



Effectiveness Analysis of BIOMOL and Light Trap Innovations Based on Environmental Impact Verification in the Wanua Wailan CSR Program in Pangolombian and Tondangow Subdistricts

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Abstract

Background The Wanua Wailan CSR program implemented by PT PLN Indonesia Power UP PLTP Lahendong in Pangolombian and Tondangow Subdistricts focuses on strengthening the circular economy through restorative agriculture and organic waste management. The main challenges include land degradation caused by the excessive use of chemical fertilizers and pesticides, as well as unmanaged organic waste. This study aims to analyze the effectiveness of BIOMOL and Light Trap innovations based on environmental impact verification in supporting the sustainability of the CSR program.

Methods This research employs a mixed-methods approach, combining quantitative analysis through data on the reduction of chemical fertilizer and pesticide usage, as well as estimated GHG emission reductions with qualitative methods, including interviews, field observations, and program documentation.

Results The results indicate that BIOMOL contributes to improving soil quality and reducing dependence on chemical inputs, while the Light Trap proves effective as an environmentally friendly pest control technology powered by renewable energy. Environmental impact verification shows a reduction in emissions of 100.4357 tons CO₂eq per year.

Conclusion The integration of BIOMOL and Light Trap has been proven effective as a CSR innovation grounded in a socio-ecological economic approach. The findings underscore the importance of appropriate technology innovation and multi-stakeholder collaboration in enhancing the environmental sustainability impact of CSR programs.

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Keywords

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Introduction

Current global environmental challenges such as the increasing volume of household and industrial waste, agricultural land degradation due to the excessive use of chemical fertilizers and pesticides, and rising greenhouse gas (GHG) emissions have become critical issues that directly affect the sustainability of community livelihoods. These conditions necessitate a development approach that is not solely economically oriented but also emphasizes ecological and social sustainability. In this context, Corporate Social Responsibility (CSR) is no longer perceived merely as a form of social assistance, it has evolved into a strategic instrument for companies to drive socio-ecological transformation through participatory, impact oriented community development approaches. The implementation of CSR in Indonesia is regulated under several legal frameworks, including ([Law No. 40 of 2007](#)) concerning Limited Liability Companies. Article 1, paragraph 3 of the law defines Social and Environmental Responsibility as a company's commitment to participate in sustainable economic development in order to improve the quality of life and the environment, benefiting the company itself, local communities, and society at large. Therefore, effective CSR programs are expected to deliver tangible contributions to environmental improvement while simultaneously enhancing the economic and social independence of communities ([Asmara et al., 2023](#); [Hasibuan et al., 2023](#); [Setiawati et al., 2022](#)).

PT PLN Indonesia Power PLTP Lahendong Units 1 & 2 initiated the Wanua Wailan CSR Program (Wadah Menuju Sejahtera melalui Wawasan Inisiatif Lingkungan dan Pertanian / A Platform for Prosperity through Environmental and Agricultural Initiatives). The program is implemented in Pangolombian and Tondangow Subdistricts and represents a social innovation that integrates restorative agriculture, integrated waste management, renewable energy utilization, and family empowerment within a green circular economy framework. One of the program's key strengths lies in its ability to transform waste into productive resources through a circular economy approach. The processed waste includes organic and inorganic waste, PVC waste, wood packaging waste, and residual water from the cooling tower. This approach demonstrates that waste should not be viewed merely as an environmental burden, but rather as a productive input that supports green agriculture and environmentally based MSME development ([Toplicean & Datcu, 2024](#)). As a result, the Wanua Wailan CSR Program is capable of establishing a circular economic system that not only reduces waste but also creates added economic value for the community through the sustainable use of local resources.

