ASEAN ENERGY AWARDS 2023

ASEAN Energy Awards 2023: Best Practices in Renewable Energy Projects

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ASEAN Energy Awards 2023: Best Practices in Renewable Energy Projects

About ACE

Established in 1999, the ASEAN Center for Energy (ACE) is an intergovernmental organisation within the ASEAN structure that independently represents the interests of the 10 ASEAN countries in the energy sector. The Centre accelerates the integration of energy strategies within ASEAN by providing relevant information and expertise to ensure the necessary energy policies and programmes are in harmony with economic growth and the region's environmental sustainability. It is guided by a Governing Council composed of senior officials and energy leaders from each ASEAN Member State and a representative from the ASEAN Secretariat. Hosted by Indonesia's Ministry of Energy and Mineral Resources (MEMR), its office is located in Jakarta, Indonesia.

Acknowledgements

This report is developed by the ASEAN Centre for Energy (ACE), under the overall guidance of Dr Nuki Agya Utama – Executive Director of the ASEAN Centre for Energy (ACE), Mr Beni Suryadi – Acting Manager of the Sustainable and Renewable Energy Team (ACE), and Mr Christopher G. Zamora – Senior Manager of APAEC (ACE) to support the regional target of a 23% renewable energy (RE) share in total primary energy supply by 2025 and a 35% RE share in total installed capacity by 2025 under the ASEAN Plan of Action for Energy Cooperation (APAEC) Phase II (2021 – 2025).

The writing of the report was completed by Ms Zahrah Zafira – Associate Research Analyst (ACE), Ms Monika Merdekawati – Research Analyst (ACE), Mr Tung Phuong – Senior Program Officer-USAID Smart Power Program (ACE) , Ms Dynta Trishana Munardy – Officer of APAEC (ACE) and Mr Rizky Aditya Putra – Senior Officer of APAEC (ACE).

The review and valuable suggestions were provided by other senior management and staff at ACE, as well as the Renewable Energy Sub-Sector Network (RE-SSN) Focal Points and the Board of Judges of the ASEAN RE Project Awards 2023. The Members of the Board of Judges for the ASEAN Renewable Energy Awards 2023 are listed below:

Country	Principal Judges	Alternate Judges
Brunei Darussalam	Mr Hasbur Rahman Bin Yahya	Ms Dalina Rasyidah Danan
Cambodia	Mr San Sereyvathna	Mr Chiphong Sarasy
Indonesia	Mr Praptono Adhi Sulistomo	Mr Trois Dilisusend
Lao PDR	Ms Alounny Phommakone	Ms Viengsavanh Inthirath
Malaysia	Mr Saiful Hakim bin Abdul Rahman	Dr Zawani binti Zainuddin
Philippines	Ms Ruby B De Guzman	Ms. Liza V. Pangilinan
Singapore	Mr Darryl Ang	Mr Brian Tham
Thailand	Ms Rungrawee Yingyuad	Dr Yaowateera Achawangkul

Foreword

In a time marked by the pressing need to shift towards sustainable energy solutions, and also enhance regional energy security, the importance of renewable energy is undeniable. While nations confront the task of reducing their dependence on fossil fuels, they must, at the same time, search for cleaner and more sustainable alternatives. These quests within the ASEAN region illuminate avenues that could guide us towards a prosperous future with both environmental sustainability and enhanced energy resilience.

The ASEAN RE Awards 2023 emerged as a pivotal media in the region's dynamic energy evolution landscape. It reflects the region's commitment to the renewable energy agenda and serves as a platform for recognising and promoting outstanding contributions to renewable energy across the ASEAN region. Its purpose is clear: to encourage innovation, foster collaboration and celebrate the champions of sustainable energy solutions. At its core, the ASEAN RE Awards epitomise our shared vision of a region where renewable energy plays a pivotal role in shaping a sustainable future.

This report is a testament to our unwavering dedication to catalysing energy strategies into collective action. It offers a comprehensive insight into the outstanding projects and initiatives that came to light in this year's competition, and reiteratess the need for countries to transition to cleaner energy sources, reduce emissions and enhance energy security. Beyond recognising exemplary projects, this report delves into the wider implications and lessons that they offer and underscores the importance of embracing renewable energy technologies, fostering community engagement and promoting cross-sectoral collaboration.

The awards are more than just a celebration of achievements; they signify a resounding partnership within ASEAN and beyond. We are poised to shape a future defined by sustainable energy progress, promoting our commitment to regional energy cooperation and sustainability. The journey towards a cleaner and greener energy landscape is an ongoing process, and the ASEAN RE Awards and this report are milestones along the way.

We extend our heartfelt gratitude to all the participants, experts and organisations that have played a significant role in making the ASEAN RE Awards 2023 a reality. Their dedication and innovation exemplify this initiative's spirit of collaboration and progress.

As the ASEAN Plan of Action for Energy Cooperation (APAEC) Phase II: 2021-2025 charts an ambitious path towards a substantial share of renewable energy in the total primary energy supply by 2025, this report not only addresses the present challenges but also contributes significantly to the broader regional energy agenda. It aligns with the aspirations of a region committed to harnessing its renewable potential. Together, let us embark on this journey to a more sustainable future, guided by the beacon of the ASEAN RE Awards and fuelled by the collective efforts to shape a world powered by renewable energy.

Dr Nuki Agya Utama
Executive Director of ASEAN Centre for Energy (ACE)

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Abbreviations

ACE	ASEAN Centre for Energy
AEC	Alternative Energy Consumption
AEDP	Alternative Energy Development Plan
AEDS	ASEAN Energy Database System
AEO7	The 7th ASEAN Energy Outlook
AIMS	ASEAN Interconnection Masterplan Study
AMEM	ASEAN Ministers on Energy Meeting
AMS	ASEAN Member States
APAEC	ASEAN Plan of Action for Energy Cooperation
ASEAN	The Association of Southeast Asian Nations
BOJ	Board of Judges
CAPEX	Capital Expenditure
CHP	Combined Heat and Power
COD	Chemical Oxygen Demand
CO_2	Carbon Dioxide
CH_4	Methane
CFC	Chlorofluorocarbons
CPO	Crude Palm Oil
CSR	Corporate Social Responsibility
ESC	Eastern Sugar Corporation
GHG	Greenhouse Gas
HVO	Hydrotreated Vegetable Oil
IDR	Indonesian Rupiah
IoT	Internet of Things
ISCC	International Sustainability Carbon Certification
IRR	Internal Rate of Return
ISO	International Organization for Standardization
$KgCO_2e$/dry ton CPO	Kilograms of Carbon Dioxide Equivalent per Dry Ton of Crude Palm Oil
ktoe	Thousand ton of oil equivalent
kWh	Kilowatts peak
kWp	Kilowatt-hour
LCOE	Levelised Cost of Energy
MHEPP	Mini Hydro Electric Power Plant
MJ	Megajoule
MOH	Ministry of Health
MW	Megawatt

NL	Nanoliter
Nm^3	Normal cubic meters
NO	Nitric oxide
NPV	Net Present Value
POM	Palm Oil Mill
POME	Palm Oil Mill Effluent
QSR	Quick Sludge Removal
RBDPO	Refined Bleached Deodorised Palm Oil
RE	Renewable Energy
RE-SSN	Renewable Energy Sub-Sector Network
RM	Malaysian Ringgit
ROI	Return On Investment
SAF	Sustainable Aviation Fuel
SDG	Sustainable Development Goals
SRF	Solid Recovered Fuel
tCO_2e	Tons of Carbon Dioxide Equivalent
TDHT	Treated Distillate Hydro Treating
THB	Thai Baht
TJ	Terra Joule
USD	United States Dollar
WTP	Water Treatment Plant

Executive Summary

The ASEAN Renewable Energy Project Awards 2023, known as the ASEAN RE Awards, celebrated a substantial increase in submissions compared to 2022, receiving 35 entries across various categories. This uptick in participation can be attributed to the organisation's transition to in-person judging and the implementation of improved guidelines, fostering greater engagement within the renewable energy sector. The largest number of submissions came from Malaysia and Indonesia, closely followed by Thailand.

The 2023 Awards spotlit the growing interest in the off-grid category, particularly in innovative and decentralised renewable energy solutions. In the off-grid category, Indonesian projects emerged as the primary winners, with strong showings from Malaysia and Thailand as runners-up.

Conversely, the on-grid category was dominated by Indonesia and Thailand, showcasing their leadership in grid-connected renewable energy projects. Indonesia particularly excelled in the biofuel and combined heat and power (CHP) segments. These winning projects introduced innovative approaches to sustainability, emphasising the use of used or waste feedstocks, such as used cooking oil and recovered fuels, highlighting their commitment to resource efficiency and environmental responsibility.

Special submissions, though not resulting in award winners, showcased a diverse range of impactful projects spanning various scales and contexts. These projects highlighted the breadth of actions being taken to promote and enhance renewable energy adoption across different regions.

Several recommendations were made to further enhance the upcoming ASEAN RE Awards:

1. Detailed Descriptions and Scoring Criteria: The addition of more comprehensive project descriptions and scoring criteria was found to be effective in increasing participation. This approach allowed for a broader range of projects and innovative approaches to be recognised.

2. Integration of Renewable and Conventional Energy Sources: Many winning projects emphasised the importance of combining renewable energy with conventional energy sources, such as co-firing biomass in coal-fired plants. This approach not only reduces emissions but also highlights the potential for harmonising different energy systems, promoting greater acceptance of renewable energy.

3. Involvement of Local Communities: The winning projects all illustrated that engaging local communities not only enhances acceptance but also contributes to the sustainability of projects. Community involvement fosters a sense of ownership and responsibility, driving the success of project initiation and long-term operation.

4. Investment in Innovative Technologies: Several projects drew attention to the value of investing in innovative technologies to improve operational efficiency and address specific challenges. The adoption of cutting-edge technologies was shown to be a critical driver of success in the industry.

5. Holistic Environmental Benefits: All of the winning projects demonstrated how their achievements extended beyond mere carbon emissions reduction. They addressed a wide array of environmental concerns simultaneously.

The ASEAN RE Awards 2023 celebrated outstanding achievements in renewable energy, fostering a culture of innovation and sustainability in the ASEAN region. These projects, while diverse in nature and still representing a minor share of the operational renewable energy projects, collectively represent a commitment to a greener and more sustainable future. They provide valuable insights and inspiration for the broader adoption of renewable energy solutions and collaboration across various sectors, transcending traditional boundaries.

