countries like Denmark, Germany, and the Netherlands have integrated co-generation into both industrial infrastructure and urban energy systems, including district heating networks. Similarly, Japan and South Korea have applied the technology across various sectors, ranging from heavy industries to residential and commercial buildings. These cases highlight the adaptability and scalability of co generation technology across different energy needs.

Unfortunately, the deployment of co generation systems in Indonesia remains limited. A major contributing factor is the lack of awareness among industrial stakeholders about the long term benefits of such systems. Many still perceive the upfront investment costs as prohibitive, often without considering the long-term savings in energy and operational expenses. Additionally, challenges persist in the regulatory framework, fiscal incentives, and the availability of suitable technologies and skilled professionals (Plant, 2023).

On the regulatory front, while the Indonesian government has enacted policies promoting energy conservation such as Government Regulation No. 70 of 2009 on Energy Conservation enforcement and practical implementation remain insufficient. Incentives to encourage industries to adopt energy saving technologies like co-generation are still inadequate. Moreover, the misalignment between national energy policies and environmental regulations has further hampered widespread adoption (Yana & Mauliza, 2024).

Nevertheless, global advancements in co-generation technologies present opportunities for Indonesia to adopt and adapt these innovations to local conditions. Academic institutions, research centers, and private entities in the country have begun exploring and developing locally suitable co generation systems that are cost-effective and tailored for small to medium-scale industries. Pilot projects such as micro-CHP systems utilizing biogas or agricultural waste as fuel have already been tested in several regions (Saroinsong et al., 2017).

Given the vast potential of industrial waste heat and the urgent need for improved energy efficiency, investigating the application of co-generation systems is both timely and essential. This study aims to explore the potential for waste heat utilization in Indonesian industries and to assess feasible models for co-generation implementation using locally adapted technologies. Furthermore, the research seeks to identify the technical, economic, and policy-related challenges and opportunities that could influence the adoption of this system.

Ultimately, this paper aspires to contribute to national energy efficiency improvements, strengthen energy security, and support Indonesia's commitment to reducing carbon emissions as outlined in its Nationally Determined Contribution (NDC) under the Paris Agreement. Co-generation should not merely be considered an alternative but rather, a concrete solution for building a more efficient, cost effective, and environmentally sustainable industrial energy future in Indonesia.

## RESEARCH METHODOLOGY

This study employs a descriptive qualitative approach aimed at systematically and factually illustrating both the potential and the challenges of utilizing industrial waste heat for co-generation systems. The primary research methods consist of literature review and case study analysis. The literature review involved examining relevant secondary sources, including accredited national journals, technical reports, and official energy policy documents issued by institutions such as the Ministry of Energy and Mineral Resources (MEMR), the Agency for the Assessment and Application of Technology (BPPT), and the Indonesian Institute of Sciences (LIPI). These sources were critically analyzed to gain insight into the development of co generation technologies, supportive regulatory frameworks, and energy efficiency performance both within Indonesia and internationally.

In addition to the literature review, a case study was conducted at a metal manufacturing plant located in West Java, known to produce significant amounts of waste heat from its machinery and furnace operations. Primary data collection included direct observation of the plant's operational processes and semi-structured interviews with technicians, operations managers, and energy specialists working on-site. Observations focused on identifying specific sources of waste heat, measuring temperature and output volume, and assessing the current energy utilization systems implemented at the facility.

The interviews were designed to explore in depth perspectives from technical staff and management regarding the effectiveness of current waste heat recovery practices, technical obstacles encountered, and their views on the viability of adopting co-generation systems as a long-term solution. Data analysis was conducted using a qualitative analytical framework, involving data reduction, data presentation, and conclusion drawing. The assessment of waste heat utilization potential was based on several key parameters, including thermal energy efficiency, feasibility of c -generation system integration, and estimated energy and operational cost savings.

By using this methodological approach, the study aims to provide a comprehensive overview of the potential for implementing co-generation systems in Indonesia's industrial sector. Furthermore, the findings are intended to offer evidence-based policy recommendations grounded in empirical insights.