One of the key innovations within the Wanua Wailan CSR Program is BIOMOL (Lahendong Local Microorganism Biocontrol), a local microorganism solution developed from the utilization of residual water from the Lahendong geothermal power plant cooling tower. BIOMOL contains microorganisms such as *Lactobacillus* sp. and *Bacillus* sp., which play a role in accelerating organic matter decomposition, enhancing soil fertility, and suppressing pathogens, thereby functioning as a biocontrol agent in environmentally friendly agricultural systems. This innovation is highly relevant in addressing soil quality issues resulting from land degradation caused by the excessive use of chemical fertilizers and pesticides. BIOMOL is positioned as a restorative agricultural solution that enhances soil nutrient use efficiency while reducing dependence on chemical-based farming. In addition to BIOMOL, the Light Trap innovation has been developed as an energy efficient and environmentally friendly pest control technology. The Light Trap is utilized to reduce the use of chemical pesticides by

controlling insects through energy saving LED light and the use of reusable materials. This innovation not only serves as a pest prevention tool but also acts as an ecological education medium that encourages farmers to transition toward low pesticide, technology based agricultural systems. Thus, BIOMOL and Light Trap represent two strategic innovations within the Wanua Wailan CSR Program that are directly aligned with climate change mitigation goals, sustainable agriculture, and environmental quality improvement ([Ali & Rahman, 2024](#); [Chaturvedi et al., 2020](#); [Firmansyah et al., 2016](#); [Pratama et al., 2026](#)).

The Wanua Wailan CSR Program is aligned with the concept of a circular economy, which emphasizes resource efficiency through reuse, recycling, and waste reduction. This concept reframes waste not as residual material to be discarded, but as an alternative resource that can be reprocessed and utilized. Its implementation is particularly relevant in the agricultural sector. The concept of restorative agriculture is also highly applicable, as it emphasizes improving soil quality and ecosystem health through the use of organic fertilizers, local microorganisms, and the reduction of chemical fertilizers and pesticides that can damage soil structure over the long term ([Morseletto, 2020](#); [Pomoni et al., 2024](#)).

Organic waste management within this framework adopts two commonly used approaches bioconversion (such as the use of maggots) and decomposition methods like composting and vermicomposting. Both approaches not only help reduce environmental burdens but also generate economic benefits for communities. Vermicomposting, in particular, produces high-value organic fertilizer that improves soil structure and enhances agricultural productivity ([Goldan et al., 2023](#)). This is consistent with the Wanua Wailan CSR Program, which aims to convert organic waste into fertilizer to support soil fertility restoration and reduce farmer's dependence on chemical inputs. Meanwhile, the reuse of inorganic waste as agricultural infrastructure helps reduce environmental pollution and lowers GHG emissions that would otherwise result from waste burning. Therefore, the BIOMOL and Light Trap innovations can be understood as forms of appropriate, community based technology that support environmental sustainability while fostering healthier and more efficient agricultural production systems.

Although BIOMOL and Light Trap have been implemented within the Wanua Wailan CSR Program, further research is required to specifically assess their effectiveness based on environmental impact verification ([Heru Kurniawan et al., 2025](#); [Pratama et al., 2026](#); [Telaumbanua et al., 2025](#); [Wahyuni et al., 2022](#)). This is essential because the success of CSR programs should not be evaluated solely based on activity outputs, but also on measurable outcomes and impacts, both quantitatively and qualitatively. Existing findings indicate that the Wanua Wailan CSR Program has contributed to reducing GHG emissions through various environmental interventions.

Based on this background, this study focuses on analyzing the effectiveness of BIOMOL and Light Trap innovations within the Wanua Wailan CSR Program implemented in Pangolombian and Tondangow Subdistricts. The study examines the extent to which BIOMOL contributes to reducing environmental impacts, particularly through GHG emission reductions and land restoration, based on verified environmental impact data. In addition, the study analyzes the role of the Light Trap as an environmentally friendly pest control innovation that reduces reliance on chemical pesticides. Furthermore, it explores how the integration of these two innovations strengthens a community development-based CSR model aligned with the principles of a green circular economy and sustainable

development.