1

ASEAN Energy Awards

This report showcases the successful practices, technologies and operations strategies that the award winners employed to develop innovative renewable energy projects and contribute to lower emissions. It aims to disseminate these proven measures, encourage companies to adopt a proactive stance towards decarbonisation and minimise project risk by identifying and sharing best practices.

1.1. History

The ASEAN Energy Awards represent Southeast Asia's highest reward for excellence in energy. They were introduced during the 18th ASEAN Ministers of Energy Meeting (AMEM) in July 2000, which took place in Hanoi, Vietnam. The ASEAN Energy Awards is a yearly event coordinated by the ASEAN Centre for Energy (ACE) in collaboration with the specialised energy bodies and sub-sector networks of ASEAN, namely the ASEAN Specialised Energy Bodies (SEBs) and Sub-Sector Networks (SSNs). Their primary objective is to enhance the recognition and involvement of the private sector in the advancement of renewable energy (RE), energy efficiency (EE) and clean coal technology (CCT). The awards also serve as a catalyst for innovation within ASEAN by inspiring organisations to constantly explore, compare and initiate exemplary methods that contribute to achieving energy security, accessibility, affordability and sustainability for everyone.

1.2. Award Categories

The ASEAN Renewable Energy Projects award recognises various renewable energy sources, including **biomass** (solid biofuels, renewable waste, biogas, liquid biofuels), **hydropower** (micro, small, medium), **solar, geothermal, ocean thermal (marine) and wind energy**. It encompasses both electricity generation and thermal utilisation of RE. Emerging technologies like waste tyres and green hydrogen will be considered in the future, with discussions taking place with the RE-SSN Focal Points.

It began in 2001 with the name ASEAN Excellence in RE Project Management Competition, and started with only two categories: 1) on-grid and 2) off-grid. In 2005, the RE-SSN agreed to introduce a new category: cogeneration. At present, there are five categories in total. These are described in the following sections.

1.2.1. On-Grid

The on-grid category includes RE projects connected to the national power grid in provincial or remote areas. These projects utilise various technologies and methods to enhance the dispatch ability of generated electricity, improve profitability and reduce maintenance and operation costs. Examples include using storage systems, hybrid designs which combine multiple renewable energy technologies, innovative financing schemes, supply and demand side management, digitalisation, and implementation in other sectors like agriculture, fisheries or textiles.

The on-grid category is further categorised into two types: national grid and local grid. National grid projects involve electricity generation from various renewable energy sources with an installed capacity larger than 5 MW. By comparison, local grid projects have a smaller capacity and focus on increasing electrification in remote areas. On-grid projects do not cover direct heat or mechanical energy uses without power generation. They are applicable for own use or rooftop installations, complying with global initiatives like RE100, Science Based Technology Initiative (SBTi)'s Corporate Net Zero Standards, and prioritising self-generated renewable electricity or exporting excess energy through net-metering schemes.

1.2.2. Off-Grid

The off-grid category of renewable energy projects refers to projects not connected to the national power grid, often located in regional or remote areas. These projects employ technologies and methods similar to on-grid projects, but their objective is to generate reliable power and reduce the costs of developing and sustaining local economic activities.

Off-grid projects can be categorised into two types: power generation and thermal applications. Power generation projects, with a capacity of less than 10 MW, provide electricity for standalone systems like solar home systems, solar lighting solutions and mini-grids powered by biogas, solar or hydro sources. On the other hand, thermal projects utilise RE sources for direct heating, cooking and preserving purposes, including solar hot water, biogas for cooking and biomass for steam. However, these thermal applications are not applicable in areas with access to the national grid and electricity.

1.2.3. Biofuels

The biofuels category includes projects that involve converting renewable biological sources into liquid or solid fuels to address transportation and electricity generation needs. These projects utilise conversion technologies and methods to ensure sustainable production. The feedstocks are derived from food and energy crops or waste materials. The projects aim to demonstrate lower greenhouse gas emissions than fossil fuel alternatives that can be proven via life cycle assessments. Additionally, the projects must show the implementation of sustainability practices, such as cost-effectiveness and competitiveness with fossil fuels, food and water security preservation, and promotion of local economic development.

1.2.4. Combined Heat and Power (CHP) Generation

The combined heat and power (CHP) generation category encompasses projects that efficiently produce electricity and thermal energy from biogas, biomass or solar. These projects aim to minimise power loss and use wasted energy by applying it to facility loads through hot water, chilled water, process heating or steam. Exemplary CHP projects employ various technologies and fuels to improve overall efficiency, including heat recovery units and using waste as feedstocks.

The categorisation of CHP projects includes generating heat and power from biogas or biomass with a closed-loop heat recovery system. Biogas feedstocks comprise organic waste degradation such as landfill gas, and gas from sewage digesters and animal waste digesters. By contrast, biomass feedstocks include forest residues, wood wastes, crop residues and municipal solid waste (MSW). Solar heat can be obtained from concentrated solar power or other advanced technologies. This category does not have electricity or heat generation capacity limitations and may include prototype-sized projects.

1.2.5. Special Submissions

The special submission category is for unique projects that involve research, studies or the development of innovative applications using emerging RE technologies. These projects, including research and development initiatives and renewable waste-to-energy projects, aim to expedite the energy transition and enhance energy resilience.

1.3. Assessment Criteria

Seven criteria are used to assess the submitted projects. Each criteria have a set of more specific parameters with different score weights to help the judges evaluate the award applicants. Table 1-1 captures the score guiding criteria used by the 2023 RE Awards.

Table 1-1 Assessment Criteria

No.	Criteria	Description	Aspects	Distribution of Score (%)	
				Off-Grid, On-Grid, CHP Generation	Biofuels
1.	Originality	Able to highlight the concept of idea, novelty, replicability and implementation approach	a. Design	4%	4%
			b. Application	4%	4%
			c. Approach	2%	2%
		Total		**10%**	**10%**
2.	Environmental Considerations	Clearly describes the positive physical environmental impacts and advantages from the project	a. Waste management	5%	5%
			b. Avoided GHG emissions	5%	5%
			c. Impact to ecosystems	5%	5%
		Total		**15%**	**15%**
3.	Social Considerations	Clearly describes the positive social impacts and advantages to surrounding communities	a. Community awareness, participation and acceptance	3%	5%
			b. Corporate Social Responsibility programme	4%	5%

			c. Benefit to user, community and country	3%	5%
		Total		**10%**	**15%**
4.	Technical, Economic, and Market Considerations	Able to explain the technology advantages in terms of reliability, durability, economics and accountability	a. Technical design (installed capacity, system)	6%	5%
			b. Technical performance (rated capacity & actual capacity)	6%	4%
			c. Investment indicator (investment cost, IRR, ROI, payback period and effectiveness ratio- cost/ MW.)	6%	4%
			d. Financial scheme/ livelihood project (fully/ semi-commercial, government, PPP)	2%	2%
			e. Funder (government and non-government)	2%	2%
			f. Market size (potential within five years)	2%	2%
			g. Local Manufacturing/ content of the system	2%	2%
			h. Amount of fossil energy avoided (ktoe, etc.)	2%	2%
			i. Life of project	2%	2%
		Total		**30%**	**25%**
5.	Operation and Maintenance Schemes	Satisfactory description of the optimisation and preservation approach to maintain the project as a successful and practical benchmark	a. Operation hours	5%	5%
			b. Maintenance scheme (in-house, contracted out service, government, other)	3%	3%
			c. Other maintenance measures (training, after-sales service)	3%	3%
			d. Energy conservation and cost reduction system	4%	2%
			e. Local service content	4%	3%
			f. ISO for Environment and Quality	1%	1%
			g. Farm management or feedstock management, sustainability supply and resources of raw materials	N/A	3%
		Total		**20%**	**20%**

6.	Replicability	Satisfactory description of the practical implementation to be adopted in other projects	a. Relevance, impact and efficiency	3%	3%
			b. Cost-effectiveness (no/ low/high cost)	3%	3%
			c. Sustainability of project	4%	4%
		Total		**10%**	**10%**
7.	Presentation of Documentation (figures, tables and photos)	Clear presentation of the key facts and evidence	a. Figures, tables and photos	3%	3%
			b. Title/brief of description (abstract)	2%	2%
		Total		**5%**	**5%**

1.4. Submissions Framework

The RE Awards 2023 commenced with the opening of application submissions and the request for Board of Judges (BOJ) nominations from each member country on 30 January 2023. All submissions go through RE-SSN, a distinctive feature from other awards mechanism that would strengthen the coordination between government and private entities. The participating entities are required to submit their documentation according to the guidelines and adhering to the specified deadline.

Figure 11 compares the procedures for the RE Awards 2023 with those of the preceding years. The first batch of nominated judges was received on 28 February 2023. The finalisation of the BOJ and award guidelines were discussed in the BOJ orientation meeting on 10 April 2023, just before the submission deadline of 11 April 2023.

Figure 1-1 Procedures for the ASEAN RE Awards 2023

ACE, as part of the RE Awards team then began with a pre-qualification screening, followed by the pre-judging phase. Once this initial evaluation was completed, the project documents progressed to the next stage: the assessment and scoring by the BOJ. Then, this judgement process resulted in the selection of several distinguished awardees across various categories. The final stage of the award was the awarding ceremony, at which the deserving winners were celebrated and acknowledged for their remarkable achievements in advancing renewable energy practices.

1.5. Overview of Renewable Energy Project Submissions

Since the Awards' inception, there has been growing involvement of various companies in ASEAN that are actively developing novel innovations in RE. Between 2010 and 2023, numerous companies proposed and submitted their entries, resulting in over 300+ projects participating in the RE Awards. New categories have also been introduced over time. The increasing participation demonstrates the programme's success in motivating the sector to consistently enhance best practices in RE project design and development, identify potential opportunities for innovative applications, and raise environmental awareness. These efforts contribute to a reduction in energy consumption (measured in kWh) and CO_2 emissions. Figure 12 illustrates the trends in the number of entries in each category from 2010 to 2023.