## DISCUSSION

### Characteristics of Industrial Waste Heat

Industrial waste heat represents a form of unused thermal energy generated from various high-temperature industrial processes, particularly those involving combustion and prolonged machine operations. Typically, this heat is discharged into the environment via exhaust stacks, cooling systems, or exposed surfaces of machinery operating continuously. The temperature of exhaust gases from internal combustion engines or industrial heating processes can range from 200°C to 600°C, depending on the type of industry and the fuel source employed (Digdoyo et al., 2021). These elevated temperatures highlight a significant opportunity for thermal energy recovery through technologies such as co-generation systems, heat exchangers, or Organic Rankine Cycle (ORC) systems.

A study conducted in a metal manufacturing plant in West Java identified metal smelting furnaces and industrial heaters as the primary sources of waste heat. These systems, which operate continuously as part of the production line, generate an estimated 500 kW of waste heat per day. Unfortunately, most of this energy is still vented into the atmosphere without any form of recovery or reuse. In fact, if harnessed through efficient thermodynamic systems such as ORC units or steam turbines this thermal energy could be repurposed for internal electricity generation, reheating processes, or other industrial energy needs. This would directly enhance overall energy efficiency and reduce operational costs (Permana & Mahardika, 2019).

Several key characteristics determine the feasibility and efficiency of waste heat recovery: temperature, flow rate, continuity, and exhaust gas composition. Higher temperatures and flow rates generally indicate greater potential for energy conversion. Moreover, consistent and continuous heat emissions are essential for maintaining a reliable energy supply. Research by Redaksi (2021) suggests that industrial sectors such as petrochemicals, cement production, metallurgy, and food and beverage manufacturing typically produce stable and large volumes of waste heat, making them ideal candidates for thermal recovery technologies.

Overall, waste heat recovery plays a dual role: it conserves energy and reduces greenhouse gas emissions, thereby contributing to national energy efficiency goals. In light of the global transition toward greener and more sustainable industrial practices, waste heat utilization should be regarded as a strategic element of any national energy conservation agenda.

### The Concept of Co Generation Systems

Co generation, also known as Combined Heat and Power (CHP), is an energy efficiency strategy that has gained increasing traction in industrial sectors particularly in facilities that generate substantial amounts of waste heat. This system captures residual thermal energy from industrial processes, such as exhaust from chimneys, gas turbines, or diesel engines, and converts it into additional usable energy in the form of electricity and/or heat. In terms of energy optimization, co-generation significantly improves fuel utilization while simultaneously reducing both energy intensity and carbon emissions (ELEKTRO, 1999).

The core principle of co-generation lies in transforming heat that would otherwise be released into the atmosphere into productive energy. In practice, co generation systems are typically categorized into two main configurations: back-pressure steam turbines and gas turbines coupled with Heat Recovery Steam Generators (HRSGs). The back-pressure steam turbine operates by utilizing high pressure steam to drive a turbine, after which the lower-pressure steam is redirected to industrial processes requiring heat. Conversely, gas turbine systems with HRSG units harness exhaust heat from the turbine to produce steam, which is then used either for process heating or for generating supplementary electricity (Rozaq & Setyaningsih, 2016).

One of the major advantages of co-generation is its high thermal efficiency, which in some cases can reach up to 80%. This far exceeds the efficiency levels of conventional, separate heat and power generation, which typically ranges from 45% to 50%. Such enhanced efficiency translates into fossil fuel savings of approximately 30%–40% and results in a significant reduction in greenhouse gas emissions and overall air pollution. These outcomes align directly with industrial decarbonization efforts and contribute to Indonesia's Nationally Determined Contribution (NDC) goals for emissions reduction.

Moreover, co generation supports the principles of a circular economy within the energy sector by promoting the reuse of available energy resources. Countries such as those in Europe and Japan have implemented co generation since the 1980s, with Indonesia now beginning to follow suit. Research has identified the food processing, petrochemical, and heavy metal industries as having the highest potential for adopting co-generation, due to their consistent and high thermal and electrical loads (Dahlan, 2022).

Nevertheless, the successful deployment of co-generation systems is heavily dependent on several factors: technological reliability, the availability of initial capital investment, and strong regulatory and policy support favoring energy efficiency. To accelerate the adoption of co-generation technology in Indonesia, a collaborative approach involving the government, industry stakeholders, and research institutions is essential.

**Economic and Environmental Benefits**

The application of co generation systems in industrial settings offers not only technical advantages, such as improved energy efficiency, but also delivers significant economic and environmental benefits. Economically, the reduction in fuel consumption directly translates into lower operational costs particularly in the energy sector, which accounts for a large portion of production expenses in manufacturing industries. A study conducted by Indonesia's Ministry of Energy and Mineral Resources (2020) found that implementing co-generation technology in textile industries across West Java led to an annual energy cost reduction of up to 35%, primarily by utilizing waste heat that would otherwise be discarded.