Thus, this study is expected to provide academic contributions by strengthening the discourse on transformative CSR based on environmental innovation. It also serves as a practical reference for companies and stakeholders in developing CSR programs with measurable impacts. Moreover, the study offers a basis for recommendations to improve similar programs, particularly in evaluating the effectiveness of local microorganism-based innovations and environmentally friendly pest control technologies in supporting sustainable development. Ultimately, this research is expected to reinforce the replicability of socially driven, circular economy-based CSR models in other regions facing similar challenges.

Methods

This study employs a mixed methods approach, integrating both quantitative and qualitative data collection conducted simultaneously to obtain a comprehensive understanding of the effectiveness of BIOMOL and Light Trap innovations within the Wanua Wailan CSR Program ([Cresswell & David Cresswell, 2018](#)). This approach is selected because program effectiveness cannot be assessed solely based on numerical indicators, such as GHG emission reductions derived from environmental impact verification, but must also be understood from the social context of the community, the innovation implementation process, and the level of community engagement in building a circular economic system.

The research adopts a case study method focusing on the implementation of the Wanua Wailan CSR Program in Pangolombian and Tondangow Subdistricts. The object of the study includes the BIOMOL and Light Trap innovations and their contributions to reducing environmental impacts within agricultural systems and waste management practices. The research subjects consist of stakeholders directly involved in the program. Informants were selected using a purposive sampling technique, with key criteria including active involvement in program implementation, a clear understanding of BIOMOL and Light Trap applications, and direct experience of environmental and economic changes resulting from the Wanua Wailan CSR Program.

Data collection techniques combine both quantitative and qualitative approaches. Primary data were obtained through document analysis, including program reports and ongoing program documentation, particularly environmental impact verification documents that detail GHG emission reduction achievements. Field data collection was conducted through direct observation of beneficiary groups to examine the practical application of the innovations. In-depth interviews were also carried out with program managers and community beneficiaries to explore their perceptions, experiences, and challenges during program implementation. Additionally, focus group discussions (FGDs) were conducted involving community members, academics, local government representatives, and private sector stakeholders to capture diverse perspectives on program challenges and development opportunities. Supporting data were gathered through literature reviews of scientific journals, books, and research reports related to circular economy concepts, restorative agriculture, and productive waste management, serving as the theoretical foundation for analyzing the research findings ([Wright, 2007](#)).

Data analysis was conducted integratively in accordance with the mixed methods design. Quantitative data were analyzed using a descriptive approach based on environmental

impact verification indicators. Meanwhile, qualitative data were analyzed using descriptive qualitative analysis. The results from both quantitative and qualitative analyses were then compared and integrated during the final interpretation stage to produce comprehensive conclusions regarding the effectiveness of BIOMOL and Light Trap innovations, based on environmental impact outcomes as well as the dynamics of community development implementation within the Wanua Wailan CSR Program in Pangolombian and Tondangow Subdistricts.

Results and Discussion

Overview of the Wanua Wailan CSR Program Implementation

The Wanua Wailan CSR Program implemented by PT PLN Indonesia Power PLTP Lahendong Units 1 & 2 represents a social innovation ecosystem that integrates waste management, restorative agriculture, renewable energy utilization, and environmental education into an interconnected system. This highlights that the program's key strength lies in its ability to build a socio-ecological circular system, which strengthens the social dimension through collaboration among beneficiary groups within a mutually supportive empowerment ecosystem. In this context, organic waste that was previously burned by the community is transformed into productive inputs through composting, vermicomposting, and maggot cultivation. Inorganic waste such as PVC and plastic, which typically pollutes the environment, is also converted into environmentally friendly agricultural infrastructure. Meanwhile, residual water from the Lahendong cooling tower is utilized in the development of BIOMOL, a local microorganism innovation that enhances agricultural resilience.

This model reflects a shift from CSR as mere aid distribution toward CSR as a mechanism for community empowerment, capacity building, and the development of sustainable systems that can be replicated in other regions. Therefore, the Wanua Wailan CSR Program not only generates activity outputs but also establishes a socio-ecological production system capable of delivering measurable environmental impacts alongside broader socio-economic benefits.