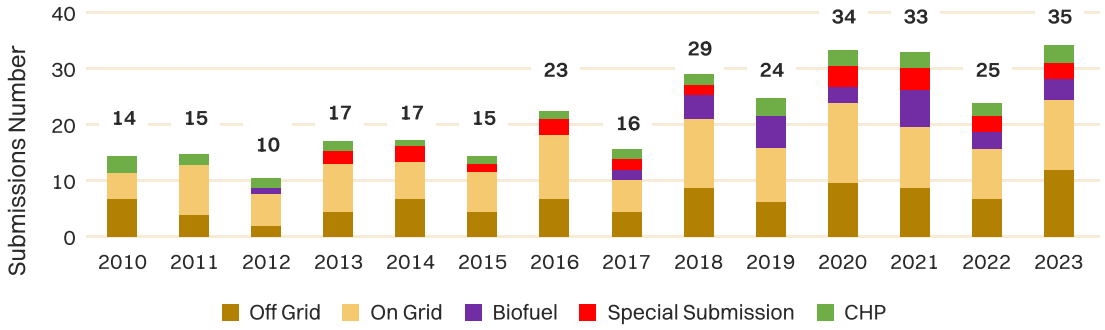


Figure 1-2 Number and Category of RE Awards Entries between 2010 – 2023

We can see an upward trend in the total number of entries. However, there was a noticeable decrease in 2022, the second year of online RE awards, due to the pandemic. More details about the RE Awards 2023 applicants are given below.

1.6. Relevancy with National Energy Awards

Regional awards in the clean energy sector serve to recognise and celebrate outstanding contributions to advancing RE solutions.

In Cambodia, the "EnergyLab's 2022 Clean Energy Awards" aim to acknowledge individuals and organisations which are driving sustainable energy practices. Specific details and categories are unavailable.

Similarly, the "Subroto Awards" in Indonesia are considered prestigious and honour impressive achievements in the energy sector, highlighting innovative initiatives and technological advancements contributing to Indonesia's energy transition.

In Malaysia, the "National Energy Awards" provide a distinguished platform to honour exceptional contributions to the renewable energy landscape. With categories like "Solar PV Project of the Year" and "Energy Efficiency Project of the Year", these awards recognise individuals, organisations and projects that promote RE adoption and sustainable practices.

The "Solar Future Awards" in the Philippines focus on the country's solar industry and recognise leaders and top performers who have significantly contributed to its advancement. These awards showcase innovation, expertise and dedication in driving the growth of solar power in the Philippines.

Like the Philippines, Singapore's Energy Market Authority presents the "Singapore Energy Award", which celebrates noteworthy accomplishments in the energy sector. This award shapes Singapore's energy landscape by recognising energy efficiency, sustainability and innovation achievements.

In Thailand, the "Thailand Energy Award" acknowledges exceptional contributions and innovations across various sectors, including renewable energy, energy efficiency and sustainable practices. This award highlights impactful initiatives that promote sustainable energy solutions.

Vietnam's "Solar Future Awards" honours individuals and organisations that make significant contributions to developing and adopting solar power. By showcasing their remarkable achievements, these awards underscore the positive impact of their work on Vietnam's solar industry.

Overall, the national awards of the ASEAN Member States (AMS) align with the objectives of the "ASEAN RE Awards" by acknowledging individuals, organisations and projects that drive the transition towards clean and sustainable energy solutions. They contribute to the overall progress and development of RE in the ASEAN region by highlighting success stories and best practices at the national level. They also serve as valuable channels for identifying potential candidates or projects demonstrating exceptional performance and could be considered for the ASEAN RE Awards.

Only a few national energy awards from the above list have been connected to the ASEAN RE Awards. Among the reasons hampering their integration is the difficulty of matching the implementation timeline at the national and regional levels. Moreover, the RE-SSN focal points or appointed BOJ are not directly involved in the national awards. However, by connecting the national-level awards with the ASEAN RE Awards, a cohesive recognition and appreciation of the collective efforts will deliver a greater impact and reinforce the fact that the AMS are working hand in hand in promoting sustainable energy and contributing to the region's RE goals.

2

On-Grid Category

2.1. On-Grid: Local Category

2.1.1. Overview of the Winners

The winners of this category, the Gunung Wugul Mini Hydro Electric Power Plant (MHEPP), Koh Jik ReCharge Renewable Energy Microgrid and Captive Power and Sime Darby's Rural Community Electrification, have achieved significant milestones in RE development. These projects showcase the positive impact of RE in addressing environmental challenges while fostering social and economic development. Embracing sustainable practices and technologies is crucial for a greener and more resilient future.

The three winners in this category demonstrate the tangible benefits of renewable energy in addressing environmental challenges while simultaneously driving social and economic development. For instance, *Gunung Wugul MHEPP* harnessed **hydropower energy**, reducing emissions through automation and environmental management. Similarly, *Koh Jik ReCharge's* **solar microgrid** improved residents' lives by reducing tariffs and providing clean energy. Additionally, *Sime Darby Plantation's* replacement of diesel with **biogas** reduced energy costs, created jobs and contributed to sustainability.

2.1.1.1. Winner: Gunung Wugul Mini Hydro Electric Power Plant's Project Digital Automation to Reducing Greenhouse Gas Emissions (by PLN Indonesia Power Mrica PGU)

The Gunung Wugul MHEPP project in Indonesia has achieved success and recognition. It is a hydroelectric power plant with a capacity of 2 x 1.5 MW, using a "run-of-river" approach. It has successfully reduced greenhouse gas (GHG) emissions by over 11,353 tCO_2 per year while generating 14.2 GWh of clean energy per year. These impressive results can be attributed to digital technology automation, optimising power generation through efficient water level management, using the SCADA system, and the G-Action Mobile platform. Gunung Wugul MHEPP is playing a crucial role in minimising GHG emissions compared to conventional fossil fuel-based power plants.

Beyond its environmental benefits, the Gunung Wugul MHEPP project exemplifies corporate social responsibility (CSR) by actively engaging in environmental management and preservation activities to ensure the long-term sustainability of its business processes. In addition, the project is creating employment opportunities for the local community, and fostering economic development and social well-being. These commendable efforts have garnered recognition for the Gunung Wugul MHEPP project. It won first place in the "Green Energy Development Unit New Renewable Energy on Grid Jamali" category and was also awarded Best Power Plant Company in the renewable energy category at the 2022 Indonesia Best Electricity Awards (IBEA).

In summary, the Gunung Wugul MHEPP project showcases Indonesia's commitment to clean energy and emissions reduction, and demonstrates the effective use of digital technology automation in power generation. With its run-of-river hydroelectric approach, the project significantly minimises environmental impacts. Moreover, its CSR ensures long-term sustainability and benefits the local community. The project's recognition at the Indonesia Best Electricity Awards reflects its exceptional achievements in advancing renewable energy development.

Figure 2-1 Gunung Wugul Mini Hydro Electric Power Plant (MHEPP)

2.1.1.2. 1st Runner Up: Koh Jik ReCharge: Renewable Energy Microgrid for Community Sustainability (by Koh Jik Community)

The Koh Jik Island micro-grid project in Thailand has performed well in addressing the issue of electricity access on the island. By replacing lanterns and a small diesel generator with a renewable micro-grid, the project significantly reduced the retail electricity tariff from THB 30-40/kWh (USD 0.88-1.17/kWh) to only THB 15-17/kWh (USD 0.3844-0.5/kWh). In addition, the project earned USD 50,000 by selling environmental benefits in form of renewable energy credits. These funds are used to offer subsidies of 2 THB/kWh (0.05 USD/kWh) to end users, amounting to a net retail tariff of 11 THB/kWh (0.32 USD/kWh). This substantial cost reduction is a result of raising the share of solar in total renewable energy production from 30% to 97%. Koh Jik eliminates 31,974 L of diesel fuel consumption per year which is equivalent to a net carbon emissions reduction of 86,291 $kgCO_2e$/year. Over the project lifetime of 20 years, the total emissions reduction is expected to be 1,725,820 $kgCO_2e$. The Koh Jik Island microgrid project has brought numerous benefits to the community. Residents now enjoy access to electricity 24/7, eliminating unexpected blackouts and improving their quality of life. Installing additional street lights through the microgrid enhances community safety at night and in the early morning. Additionally, the project demonstrates CSR by exempting public buildings such as schools, temples and medical centres from electricity charges.

The success of the Koh Jik Island micro-grid project can be attributed to its robust business model and community ownership. It ensures reliable electricity payments and implements routine maintenance plans to sustain its operations effectively. Notably, its financial model indicates that by the end of the project's 20-year lifetime, the Koh Jik community will have sufficient funds to self-invest in upgrading its energy infrastructure with state-of-the-art technology. This self-sufficiency marks a significant milestone in the community's energy security, eliminating the need for external funding and ensuring the long-term sustainability of its energy systems.

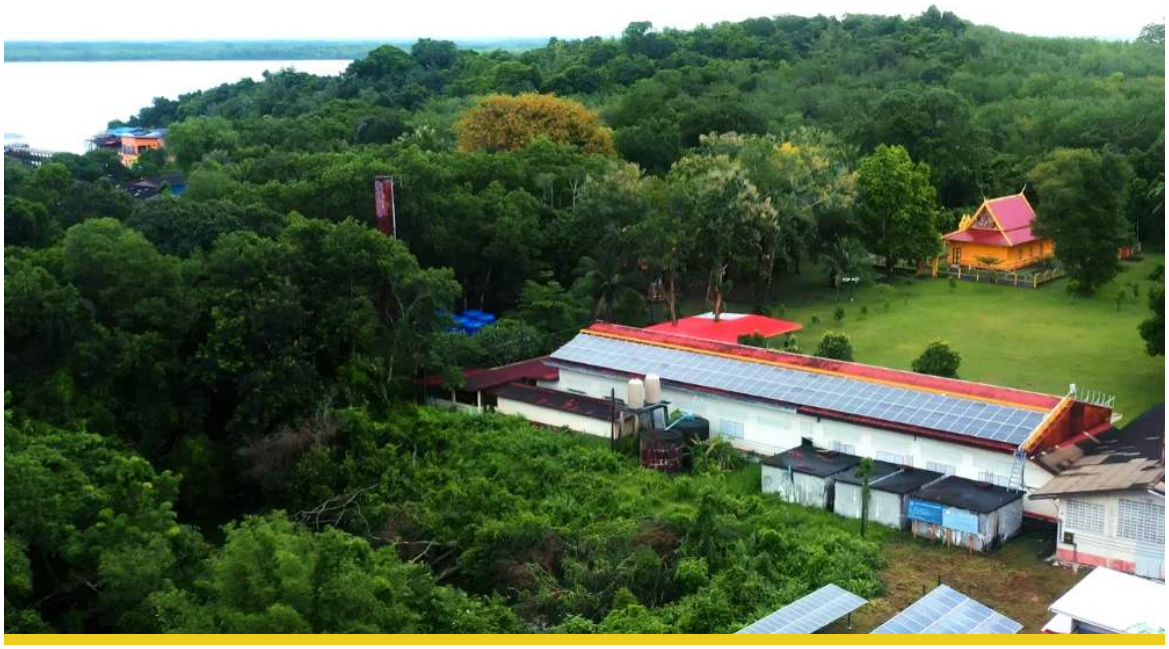


Figure 2-2 Koh Jik Island's Physical Information

2.1.1.3. 2nd Runner Up: Captive Power and Rural Community Electrification via Renewable Energy Sourcing from Palm Oil Mill Effluent at Sandakan Bay Biogas Power Plant (by Sime Darby Plantation Renewable Energy Sdn Bhd)

The Sime Darby Plantation (SDP) greatly reduced carbon emissions. Their carbon footprint and impact study revealed that the SDP accounted for 82.5% of the Sime Darby Group's total emissions in 2009, with palm oil mill effluent (POME) treatment accounting for 80%. Recognising the urgency of mitigating GHG emissions, the SDP developed a roadmap aligned with the SBTi Net Zero Standard, focusing on biogas projects as a critical initiative to reduce carbon emissions in their Upstream Operations.