Moreover, enhanced energy efficiency improves industrial competitiveness by lowering the cost of goods sold and increasing profit margins. In the long term, this supports the sustainability of industrial operations and contributes to national economic stability by reducing reliance on fossil fuels.

From an environmental perspective, co-generation systems play a crucial role in lowering greenhouse gas emissions, particularly carbon dioxide ($CO_2$), a major contributor to global warming. According to data from the Ministry of Environment and Forestry, the industrial sector accounts for approximately 22% of total national emissions. Energy efficiency strategies, such as co-generation, are among the key mitigation measures highlighted in the National Action Plan for Greenhouse Gas Emissions Reduction (RAN-GRK).

**Challenges and Recommendations for Implementation**

The deployment of co-generation technology in Indonesia's industrial sector continues to face various structural and technical challenges. One of the primary obstacles is the limited capability of local industries to design and manufacture integrated power systems such as steam turbines, Organic Rankine Cycle (ORC) units, and Heat Recovery Steam Generators (HRSG). As a result, key components must still be imported, which leads to high capital costs and lengthy procurement processes.

Moreover, fiscal incentives and government support policies for renewable energy and energy efficiency remain relatively modest and lack the aggressive push needed to accelerate adoption. Although there are existing regulations such as Presidential Regulation No. 112 of 2022 on the Acceleration of Renewable Energy Development for Electricity Supply implementation often stalls due to bureaucratic inefficiencies and misalignment between national and local authorities (Putri et al., 2022). Small and medium-sized enterprises (SMEs), which form the backbone of Indonesia's manufacturing sector, typically lack access to financing, technological information, and technical support necessary for adopting co-generation systems.

In addition to infrastructure and policy barriers, the availability of skilled human resources in energy efficiency and thermal power systems remains limited. The scarcity of technical training and the lack of higher education curricula integrating waste heat recovery or co-generation technology represent a long-term constraint to building industrial readiness for energy transition (Firdaus, 2022). The successful implementation of this technology heavily depends on the availability of experts who can design, operate, and maintain the systems efficiently and effectively.

To overcome these challenges, several strategic recommendations are proposed. First, stronger fiscal incentives should be introduced, such as tax holidays, initial subsidies for waste heat recovery technologies, and feed-in tariff schemes for electricity generated through co-generation. Second, it is crucial for the government to foster stronger collaboration between industry players, research institutions, and universities to develop localized technologies tailored to Indonesian industrial needs. Third, a national roadmap for industrial waste heat utilization should be developed, complete with performance targets, budget allocations, and the establishment of national technical training centers to support workforce development. With a coordinated and comprehensive approach, the implementation of co-generation systems in Indonesia has the potential to contribute significantly to building an energy-efficient, low-emission, and globally competitive industrial sector.

## CONCLUSION

The utilization of industrial waste heat, particularly through co-generation systems, presents a substantial opportunity to enhance energy efficiency while supporting environmental sustainability. Waste heat sources such as exhaust gases from chimneys or high-temperature machine surfaces still contain recoverable thermal energy that can be converted into electricity or reused in production processes. Co-generation technologies, including back-pressure steam turbines and gas turbines equipped with Heat Recovery Steam Generators (HRSG), have proven capable of boosting overall energy efficiency to as high as 80%, while simultaneously lowering fossil fuel consumption and reducing greenhouse gas emissions.

Beyond the technical advantages, the adoption of these systems also provides notable economic benefits, including reduced operational costs and improved industrial competitiveness. However, widespread implementation in Indonesia continues to face several challenges such as limited access to advanced technology, insufficient fiscal incentives, and a shortage of skilled human resources. To overcome these obstacles, stronger collaboration is needed between government agencies, industry players, and academic institutions to facilitate technology transfer, develop supportive policies, and enhance workforce capacity through targeted training programs. Therefore, co-generation stands as a strategic solution for sustainable industrial energy management and aligns with national commitments to energy efficiency and climate change mitigation.

## REFERENCES


Dahlan, R. (2022). Ekonomi sirkular dan pembangunan berkelanjutan. Jejak Pustaka.