Effectiveness of BIOMOL Innovation in Emission Reduction

The BIOMOL innovation (Lahendong Local Microorganism Biocontrol) has proven to be a key intervention in supporting GHG emission reductions in the agricultural sector. BIOMOL is developed from residual cooling tower water enriched with local microorganisms and functions both as a biocontrol agent and an organic fertilizer. Based on the findings, the reduction in chemical pesticide use through the application of BIOMOL and vermicompost has resulted in a decrease of 2.4300 tons CO₂e per year. Additionally, the substitution of chemical urea fertilizer with BIOMOL and vermicompost has contributed to a further reduction of 4.0975 tons CO₂e per year. These figures indicate that BIOMOL is not merely a technical agricultural innovation but also a concrete climate mitigation strategy, as it reduces emissions originating from chemical based agricultural inputs.

From an interpretative perspective, the effectiveness of BIOMOL extends beyond emission reduction figures to encompass a shift in agricultural management paradigms. BIOMOL encourages farmers to transition from dependence on chemical fertilizers and pesticides toward locally resource based approaches. This contributes to both ecological resilience and farmers' economic resilience by lowering production costs. Academically, these findings reinforce restorative agriculture theory, which emphasizes the importance of improving soil

quality through organic matter and microorganisms as a long term strategy for maintaining land productivity. BIOMOL also demonstrates how simple, community-based biotechnology can serve as an effective climate change mitigation tool, indicating that emission reductions can be achieved not only through large-scale industrial technologies but also through locally driven, community-based innovations.

Furthermore, these findings align with the concept of a circular economy, as BIOMOL originates from the utilization of industrial waste specifically cooling tower water into a valuable agricultural input. This demonstrates that corporate waste can be repositioned as a productive resource when integrated with community empowerment systems. The Wanua Wailan CSR Program thus serves as a model capable of addressing corporate Life Cycle Assessment (LCA) hotspots through community-based interventions. In this sense, BIOMOL can be understood as an innovation that bridges corporate sustainability interests with community needs, emission reduction and local economic strengthening.

Effectiveness of Light Trap as an Environmentally Friendly Pest Control Innovation

The Wanua Wailan CSR Program has also developed the Light Trap innovation as a pest control technology utilizing LED light and renewable energy. Based on the study results, the Light Trap is positioned as a low-pesticide agricultural strategy that contributes to reducing chemical pesticide use. This innovation forms part of a broader emission reduction strategy through environmentally friendly agriculture, including the use of botanical pesticides and technology based pest control. Thus, the Light Trap is not merely a technical tool but an ecological innovation that supports behavioral transitions among farmers toward healthier and more sustainable farming systems.

The findings show that the Light Trap strengthens the preventive dimension of agricultural management. Its use shifts farmers' approaches from reactive addressing pest infestations after they occur using chemical pesticides to preventive, by controlling pest populations ecologically from the outset. The Light Trap also contributes to the literature on sustainable agriculture by linking technological application with behavioral change, environmental education, and CSR based facilitation systems. In this context, the Light Trap can be understood as an innovation that reinforces sustainable agriculture practices through reduced chemical use, biodiversity protection, and energy efficiency based on renewable energy sources.

The implementation of the Light Trap within the Wanua Wailan CSR Program demonstrates that CSR is not limited to infrastructure development or equipment provision, but can position technology as a driver of social change. It serves as an educational tool, showing communities that pest control does not have to rely on chemical pesticides that can harm soil and ecosystems. Therefore, this innovation provides theoretical contributions to strengthening community development approaches based on appropriate technology.

Environmental Impact as Evidence of Community Development Based CSR Effectiveness

The study results indicate that the Wanua Wailan CSR Program has generated various forms of GHG emission reductions through activities such as organic waste processing, vermicompost utilization, reduction of chemical fertilizers and pesticides, and the conversion of inorganic waste into agricultural infrastructure. One notable achievement is the reduction

of 0.4827 tons CO₂e per year from processing inorganic waste into agricultural infrastructure. This outcome demonstrates that the program has successfully transformed community behavior from burning waste to adopting productive waste management practices that support agriculture.