In the financial year of 2022, the biogas power plant implemented by the SDP made significant strides in electricity generation. The plant successfully supplied approximately 32.3% of its capacity factor, delivering a total captive electricity output of 2.8 GWh. This achievement played a crucial role in reducing the operating costs of KKS Sandakan Bay, which had previously relied solely on diesel fuel for electricity. By replacing diesel fuel with biogas, the project saved an estimated RM 3.6 million (USD 771,000) and reduced carbon emissions by approximately 36,446.8 tCO_2e per year.

Furthermore, this project positively impacted the local community by creating employment opportunities. The plant operations involved a competent team of plant supervisors, operators, skilled engine drivers and a plant engineer who ensured the smooth functioning of the facility. It also strictly follows a scheduled maintenance plan, guaranteeing high plant availability. Regular maintenance activities were performed to uphold the plant's efficiency, including lubrication oil changes, part replacements and biogas scrubber cleaning using the quick sludge removal (QSR) process. These efforts became even more crucial due to the recent surge in diesel prices, which significantly increased the overall operational costs of power generation.

Figure 2-3 Sandakan Bay Biogas Power Plant

2.1.2. Avoided Emissions

Gunung Wugul MHEPP generates 14.2 GWh of electricity annually, reducing emissions by more than 11,352.8 tCO_2 per year. In addition, the electricity generated by Gunung Wugul MHEPP can replace electricity from the grid, reducing fossil fuel consumption by approximately 2.44 ktoe.

Koh Jik ReCharge's Renewable Energy Microgrid has successfully reduced emissions on Koh Jik island. Before the project, the total consumption of the island was 94.9 MWh/year, with 70% coming from diesel and 30% from solar PV + battery. This resulted in a baseline diesel consumption of 33,491 litres per year and total emissions of 90,385 $kgCO_2e$/year. After the implementation of the project, the island's RE share reached 97% (92,053 kWh), with only a small portion of diesel consumption remaining. The total emissions equivalent of the project currently stands at 4,094 $kgCO_2e$/year, resulting in a net emissions reduction of 86,291 $kgCO_2e$/year. Over the 20-year expected project lifetime, the total emissions reduction is projected to be 1,725.82 tCO_2e.

Sime Darby's Captive Power and Rural Community Electrification via Renewable Energy Sourcing from Palm Oil Mill Effluent achieves emission reductions through two categories. The primary decline is attributed to the biogas captive power plant, which operates at an efficiency of 89.6%. This leads to an avoidance of 3,505.67 tCO_2e/year. The secondary reduction comes from total emissions offsets resulting from the displacement of fossil fuel sources—the emission offsets in this category amount to 751.54 tCO_2e/year. The project achieves a total emissions reduction of 30,954.19 tCO_2e/year, considering both primary and secondary reductions.

Table 2-1 Avoided Emissions of On-Grid: Local Category

Project Name	Status	Total Potential Carbon Emissions Reduction per year (tCO_2e/yr)
Gunung Wugul Mini Hydro Electric Power Plant's Project Digital Automation to Reducing Greenhouse Gas Emissions	*Winner*	11,352.80
Koh Jik ReCharge: Renewable Energy Microgrid for Community Sustainability	*1st Runner Up*	86.29
Captive Power and Rural Community Electrification via Renewable Energy Sourcing from Palm Oil Mill Effluent at Sandakan Bay Biogas Power Plant	*2nd Runner Up*	30,954.19

Table 2-1 indicates these three projects' significant contributions to emissions reductions in their respective contexts. Gunung Wugul MHEPP reduces CO_2 emissions by replacing electricity from fossil power plants, while Koh Jik ReCharge's microgrid project substantially reduces diesel consumption and associated emissions. The Captive Power and Rural Community Electrification project uses biogas and displaces fossil fuel sources, reducing considerable emissions. These projects exemplify successful renewable energy initiatives with tangible environmental benefits.

2.1.3. Technical Performance

The Gunung Wugul MHEPP has a capacity of 3 MW and operates with a capacity factor of 55.52%. It generates approximately 14.2 GWh of energy per year and is designed to have a useful lifespan of 30 years. It uses the run-of-river as its raw material and consumes 328,320 m2/day of water from the Urang River. It has exceeded its capability factor target of 33.6% by implementing innovative power plant measures, which include continuous monitoring and improvements to increase production.

In the case of *Koh Jik ReCharge*, the solar PV capacity is 72 kWp, and the energy storage system has a capacity of 266 kWh, with 240 kWh usable capacity. It operates with a capacity factor of 15% and generates 94.9 MWh of energy per year. Its useful lifespan is projected to be 20 years, and it employs a solar PV system coupled with batteries and a 50 kW inverter to transform the community grid's DC power to 3-phase 230/400V AC. The old solar PV system of 40 kWp serves as a backup source during maintenance periods.

Sime Darby's Captive Power and Rural Community Electrification via Renewable Energy Sourcing from Palm Oil Mill Effluent has a capacity of 1 MW and operates with a capacity factor of 32.3%. It generates approximately 2.8 GWh of energy per year and has a useful lifespan of 20 years. The project uses anaerobic digester tanks to process fresh POME under controlled pH and temperature conditions. Critical parameters are monitored daily, including the temperature, pressure, flow rate and various chemical properties of the digester. The project encountered technical challenges during the commissioning phase, including inconsistent biogas production due to high oil content in the POME, pump failures, and mechanical and electrical malfunctions. These issues were resolved through troubleshooting, system adjustments and modifications to improve biogas production and overall plant performance.

These technical performance indicators highlight the operational characteristics and challenges of each project. *The Gunung Wugul MHEPP* demonstrates a higher capacity factor, indicating efficient power generation. *The Koh Jik ReCharge* operates with a lower capacity but utilises solar PV and energy storage technology. *Sime Darby's Captive Power and Rural Community Electrification* uses anaerobic digestion. It faced initial challenges in biogas production and plant operation, but these were soon resolved.

2.1.4. Investment Parameters

The Gunung Wugul MHEPP required a total capital expenditure (CAPEX) of IDR 74.3 billion (USD 5.2 million). The project's operations and maintenance (O&M) costs amount to IDR 156.4 million (USD 10,965). Its investment indicators include an internal rate of return (IRR) of 9.19%, a return on investment (ROI) of 11% and a payback period of nine years.

For *the Koh Jik ReCharge*, the total CAPEX was USD 180,000: machinery (65%), engineering, procurement and construction (EPC) (20%), civil construction (5%) and administrative costs (10%). The O&M costs amount to 3% of the CAPEX. The project's investment indicators consist of an IRR of 9.3%, ROI of 90%, and a payback period of eight years. The discount rate used for the project is 7%.

In the case of *Sime Darby's Captive Power and Rural Community Electrification*, the total CAPEX was RM 12.3 million (USD 2.9 million). The O&M costs for the project are RM 930,125, equivalent to approximately USD 218,062. The project's investment indicators include an IRR of 15.1%, ROI of 29% and a payback period of 6.5 years. The discount rate used for the project is 10%.

Table 2-2 Investment Parameters of On-Grid: Local Category

Parameters	Project Name		
	Gunung Wugul Mini Hydro Electric Power Plant's Project Digital Automation to Reducing Greenhouse Gas Emissions	Koh Jik ReCharge: Renewable Energy Microgrid for Community Sustainability	Captive Power and Rural Community Electrification via Renewable Energy Sourcing from Palm Oil Mill Effluent at Sandakan Bay Biogas Power Plant
	Winner	*1st Runner Up*	*2nd Runner Up*
Total CAPEX	USD 5,216,317	USD 180,000	USD 2,877,050
O&M costs (excluding fuel)	USD 10,965	USD 5,400	USD 218,062
IRR	9.19%	9.30%	15%
ROI	11%	90%	29%
Payback Period (years)	9	8	6.5

Table 2-2 provides a comparison of each project's finances. These indicators offer insights into the financial feasibility and potential returns on investment for each renewable energy project. *The Gunung Wugul MHEPP* has a moderate IRR and ROI, with a longer payback period of nine years. *The Koh Jik ReCharge* demonstrates a slightly higher IRR and a significant ROI of 90%, with a relatively shorter payback period of eight years. *Sime Darby's Captive Power and Rural Community Electrification* has the highest IRR and ROI and the shortest payback period of 6.5 years.

2.1.5. Operation and Maintenance

The Gunung Wugul MHEPP annual operating schedule spans 8,160 hours, adjusted according to both internal and external power plant maintenance schedules. The plant's operations are sensitive to weather conditions which impact generator performance. The maintenance scheme relies on a comprehensive asset management system implemented by PLN Indonesia Power. Maintenance staff receive extensive training to continuously improve their proficiency. Gunung Wugul MHEPP is also making efforts to maintain reliability and reduce the production cost of generators by applying the condition-based maintenance method, which resulted in a 66% cost reduction. Moreover, a focus on local service content ensures the availability of spare parts and maximises the use of local resources for efficient maintenance.

The Koh Jik ReCharge operates continuously, providing 24/7 electricity to Koh Jik Island. Maintenance is predominantly managed in-house by local technicians who perform daily, weekly and monthly maintenance tasks, including PV panel cleaning and tree trimming to prevent shading over the panels. Routine preventive maintenance is conducted every six months, and the project's investors perform yearly maintenance. Local technicians receive essential system operation and maintenance training, encompassing visual inspections, safety training and rudimentary generator maintenance. Everyone involved in the project is also trained in energy management and financial administration, promoting efficient resource utilisation and community engagement. Although there is no calculation regarding the energy conserved and energy efficiency, all of the island's residents are trained to save energy in their daily activities. Notably, a substantial portion of the project's CAPEX and overall project cost is allocated to local services and maintenance, thus contributing to sustainable community development.