Digdoyo, A., Surawan, T., Djamruddin, D., Yuniati, E., & Saputra, A. A. (2021, August). Pemanfaatan Limbah Panas Dari Internal Combustion Engine Sebagai Energi Terbarukan Melalui Proses Pemulihan Gas Buang. In Proceeding Technology of Renewable Energy and Development Conference (Vol. 1).

ELEKTRO. (1999). Prospek Bisnis dan Perkembangan Teknologi Cogeneration. Majalah ELEKTRO, No. 27, Tahun VI, Agustus 1999. Jakarta: ELEKTRO Online. Diakses dari https://www.elektroindonesia.com/elektro/ut27.html.

Firdaus, I. (2022). Dukungan kebijakan dan peraturan perundang-undangan untuk mengakselarasi aktivitas riset energi baru terbarukan di Indonesia. Jurnal Rechts Vinding: Media Pembinaan Hukum Nasional, 11(3).

Gani, F. Q., MAGISTER, P., & TERBARUKAN, B. K. R. E. (2017). Analisis Keberlanjutan Energi Pada Industri Gula Menggunakan Multi-Criteria Decision Analysis (MCDA) (Doctoral dissertation, Institut Teknologi Sepuluh Nopember).

Indonesia. Departemen Energi dan Sumberdaya Mineral. (2020). Rencana strategis Kementerian Energi dan Sumber Daya Mineral, 2020-2024. Kementerian Energi dan Sumber Daya Mineral.

Kartika, S. A. (2018). Analisis konsumsi energi dan program konservasi energi (studi kasus: gedung perkantoran dan kompleks perumahan TI). Sebatik, 22(2), 41-50.

Mulyani, D., & Hartono, D. (2018). Pengaruh efisiensi energi listrik pada sektor industri dan komersial terhadap permintaan listrik di Indonesia. Jurnal Ekonomi Kuantitatif Terapan, 11(1), 1-17.

Permana, D. I., & Mahardika, M. A. (2019). Pemanfaatan Panas Buang Flue Gas Pltu Dengan Aplikasi Siklus Rankine Organik. Barometer, 4(2), 197-202.

Plant, C. G. (2023). Implementasi E-Monitoring dan E-Logsheet pada Pabrik Gresik Gas Co-Generation Plant PT Pupuk Indonesia Utilitas pada Package Boiler Implementation of E-Monitoring and E-Logsheet at Gresik Gas Co-Generation Plant PT Pupuk Indonesia Utilitas in Package Boiler. Jurnal Otomasi Kontrol dan Instrumentasi Vol, 15, 1.

Putri, D. S., Arsalan, H., & Ulfa, M. (2022). Partisipasi Publik Dalam Kebijakan Investasi Energi Terbarukan Di Indonesia: Perspektif Demokrasi Energi (Public Participation In Renewable Energy Investment Policy In Indonesia: A Democratic Energy Perspective). Jurnal Rechts Vinding: Media Pembinaan Hukum Nasional, 11(3), 473-491.

Ramlan, M. (2004). Teknologi Combined Heat and Power Di Indonesia. Jurnal Teknologi Lingkungan BPPT, 5(1), 148922.

Redaksi, T. (2021). Naskah Prosiding Seminar Nasional BSKJI 2021. Indonesian Journal of Industrial Research, 453583.

Rozaq, I. A., & Setyaningsih, N. Y. D. (2016). Perencanaan Penghematan Energi Dengan Sistem Kogenerasi/Combine Heat And Power (CHP) Capstone Microturbine C-30 Di PT Dua Kelinci. Jurnal SIMETRIS, 7(2).

Saroinsong, T., Thomas, A., & Mekel, A. N. (2017). Prosiding: Desain Dan Pembuatan Turbin Ulir Archimedes Untuk Pembangkit Listrik Tenaga Mikrohidro. In Prosiding Seminar Nasional Terapan Riset Inovatif (Sentrinov) (Vol. 3, No. 3, pp. 159-168). Politeknik Negeri Malang.

Ulimaz, A. (2021). Pengembangan Bahan Ajar Berbasis Inkuiri Terbimbing pada Mata Kuliah Teknologi Pengolahan Limbah. Jurnal Pendidikan Hayati, 7(3).

Yana, S., & Mauliza, P. (2024). Energi Terbarukan dalam Perspektif Bio-Ekonomi: Analisis Terpadu Dampak Lingkungan dan Manfaat Finansial. Jurnal Serambi Engineering, 9(2).