These findings highlight a direct relationship between waste management innovation and climate change mitigation contributions. They demonstrate that community development based CSR programs can form part of local decarbonization strategies. The results reinforce the argument that community empowerment can generate tangible ecological impacts when programs are designed as integrated systems rather than isolated projects. The Wanua Wailan CSR Program successfully integrates inputs (waste), processes (community-based management), and outputs (agricultural products and emission reductions). Additionally, the establishment of the Rumah Pupuk Kabasaran as both a processing and learning center indicates that innovation extends beyond production, evolving into a community based innovation hub.

Research Implications

The effectiveness of BIOMOL and Light Trap innovations in the Wanua Wailan CSR Program demonstrates that simple, locally developed technologies can generate significant ecological impacts when supported by strong community institutional systems and circular economic value chains. These findings imply that strengthening CSR through environmental impact verification can serve as a more credible and relevant evaluation approach in the context of corporate sustainability demands.

Moreover, the Wanua Wailan CSR Program illustrates that integrating corporate waste into community based agricultural innovation is a replicable strategy for addressing ESG demands and measurable emission mitigation. Therefore, this study not only provides conclusions regarding the effectiveness of BIOMOL and Light Trap innovations but also contributes conceptually to the development of a transformative CSR model based on circular economy principles and community development with verified environmental impacts.

Conclusion

The Wanua Wailan CSR Program implemented in Pangolombian and Tondangow Subdistricts incorporates the BIOMOL and Light Trap innovations, both of which have proven effective in supporting environmentally friendly agricultural practices and contributing to the reduction of greenhouse gas (GHG) emissions. The BIOMOL innovation has been shown to reduce community dependence on chemical fertilizers, thereby contributing to lower GHG emissions as recorded in the program's verified impact results. Meanwhile, the Light Trap serves as a pest control technology that supports the reduction of chemical pesticide use, fostering the development of sustainable agriculture.

These findings address the research objective by demonstrating that the effectiveness of both innovations is not only reflected in their environmental impact outcomes but also in their integration within the circular economy system of the Wanua Wailan CSR Program, which transforms waste into productive resources. The study implies that community development-based CSR can serve as a measurable environmental mitigation strategy when supported by appropriate innovations and community based management mechanisms.

From a practical perspective, the results emphasize the importance of environmental impact verification as an evaluation instrument for CSR effectiveness, ensuring that programs move beyond activities and deliver demonstrable, outcome-based impacts.