Sime Darby's Sandakan Bay Biogas Power Plant is intricately tied to the operation hours of the palm oil mill that provides its primary fuel source, POME. The plant operates in two modes—"power mode" during mill processing hours and "speed mode" during non-processing hours—to supply power to the mill and connected areas. Maintenance is undertaken through a combination of external contract services and in-house efforts. In-house maintenance includes routine tasks like scrubber cleaning, pump and blower servicing, and other minor mechanical work. Some specialised maintenance is outsourced to registered vendors. Training programmes are provided to enhance competency and safety awareness. The project's local service content extends beyond economic benefits, fostering local industry growth and expertise.

2.2. On-Grid: National Category

2.2.1. Overview of the Winners

The winners of this On-Grid National category, *PGE Green Living Ecosystem Optimisation, the Uttaradit Green Power Biomass Power Plant* and *the Pattani Green Biomass Power Plant*, have all achieved notable accomplishments in their respective fields.

The PGE Kamojang Unit-5 GPP in Indonesia showcases the successful use of **geothermal energy**, reducing GHG emissions while supporting local communities through various sustainable initiatives. *The Uttaradit Green Power plant* in Thailand demonstrates the effective use of **biomass** to generate electricity, benefiting the local community economically and environmentally. *The Pattani Green plant*, also in Thailand, highlights the importance of **biomass** as a renewable energy source, contributing to energy stability and CO_2 emissions reduction. All three projects exhibit solid investment indicators, indicating their financial viability and potential for long-term success. These projects are great examples of sustainable energy solutions, fostering economic growth, environmental preservation and community empowerment.

2.2.1.1. Winner: Kamojang Unit-5 GPP Green Living Ecosystem Optimisation: An Integrated Geothermal Power Plant with Eco-Social Security for Steam Resource Sustainability and Operational Stability (by PT. Pertamina Geothermal Energy (PGE) Tbk.)

The PGE Kamojang Unit-5 GPP project in West Java, Indonesia, has achieved remarkable success. With an installed capacity of 35 MW and an estimated annual power generation of 236 GWh, this geothermal power plant uses steam from the Kamojang geothermal reservoir to produce electricity supplied to the grid operator. This project enhances PGE's business and generates income for the local communities surrounding the power plant.

PGE's mission is centred around developing and operating geothermal power plants that are environmentally sustainable, socially responsible and economically viable. In addition to its primary goal of generating electricity, the company is committed to supporting the development of local communities and promoting sustainable growth in the region. The project's success hinges on the preservation of the ecosystem of the Kamojang Field, ensuring the continuous supply of steam from the geothermal reservoir which is vital for the plant's long-term operation and sustainability.

The project is expected to reduce total GHG emissions by approximately 162,027.23 tCO_2e per year by collecting steam from the geothermal fields. PGE operates the Kamojang Unit-5 GPP to further uphold sustainability with the Kang Elie - Kamojang Green Living Ecosystem programme, a CSR initiative. This programme encompasses several initiatives to improve community empowerment, such as a geothermal battery swap station, waste management, conservation and reforestation. These initiatives not only address transportation, security, healthcare, waste management and social and economic development but also contribute to the preservation of the ecosystem surrounding the Kamojang Field. This ensures the sustainability of water recharge and steam supply for electricity generation throughout the 30-year contract period.

Figure 2-4 Kamojang Unit-5 Geothermal Power Plant

2.2.1.2. 1st Runner Up: Uttaradit Green Power 9.5 MW, Biomass Power Plant for Community (by Uttaradit Green Power Company Limited)

Uttaradit Green Power is a biomass power plant in Uttaradit Province, Thailand which uses locally-procured rice husks, wood chips and agricultural waste materials, such as sugarcane leaves, for electricity generation. With an installed capacity of 9.5 MW, the plant has supplied 8.0 MW of electricity to the Provincial Electricity Authority (PEA) since June 2021 under a 20-year Non-Firm Feed-in-Tariff power purchase agreement. The power plant integrates modern technologies using a multi-fuel biomass boiler to efficiently generate electricity and reduce environmental problems caused by burning or leaving agricultural waste materials at their source.

The project plays a significant role in the local community, creating job opportunities and additional income through biomass sales and employment. It helps reduce greenhouse gas emissions by using approximately 100,000 tons of biomass fuel annually. This contributes to an avoidance of approximately 29,852 tCO_2e emissions, as well as a strengthening of energy, social and economic security for the community and the nation.

The required CAPEX amounts to approximately USD 24.5 million, with an IRR of 22.2% and a payback period of around seven years. The plant complies with environmental laws and requirements, regularly monitoring air, noise, water, waste and wastewater quality.

Figure 2-5 Uttaradit Biomass Power Plant

2.2.1.3. 2nd Runner Up: Pattani Green 23 MW: Biomass Power Plant to Enhance Electricity Security for the Southern Border of Thailand (by TPC Power Holding Public Company Limited)

Pattani Green is a thermal biomass power plant located in Pattani Province, Thailand, with an installed capacity of 23 MW and an exported capacity of 21 MW. The plant has made significant achievements since its commercial operation began on 19 May 2020, supplying electricity to the Electricity Generating Authority of Thailand (EGAT). By using biomass from various sources, including rubber trees, palm oil and agricultural waste within a 200-kilometer radius, this project generates approximately 176 GWh of electricity annually. This contributes to the stability of the local economy and energy supply in the southern region of Thailand.

This power plant was designed with advanced technologies to optimise electricity generation performance. Using agricultural waste as a fuel source reduces the environmental impacts and pollution associated with biomass disposal and provides an additional income stream for local farmers and communities. The project has undergone a thorough Environmental Impact Assessment (EIA) to ensure compliance with environmental standards related to water, air, noise, waste and wastewater. Regular monitoring and control measures are in place to maintain the quality of the environment.

Figure 2-6 Pattani Biomass Power Plant

In 2022, the power plant's consumption of approximately 258,043 tons of biomass fuel replaced over 14,997 tons of fossil fuel energy and avoided approximately 77,476 tCO_2e in emissions. Over its projected lifespan of 25 years, the project is estimated to contribute to a total reduction of more than 1.94 million tCO_2e emissions. With an investment cost of approximately USD 43.97 million, the project demonstrates a solid financial performance, boasting an IRR of 18.83% and a payback period of six years and two months.

The success of this biomass power plant showcases the viability and benefits of using biomass as a sustainable fuel source for power generation. It is a good role model for other organisations and communities with abundant biomass resources. Optimising the size and operational pattern of the power plant is essential for efficient and cost-effective operation, further promoting the adoption of biomass-based energy solutions.

2.2.2. Avoided Emissions

The Kamojang Unit-5 Plant aims to reduce GHG emissions by generating electricity through geothermal energy instead of fossil fuels. Over its 25-year lifespan, the project is expected to avoid approximately 162,027.23 tCO_2e per year, equivalent to over 3.29 million tCO_2. The project reduces baseline emissions and fossil fuel-related air pollution by replacing electricity from the national grid with geothermal energy, significantly reducing GHG emissions.

The Uttaradit Green Power Plant generates approximately 67.8 GWh of electricity per year. This renewable energy generation is estimated to reduce the carbon emissions from fossil fuel-based electricity generation by about 29,839 tCO_2e per year, or 745,900 tCO_2, over the project's 25-year lifespan.

The Pattani Green Plant, using biomass as its fuel source, generated 176 GWh of electricity in 2022. It is estimated to reduce GHG emissions from fossil fuel-based electricity generation by approximately 77,476 tCO_2e per year, or over 1.94 million tCO_2, throughout the project's 25-year lifespan. By replacing electricity from the national grid with biomass energy, the project significantly contributes to emissions reductions.

Table 2-3 summarises the substantial avoided emissions from the use of RE sources in the three projects. *The Kamojang project* showcases the potential for geothermal energy to replace fossil fuels, resulting in significant CO_2 reductions. Similarly, *the Uttaradit and Pattani biomass power plants* contribute to emissions reduction by displacing fossil fuel-based electricity generation. These projects highlight the importance of transitioning to cleaner and sustainable energy sources to mitigate climate change and reduce environmental impacts.

Table 2-3 Avoided Emissions of On-Grid: National Category

Project Name	Status	Total Potential Carbon Emissions Reduction per year (tCO_2e/yr)
Kamojang Unit-5 GPP Green Living Ecosystem Optimization: An Integrated Geothermal Power Plant with Eco-Social Security for Steam Resource Sustainability and Operational Stability	*Winner*	162,027
Uttaradit Green Power 9.5 MW, Biomass Power Plant for Community	*1st Runner Up*	29,839
Pattani Green 23 MW: Biomass Power Plant to Enhance Electricity Security for the Southern Border of Thailand	*2nd Runner Up*	77,476

2.2.3. Technical Performance

The Kamojang Unit-5 Plant operates with intensive capacity production, generating electricity for an average of 357 operational days or 8,568 hours per year. This plant has an installed capacity of 35 MW, with 33 MW exported to the grid. It uses 2 million tons of geothermal steam annually, resulting in a high-capacity factor of 90%. The generated energy amounts to 236.5 GWh annually, of which 221.2 GWh is sold to the grid, while 15,323 MWh is used internally.

The Uttaradit Green Power Plant has an installed capacity of 9.5 MW, with 8 MW exported to the grid. It generates approximately 67.8 GWh of power, with 9.4 GWh used for station service. The biomass consumption rate is 230 tons per hour, with a biomass heat input of 13.5 MJ. This power plant demonstrates a gross thermal efficiency of 28.5% and a net thermal efficiency of 24.5%. The capacity factor is 14.8%, reflecting its operational performance.

The Pattani Green Plant operates with a well-defined capacity production plan, averaging 346 operational days or 8,304 hours per year. It has an installed capacity of 23 MW, with 21 MW exported to the grid, and generates approximately 176 GWh of energy, with 156.9 GWh exported and 17.9 GWh used for station service. It consumes 258,043 tons of biomass and has a biomass heat input of 2,500.4 TJ. It achieves a gross thermal efficiency of 25.35% and a net thermal efficiency of 22.59%. The capacity factor, also known as the plant factor, is 87%, while the plant availability factor is 95%.

These projects vary in their technical performance metrics. *The Kamojang Unit-5* demonstrates a high-capacity factor of 90% and a substantial energy generation rate. *The Uttaradit Green Power* has a net thermal efficiency of 24.5% and a capacity factor of 14.8%. Meanwhile, *the Pattani Green* operates with high availability, a capacity factor of 87% and a net thermal efficiency of 22.59%. These technical performance factors highlight the effectiveness and reliability of each project in generating electricity and utilising their respective local energy sources.

2.2.4. Investment Parameters

The Kamojang Unit-5 Plant involved a CAPEX of USD 83.2 million. The project's O&M costs is USD 2.4 million. The project's IRR stands at 14.47%, and the discounted payback period is 13.39%. The project hurdle rate, set at 10.91%, reflects the minimum rate of return required to justify the investment.

The Uttaradit Green Power Plant had a lower CAPEX of USD 21.7 million. The O&M cost is calculated at 0.5% of the CAPEX. The fuel cost amounts to 40% of the CAPEX. The project's discounted rate is 3%, while the IRR reaches 22.2%. The ROI is 10% per year, and the payback period is projected to be seven years.

The Pattani Green Plant required a CAPEX of USD 43.8 million. The O&M costs for the project is USD 2.7 million. The fuel cost is estimated to be USD 8.5 million per ton. The project's discount rate is set at 9.59%. It achieves an IRR of 18.83% and a ROI of 25.55%. The payback period for the project is expected to be six years.

Table 2-4 Investment Parameters of On-Grid: National Category

Parameters	Project Name		
	Kamojang Unit-5 GPP Green Living Ecosystem Optimisation: An Integrated Geothermal Power Plant with Eco-Social Security for Steam Resource Sustainability and Operational Stability	Uttaradit Green Power 9.5 MW, Biomass Power Plant for Community	Pattani Green 23 MW: Biomass Power Plant to Enhance Electricity Security for the Southern Border of Thailand
	Winner	*1st Runner Up*	*2nd Runner Up*
Total CAPEX	USD 83,200,000	USD 21,700,000	USD 43,800,000
O&M costs (excluding fuel)	USD 2,400,000	USD 108,500	USD 2,700,000
IRR	14.47%	22.20%	19%
ROI	N/A	10%	25.55%
Payback Period (years)	N/A	7	6
Hurdle Rate	10.91%	N/A	N/A
Discounted Payback Period	13.39%	N/A	N/A

Table 2-4 presents each project's finances. The Kamojang Unit-5 Plant demonstrates a reasonable IRR and discounted payback period, meeting the hurdle rate set for the investment. The Uttaradit Green Power Plant has a higher IRR and shorter payback period, indicating a potentially quicker return on investment. The Pattani Green Plant exhibits a comparable IRR, shorter payback period and higher ROI. These investment indicators help assess each project's financial viability and attractiveness to potential investors.

2.2.5. Operation and Maintenance

The Kamojang Unit-5 operates for approximately 8,568 hours per year, with annual maintenance windows strategically planned to avoid unexpected issues and maintain operational stability. The focus is on proactive and preventive maintenance strategies, which include regularly scheduled maintenance based on machine operating manual data, predictive maintenance principles and degradation rate analysis. The project integrates a green living ecosystem approach to reduce energy and costs, by promoting eco-social security through programmes like Kang Elie. Moreover, Kamojang's sustainable geothermal steam supply is bolstered by subsurface monitoring and the contribution of the green living ecosystem programme. The project's local service content also includes workforce engagement and community empowerment.

The Uttaradit Green Power Plant operates 24/7 for 355 days a year, with a high plant availability index (plant factor) of 97.26%. Its maintenance scheme involves meticulous planning, with annual, main machine and monthly maintenance plans in place. Regular training enhances employee skills and knowledge, offers post-purchase services and fosters customer engagement. Notable energy conservation and cost reduction measures include using variable speed drives (VSD) to reduce electricity expenses. The project also prioritises local service content, procuring spare parts and services from within the country whenever possible.

The Pattani Green Plant operates around 8,304 hours annually, achieving a plant availability factor of 95%. Its maintenance scheme is structured around preventive strategies, including weekly, monthly and yearly maintenance plans. These plans rely on machine operating manual data, predictive maintenance principles and deterioration rate analysis. Additionally, the power plant ensures accuracy by regularly calibrating measuring instruments through accredited agencies. The project's emphasis on staff training, systematic education and on-the-job training enhances the competency of maintenance teams. It adopts energy conversion and cost reduction measures like sourcing biomass fuel locally, insulating steam piping systems and installing energy-saving LED bulbs. A solid local service content focus includes locally sourced raw materials, spare parts and services, contributing to cost-efficiency and community engagement.

3

Off-Grid Category

3.1. Off-Grid: Power Category

3.1.1. Overview of the Winners

The three winners of the Off-Grid Power category showcased innovative sustainability projects in different sectors in Indonesia. The winner, the Methane Recovery & Avoidance for Industrial Wastewater Treatment Project, addresses the environmental challenges of palm oil production by establishing a **biogas** plant that generates clean energy from POME. The 1st runner-up, the Micro Hydro Application at Gunung Ledang Water Treatment Plant, achieves a net-zero water treatment plant by installing a **micro-hydro power** generator, thus reducing CO_2 emissions and ensuring uninterrupted water treatment operations. Unlike the other two winners, the Solar Ice Maker System Project for Productive Use in Maratua Island uses **solar energy** to produce ice blocks, providing a sustainable solution for the local fishery, reducing costs and stimulating economic growth. Further explanation regarding each project's performance and mechanism will be described in the following sections.

3.1.1.1. Winner: Methane Recovery & Avoidance for Industrial Wastewater Treatment Project, Indonesia (by PT KIS Green Technology Projects)

The project is in Central Kalimantan, Indonesia, where palm oil plantations are abundant. The palm oil industry is vital to the country's economy, contributing 4.5% to the GDP and lifting many people out of poverty. However, the industry's rapid growth has led to increased waste generation from palm oil mills.

This project establishes a biogas plant using POME for power generation. It focuses on methane recovery from PT. Mita Mendawai Sejati's palm oil mill's wastewater treatment facility. With a 60 tonnes/hour capacity, the mill produces approximately 600 m^3 of wastewater daily, containing 70,000 mg COD/l of organic content. The wastewater is treated in an anaerobic digester utilising ZPHB® technology.

The biogas plant generates around 744 m^3 of biogas per hour, which powers biogas engines with a total capacity of 1.5 MW and 0.9 MW. The electricity produced primarily serves the mill's internal needs. Additionally, the project earns revenue from carbon credits due to carbon emission reductions. By replacing fossil fuel (diesel), an annual carbon credit of approximately 43,636 tCO_2e from the biogas plant and a further reduction of 5,978 tCO_2e is estimated, resulting in a total decrease of 49,614 tCO_2e annually.

Figure 3-1 Top View of the PT KIS Green Technology Project

This project produces clean energy, reduces carbon emissions and is a model for effective POME management. Utilising anaerobic digestion and biogas generation addresses the environmental challenges associated with palm oil production and demonstrates the potential for similar projects in the future.

3.1.1.2. 1st Runner Up: Micro Hydro Application at Gunung Ledang Water Treatment Plant, Tangkak, Johor Darul Takzim (by Ranhill SAJ Sdn Bhd)

The Gunung Ledang Water Treatment Plant (WTP) in Tangkak District, Johor Darul Takzim, Malaysia, provides reliable and uninterrupted water supply to approximately 16,069 accounts. Active socio-economic activities in the Tangkak district, including the recreational, textile and food and beverage sectors, have driven the demand for a reliable water supply. To meet this demand and achieve the goal of becoming a net zero water treatment plant, the WTP underwent significant improvements.

The main objective was accomplished by installing a new micro hydro power generator with a design capacity of 110 kW. This new micro hydro system replaced an ageing one that had experienced a drop in performance and efficiency over the years. By eliminating the need for a diesel genset, the WTP avoided producing 90.74 tCO_2e of emissions. The new micro hydro provides sufficient electricity to meet the demands of the WTP's building services and operational activities. An older micro hydro unit was also repurposed as a reserve, ensuring uninterrupted operation during maintenance or unexpected breakdowns. This achievement guarantees a reliable water supply sourced directly from the lush hills of Gunung Ledang and establishes a zero carbon emissions WTP, benefiting the community and the environment.

Looking ahead, the WTP has plans to sell the excess power generated by the micro hydro to the national grid. With a surplus capacity of 425.4 MWh, increasing the output to the design capacity of 110 kW would enable the WTP to further contribute to RE production. Inspired by the success of this project, Ranhill SAJ Sdn Bhd, the organisation behind the improvements, is motivated to replicate such initiatives in other assets, such as elevated reservoirs, using in-line hydro turbines. Expanding these efforts, they aim to accelerate the transition towards zero carbon emissions in their operations and reinforce their commitment to sustainable practices and environmental stewardship.

Figure 3-2 The Gunung Ledang Water Treatment Plant

3.1.1.3. 2nd Runner Up: Solar Ice Maker System for Productive Use in Maratua Island (by Yayasan Energi Bersih Indonesia (EnerBI))

Maratua Island, located in East Borneo, Indonesia, faces scarce and unreliable electricity challenges. The local fishery serves as a crucial source of income for the community. Traditionally, fishermen had to obtain ice blocks from the mainland to preserve the seafood, which was costly, time-consuming and environmentally unfriendly. The installation of a solar ice maker system in 2017 has provided a sustainable and cost-effective solution by using solar energy to produce ice blocks on the island.

The ice maker uses solar panels to generate electricity, powering the ice block production machine. This technology reduces the dependence on fossil fuels and expensive transportation costs while ensuring a reliable supply of ice blocks for the local community. Its successful implementation on Maratua Island is a model that can be replicated in other remote and off-grid areas facing similar challenges, contributing to sustainable development.

The ice maker helps stabilise ice block prices and ensures its affordability for fishermen. Additionally, the Village-Owned Enterprise (BUMKA) called BUMKA Pamoahan has the opportunity to develop a business selling ice blocks. They can supply ice blocks to fishermen, hotels and resorts on Maratua Island, further stimulating economic growth. Moreover, the ability to make ice on the island indirectly optimises the selling price of the fishermen's catches, benefiting the entire community.