References

- [Ali, I., & Rahman, A. \(2024\). Environmental Degradation: Causes, Effects and Solutions. *International Journal For Multidisciplinary Research*, 6\(3\). <https://doi.org/10.36948/ijfmr.2024.v06i03.20366>](#)
- [Asmara, T. T. P., Murwadji, T., Kartikasari, & Afriana, A. \(2023\). Corporate Social Responsibility and Cooperatives Business Sustainability in Indonesia: Legal Perspective. *Sustainability*, 15\(7\), 5957. <https://doi.org/10.3390/su15075957>](#)
- [Chaturvedi, G., Chakraborty, M., & -, A. \(2020\). Impacts of agricultural pollutants on water resources and their management. In *Advances in Environmental Pollution Management: Wastewater Impacts and Treatment Technologies* \(pp. 29–40\). *Agro Environ Media - Agriculture and Environmental Science Academy*, Haridwar, India. <https://doi.org/10.26832/aesa-2020-aepm-03>](#)
- [Cresswell, J. W., & David Cresswell, J. \(2018\). *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches* \(five editi\). Sage Publisher.](#)
- [Firmansyah, A., Jamilah, L., & Ratna Suminar, S. \(2016\). ALTERNATIVE MODEL FOR CORPORATE SOCIAL AND ENVIRONMENTAL RESPONSIBILITY: ACTIVE, PARTICIPATIVE, AND JUST. *Mimbar Hukum - Fakultas Hukum Universitas Gadjah Mada*, 28\(1\), 186. <https://doi.org/10.22146/jmh.15863>](#)
- [Goldan, E., Nedeff, V., Barsan, N., Culea, M., Panainte-Iehadus, M., Mosnegutu, E., Tomozei, C., Chitimus, D., & Irimia, O. \(2023\). Assessment of Manure Compost Used as Soil Amendment A Review. 1–16.](#)
- [Hasibuan, A., Putri Nasution, S., Triyoolanda, A., & Rahman, I. \(2023\). Community and Stakeholder Participation in the Implementation of Corporate Social Responsibility Programs, Its Impact on Rural Communities. *Journal of Industrial Engineering and Management*, 1\(1\), 12–20. <https://doi.org/10.52088/jaiem.v1i1.4>](#)
- [Heru Kurniawan, Andayanie, W. R., & Martono, D. S. \(2025\). Efektivitas Tinggi Tiang dan Warna Cahaya pada Light Trap untuk Pengendalian Hama Padi \(*Oryza sativa* L.\). *JURNAL AGRI-TEK : Jurnal Penelitian Ilmu-Ilmu Eksakta*, 26\(2\), 20–28. <https://doi.org/10.33319/agtek.v26i2.192>](#)
- [Morseletto, P. \(2020\). Restorative and regenerative: Exploring the concepts in the circular economy. *Journal of Industrial Ecology*, 24\(4\), 763–773. <https://doi.org/10.1111/jiec.12987>](#)
- [Pomoni, D. I., Koukou, M. K., Vrachopoulos, M. G., & Vasiliadis, L. \(2024\). Circular economy: A multilevel approach for natural resources and wastes under an agri-food perspective. *Water-Energy Nexus*, 7, 103–123. <https://doi.org/10.1016/j.wen.2023.12.003>](#)
- [Pratama, B. K. H., Ole, A. N., Prasetya, Y., & Yuniasih, A. W. \(2026\). Implementation of Light Trapping with Solar Panels in Controlling Rice \(*Oryza sativa*\) Pests. *Qriset Indonesia Journal of Agricultural Science*, 1\(1\), 26–33. <https://doi.org/10.33545/2618060X.2024.v7.i3i.497>](#)
- [Republic of Indonesia. \(2007\). Law No. 40 of 2007 concerning Limited Liability Companies \(Undang-Undang No. 40 Tahun 2007 tentang Perseroan Terbatas\). Jakarta: Government of Indonesia](#)
- [Setiawati, D., Ayu Astutik, Z., Soepatini, S., Alfateh, H., & Gladya Naranta, E. H. \(2022\). Corporate Social Responsibility Supervisors in Indonesia: Analysis of Local Government Regulation in 10 Province in Indonesia. *Varia Justicia*, 18\(2\), 97–113. <https://doi.org/10.31603/variajusticia.v18i2.7022>](#)
- [Telaumbanua, M., Khotimah, K., Wisnu, F. K., Rahmawati, W., Haryanto, A., & Fil'aini, R. \(2025\). Development of Solar-Powered Automatic Pest Trap for Rice Cultivation Plants in](#)

- [Indonesia. Journal of Engineering and Technological Sciences, 57\(4\), 492–504.
https://doi.org/10.5614/j.eng.technol.sci.2025.57.4.5](#)
- [Toplicean, I. M., & Datcu, A. D. \(2024\). An Overview on Bioeconomy in Agricultural Sector, Biomass Production, Recycling Methods, and Circular Economy Considerations.
Agriculture \(Switzerland\), 14\(7\)](#)
- [Wahyuni, S., Rendo, D., & Sarah, M. \(2022\). PENERAPAN TEKNOLOGI LIGHT TRAP PADA PERTANAMAN PADI DI DESA DETUSOKO BARAT, NUSA TENGGARA TIMUR. JMM \(Jurnal Masyarakat Mandiri\), 6\(1\), 217.
https://doi.org/10.31764/jmm.v6i1.6259](#)
- [Wright. \(2007\). Qualitative Research \(pp. 1–40\).](#)