Figure 3-3 Solar PV for the Ice Maker on Maratua Island

3.1.2. Avoided Emissions

The Methane Recovery and Avoidance for Industrial Wastewater Treatment Project aims to mitigate methane emissions by capturing and using them in a biogas engine, effectively replacing diesel. This substitution leads to a substantial avoidance of 5,978 tCO_2e per year. In addition, the biogas generation resulting from this project achieves an annual greenhouse gas emissions reduction of 43,636 tCO_2e. Consequently, the total GHG reduction amounts to approximately 49,614 tCO_2e annually. By actively addressing methane emissions and adopting sustainable energy practices, this project significantly contributes to reducing environmental degradation.

Similarly, *the Micro Hydro Application at Gunung Ledang Water Treatment Plant* focuses on minimising carbon emissions through various measures. Substantive carbon emission reductions are achieved through the project's emphasis on sustainable energy generation and fuel efficiency. Specifically, the project can reduce 84,240 $kgCO_2e$ emissions from electricity consumption, 6,422.40 $kgCO_2e$ from fuel consumption (particularly from genset usage) and 78.78 $kgCO_2e$ from the transportation of diesel-using lorries. Collectively, these efforts culminate in a noteworthy potential carbon emissions reduction of 90,741.18 $kgCO_2e$. This project is pivotal in fostering environmental sustainability and combatting climate change by optimising energy consumption and embracing eco-friendly practices.

Moreover, *the Solar Ice Maker System* offers multiple avenues for carbon emissions reduction. The project effectively avoids 44.74 tCO_2e per year by implementing solar-powered systems. The project also achieves a significant emissions reduction of 16,757 litres of diesel fuel consumption, contributing to the overall decrease in carbon emissions. Furthermore, the project positively impacts air quality by avoiding 187 kg/year of nitrogen oxides (NOx) and 90 kg/year of carbon monoxide (CO) emissions. Collectively, these combined efforts result in a total potential carbon emissions reduction of 44.74 tCO_2e per year, alongside reductions in NOx and CO emissions. This ice maker exemplifies the benefits of solar energy technologies in reducing carbon emissions and promoting cleaner air and a more sustainable future.

Table 3-1 Avoided Emissions of Off-Grid: Power Category

Project Name	Status	Total Potential Carbon Emissions Reduction per year (tCO_2e/yr)
Methane Recovery & Avoidance for Industrial Wastewater Treatment Project	*Winner*	49,614
Micro Hydro Application at Gunung Ledang Water Treatment Plant	*1st Runner Up*	90.74
Solar Ice Maker System for Productive Use in Maratua Island	*2nd Runner Up*	44.74

3.1.3. Technical Performance

The Methane Recovery and Avoidance at Industrial Wastewater Treatment Project features a biogas engine with a total installed capacity of 2.4 MW for power generation. The plant includes a POME treatment plant with a ZPHB® reactor of 8,400 m^3 capacity for comprehensive treatment. The biogas produced in the process is used for captive power generation in the plant, resulting in significant savings on diesel purchasing costs. While specific technical details pertaining to energy generation and useful life are not provided, its focus on biogas use highlights its sustainable energy practices and cost-saving benefits.

On the other hand, *the Micro Hydro Application at Gunung Ledang Water Treatment Plant* operates with a capacity of 110 kW and generates approximately 109 MWh of energy. The project's useful lifespan is estimated at 30 years. During the Factory Acceptance Test (FAT) and Site Acceptance Test (SAT), it was discovered that the unit's actual power output during testing was 65 kW, lower than its design capacity of 110 kW. This discrepancy was attributed to the ageing incoming pipe supply to the micro hydro system. Plans for replacing the incoming pipe are underway to achieve maximum power output and optimise performance.

The Solar Ice Maker System Project has a capacity of 56 kWp and generates 47 MWh of energy per year. Its solar PV system has a useful lifespan of 25 years and the battery has a useful lifespan of six years. Various measures were implemented to ensure high system reliability, including an oversized solar PV system, multiple maximum power point trackers, a more extensive battery energy storage system and high-quality components from trusted brands. Despite challenges in transporting the components to the remote island, the project successfully overcame them. However, there were disturbances in operational efficiency, particularly related to the inactivity of the supporting power system late in the second year, leading to production interruptions. This issue was attributed to malfunctioning batteries used for supportive roles.

3.1.4. Investment Parameters

The Methane Recovery and Avoidance at Industrial Wastewater Treatment Project has a CAPEX of USD 3 million. It demonstrates a favourable IRR of 21%, indicating its potential for financial viability. The payback period is estimated to be four years, suggesting a relatively quick return on the investment.

For *the Micro Hydro Application at Gunung Ledang Water Treatment Plant*, the CAPEX is USD 1.4 million and it's payback period is estimated to be 12 years. *The Solar Ice Maker System* involves a CAPEX of USD 330,000: the icemaker machine accounts for 23% of the total cost. The project's O&M costs, excluding fuel, amount to 2.2%, covering operator salaries (1.1% of CAPEX) and battery and PV maintenance tools (1.1% of CAPEX). As the project does not incur fuel costs, the ROI is 4% per annum at operational capacity and 9% per annum at full capacity. The IRR is 1.1% for actual operation, with an associated cash flow of IDR 11-19 million (USD 700-1200)/month, and 2.5% at full capacity, with a cash flow of IDR 30 million (USD 1,900)/month. The payback period is estimated to be nine years at full capacity and 19 years at its actual operation.

Table 3-2 Investment Parameters of Off-Grid: Power Category

Parameters	Project Name		
	Methane Recovery & Avoidance for Industrial Wastewater Treatment Project, Indonesia	Micro Hydro Application at Gunung Ledang Water Treatment Plant, Tangkak, Johor Darul Takzim	Solar Ice Maker System for Productive Use on Maratua Island
	Winner	*1st Runner Up*	*2nd Runner Up*
Total CAPEX	USD 3,047,786	USD 1,413,672	USD 330,000
O&M costs (excluding fuel)	N/A	N/A	USD 7,260
IRR	21%	N/A	1.10%
ROI	N/A	N/A	4%
Payback Period (years)	3.97	11.9	9

Table 3-2 indicates that each project has distinct investment indicators. *The Methane Recovery and Avoidance at Industrial Wastewater Treatment Project* has a higher IRR and a shorter payback period, indicating its potential for faster returns on investment. *The Micro Hydro Application at Gunung Ledang Water Treatment Plant* involves a higher CAPEX and a relatively longer payback period. Meanwhile *the Solar Ice Maker System* has a moderate CAPEX with a longer payback period.

3.1.5. Operation and Maintenance

Indonesia's Methane Recovery and Avoidance Project operates for approximately 330 days a year, with each operational day spanning 20 hours. The maintenance scheme is managed in-house, with a team of around 15 workers in three shifts. These operators have received O&M training and adhere to standard procedures to ensure smooth operations. Preventive and precautionary measures are regularly implemented to maintain the biogas plant's efficiency. Although no exact calculation is provided, the project focuses on methane reduction and fossil fuel replacement, leading to greenhouse gas reduction. Moreover, local service content is emphasised, as a local Indonesian team services the entire plant.

The Micro Hydro Application at Gunung Ledang Water Treatment Plant operates 24/7 to supply potable water to various locations. The operation involves three shifts supervised by a manager and supervisor. In-house and contracted maintenance strategies are adopted. In-house personnel perform regular inspections and preventive maintenance, while external contractors handle more specialised tasks. Training and local sourcing of spare parts contribute to a robust maintenance system. The project also focuses on energy conservation through LED lighting and prioritises local service content by involving Malaysian contractors and spare part manufacturers.

Lastly, *the Solar Ice Maker System on Maratua Island* is adaptable, producing ice blocks based on demand. The system operates 350 times annually, each production cycle taking 4.5 hours. The operator performs routine maintenance, checking mechanical and electrical components before and after ice production. Local personnel were trained to operate the system, and a unique business model shares revenue from ice block sales with operators, contributing to local engagement. The project emphasises energy efficiency in component selection, using Tier-1 components to minimise energy losses and reduce operational and maintenance costs. The project underscores local involvement in management, logistics, construction and other implementation aspects.

3.2. Off-Grid: Thermal Category

3.2.1. Overview of the Winners

The Off-Grid Thermal category had three winners, each showcasing innovative approaches to sustainability, reducing emissions and fostering economic and environmental benefits. *Nestlé's Turning Cow Manure into Blessing*, the winner, converts cow manure into **biogas** and organic fertiliser through underground biogas digesters, reducing emissions and promoting sustainable dairy farming. *Thai Eastern Bio Power*, the 1st runner-up, effectively treats wastewater, converting waste materials into **biogas**, reducing CO_2 emissions and enhancing financial viability. *Danone Indonesia's Rice Husk Fuelled Biomass Boiler,* the 2nd runner-up, reduces carbon emissions, supports the local economy and benefits farmers through the use of rice husk as the **biomass** feedstock.

3.2.1.1. Winner: Turning Cows' Manure Into Blessing (by Nestlé)

The slurry management programme implemented by Nestlé Indonesia and Yayasan Rumah Energi has assisted dairy farmers in converting cow manure into biogas and organic fertiliser. The generated biogas is a clean cooking fuel and lighting source, while the post-fermentation residue is transformed into valuable organic fertiliser. By constructing underground biogas digesters with a fixed dome system, the programme has installed over 8,500 digesters in East Java, effectively reducing emissions and promoting sustainable dairy farming practices.

In collaboration with local cooperatives, Nestlé supports dairy farmers through subsidies, soft loans and a rolling fund mechanism to encourage the adoption of the biogas programme. With subsidies ranging from 50% to 70% depending on the digester's size, farmers can finance the remaining cost through a cooperative's soft loan, repayable over 3-5 years using one litre of milk daily. The biogas digesters have proven highly effective, significantly avoiding 30-37 tCO_2e/year and producing an average annual electricity output of 4,300 GJ. These digesters, available in various sizes, can manage the manure of 4-10 cows daily.

The objectives of the biogas programme encompass multiple aspects, from emissions reduction to leakage prevention of cow manure into the environment through proper waste management. Additionally, the programme harnesses methane gas from cow manure for cooking and lighting purposes. It supports the growth of grass used as feed through bio-slurry, improving cow hygiene and the quality of fresh milk. Moreover, it contributes to the health of farmers' families by reducing their reliance on firewood and promotes economic savings by eliminating the need to purchase LPG or kerosene. Nestlé plans to continue these impactful efforts beyond 2023, further extending the positive effects of the biogas programme.

Figure 3-4 Biogas Digester for Households Using Fixed Dome

3.2.1.2. 1st Runner Up: Biogas Production from Empty Fruit Bunches and Decanter Cake (by Thai Eastern Bio Power Co. Ltd.)

Thai Eastern Bio Power Company Limited has achieved impressive sustainable wastewater management and energy production outcomes. The project improves wastewater quality and implements internal water recycling by effectively treating wastewater from Thai Eastern Group Holding Public Company Limited and its affiliates. The company's innovative approach converts waste materials, such as empty fruit bunches and decanter cake, into biogas, resulting in a 14% increase in biogas utilization compared to conventional methods. This contributes to a significant avoidance of 7,508.34 tCO_2e annually. These sustainable practices demonstrate environmental benefits and financial viability.

The holding, a major producer of rubber, palm fruit and palm kernel, faces the challenge of significant wastewater generation, amounting to 80% of its total wastewater output. To address this, Thai Eastern Bio Power was established to manage and treat the holding company's wastewater by improving wastewater quality to meet regulations and implementing water recycling within the factory. Using biogas from wastewater treatment, the company achieves an impressive 76% replacement of liquid petroleum gas in dry rubber processing. reducing reliance on fossil fuels.

Figure 3-5 Thai Eastern Bio Power Plant

Initially, Thai Eastern Bio Power used wastewater and organic waste from rubber and palm oil processing to produce biogas. However, as its holding company's palm oil processing capacity expanded, wastewater and solid waste generation increased significantly. The company embarked on extensive research and trials to tackle this issue, resulting in innovative methods for generating biogas from empty fruit bunches and decanter cake waste. These projects now produce up to 928,375 Nm^3 of biogas annually, contributing to a more sustainable and efficient production process. The emission reductions and the favourable payback period of 1.64 years underscore the success and viability of its sustainable initiatives.

3.2.1.3. 2nd Runner Up: Biomass-Rice Husk Fuel Switching from Natural Gas on Boiler Steam System at Sarihusada MilkPowder Factory (by PT. Sarihusada Generasi Mahardika)

Danone Indonesia's commitment to achieving carbon neutrality is exemplified by constructing the rice husk fuelled biomass boiler, which has yielded impressive outcomes and achievements. This facility reduces carbon emissions by 8,258 tCO_2e, equivalent to the absorption of carbon emissions through planting 120,000 trees. Additionally, it has enabled a shift from CNG to biomass, avoiding 37.3 GWh of fossil energy. The biomass boiler reduces the carbon footprint of the Prambanan Factory's production process by 32%.

The biomass facility also benefits the local economy by using rice husk, an easily accessible agricultural waste. The project supports the brick-making industry and tobacco drying by providing 80% of the husk supply within a 150 km radius and 20% from nearby rice mills. With an annual husk production of 10,500 tons, the project generates 23% husk ash, rich in silica. This ash stimulates soil microbes, reduces hard metals and increases phosphorus availability. Distributing husk ash as free fertiliser to farmers enhances rice farming and offers potential cost savings.

Figure 3-6 Biomass Boiler at Prambanan Factory Site

Farmers can save up to IDR 7.8 million (USD 500) per hectare using husk ash instead of compost and dolomite. This sustainable practice reduces reliance on costly inputs and promotes environmentally friendly agriculture. The distribution of free husk ash supports the local economy and sustainable farming practices, benefiting farmers in the area.

3.2.2. Avoided Emissions

Each project has significantly reduced its carbon footprint. Nestlé has implemented a domestic biogas digester system that substantially reduces emissions and produces electricity. This system achieves an average reduction of 30-37 tCO_2e annually from 1 unit of 6 m^3 biogas digester and generates an average of 4,300 GJ of electricity annually. With a range of digester sizes available, from 2 m^3 to 12 m^3, it can effectively manage the manure from 4-10 cows daily, processing 15-90 kg of manure. This biogas digester system mitigates emissions and minimises waste, providing a sustainable solution for dairy farmers.

Thai Eastern's biogas production from empty fruit bunches and decanter cake demonstrates significant potential for carbon emissions reduction. This project utilises waste products, such as empty fruit bunches and decanter cake, to produce biogas, resulting in a total potential avoidance of 7,508.34 tCO_2e. Over its projected lifetime of 25 years, the project is expected to avoid more than 187,708.5 tCO_2e. By effectively harnessing these waste materials, this project reduces GHG emissions and showcases a sustainable approach to energy production.

Sarihusada's biomass-rice husk fuel project has yielded impressive results in terms of emissions reduction. By replacing the combustion of CNG with a biomass steam system, the project has successfully decreased emissions from 9,949 to 1,691 tCO_2e. This signifies a substantial avoidance of 8,258 tCO_2e per year. Currently, CNG is solely used as a backup steam boiler and for other purposes, further minimising emissions. Adopting biomass-rice husk fuel has proven to be an effective strategy in reducing carbon dioxide emissions, demonstrating Sarihusada's commitment to sustainable energy practices.

Table 3-3 Avoided Emissions of Off-Grid: Thermal Category

Project Name	Status	Total Potential Carbon Emissions Reduction per year (tCO_2e/yr)
Turning Cows' Manure Into Blessing	*Winner*	329,384
Biogas Production from Empty Fruit Bunches and Decanter Cake	*1st Runner Up*	7,508.34
Biomass-Rice Husk Fuel Switching from Natural Gas on Boiler Steam System at Sarihusada MilkPowder Factory	*2nd Runner Up*	8,258

3.2.3. Technical Performance

Nestle's domestic biogas digester system offers various sizes to cater to different needs. Currently, the 6 m^3 type, which can manage 4-5 cows' manure, produces approximately 2,000 litres of gas, providing around five hours of daily cooking time. The 8 m^3 digester, accounting for 35% of the installations, manages 6-7 cows' manure and produces approximately 2,600 litres of gas, extending the cooking time to around 6.5 hours. The largest size, 12m^3, has about 4,000 litres of gas, enabling up to 10 hours of cooking per day. This system significantly reduces the use and expense of LPG cylinders, kerosene and firewood.

In *Thai Eastern's biogas production*, the production capacity allows for the processing of 60 tons of empty fruit bunches and decanter cake daily. This results in a daily biogas production of approximately 2,800 Nm^3. With a digester working volume of 16,000 m^3, the biogas system has a capacity of 928,375 Nm^3 per year. The project's useful life is estimated to exceed 25 years, ensuring long-term sustainability.

Sarihusada's biomass-rice husk fuel project has demonstrated reliable performance. After one year of operation, the biomass steam plant achieved a service level of 98.4%, indicating its reliability. The CNG steam boiler is maintained as a backup option and is used only when the biomass boiler is unavailable, ensuring 100% steam supply reliability. The biomass steam plant has a capacity of eight tons per hour and is expected to have a useful life of 15 years. It operates at an impressive capacity factor of 80%, generating 37,276 MWh of energy. These technical performance indicators highlight each project's efficiency, reliability and long-term viability, contributing to sustainable energy generation and resource management.

3.2.4. Investment Parameters

The CAPEX for *the domestic biogas digester system* is USD 4,072 million. Between 2010 and 2019, Nestlé allocated IDR 2-3 million (USD 120-190) per digester. However, since 2021, it has fully subsidised the programme with IDR 4.5 million (USD 290) per digester. Dairy farmers cover the remaining costs through soft cooperative loans. Farmers are to repay the loan within 3-5 years by allocating 1 litre of milk daily, ensuring a sustainable and manageable repayment scheme.

Thai Eastern's biogas production demonstrates attractive investment indicators. With a CAPEX of USD 114,235.52, the project showcases a cost-effective solution for sustainable energy production. The O&M cost, excluding fuel for the biomass project, amounts to USD 64,045.12, representing 56% of the total CAPEX. This indicates a reasonable level of ongoing expenses. The project's IRR stands at a notable 56.06%, highlighting its potential for profitable returns. Moreover, the payback period for the investment is estimated to be just 1.64 years, indicating a relatively quick recouping of the initial investment. These investment indicators demonstrate the project's economic viability and attractiveness.

Sarihusada's biomass-rice husk fuel project has a unique investment arrangement. Due to the investment mechanism that Danone uses for this project, the CAPEX is zero. Instead of incurring direct investment costs, Danone benefitted from energy savings achieved through biomass steam compared to CNG. These savings amount to approximately 20%. Danone's Prambanan Factory has a steam supply agreement with their trusted partner BECIS, also known as Tasma Bioenergy, for the biomass steam supply in this project. BECIS manages all investments, operational costs and biomass boiler maintenance. Danone pays for the steam usage on a monthly basis. This arrangement allows Danone to leverage the advantages of biomass-rice husk fuel without bearing any upfront investment expenses.

Table 3-4 Investment Parameters of Off-Grid: Thermal Category

Parameters	Project Name		
	Turning Cows' Manure Into Blessing	Biogas Production from Empty Fruit Bunches and Decanter Cake	Biomass-Rice Husk Fuel Switching from Natural Gas on Boiler Steam System at Sarihusada MilkPowder Factory
	Winner	*1st Runner Up*	*2nd Runner Up*
Total CAPEX	USD 4,072,000	USD 114,235.52	N/A
O&M costs (excluding fuel)	USD 516,493	USD 64.045.12	N/A
IRR	N/A	56.06%	N/A
Payback Period (years)	3	1.64	N/A

3.2.5. Operation and Maintenance

Nestlé's domestic biogas digester system operates continuously, 24 hours a day. The digester is equipped with geotagging tools that enables monitoring of its utilisation. Daily maintenance of the digester is primarily handled by dairy farmers, who undergo training to acquire the necessary skills for digester maintenance. The digester's fixed dome design can minimise the need for extensive daily maintenance. In cases where additional maintenance services are required, the construction partner organisation provides the necessary support. However, regular inspections to check for potential leakage at the pipeline and equipment connections are crucial and performed daily.

Thai Eastern's biogas production operates nearly daily, with scheduled preventive maintenance breaks of three days each month. The maintenance strategy relies on a dedicated team of 15 full-time technicians who work round the clock without external contractors. The staff also undergoes training to perform parameter checks, quality inspections and control procedures daily, weekly and monthly. Additionally, the project implements an annual energy management policy to promote energy conservation and cost reduction. For example, the reduction of the electricity consumption target to 1.2 kW/m2 can be achieved through several measures such as installing inverters, adjusting machine duty cycles and improving machinery efficiency. The project emphasises local service content, with over 60% of the tools and equipment sourced from local manufacturers and suppliers to support domestic entrepreneurship.

Sarihusada's biomass-rice husk fuel project operates 8,616 hours per year, equivalent to 359 days or 98.35% of the time. The maintenance of the biomass boiler plant is undertaken by BECIS, which serves as Danone's trusted partner. Local third-party providers assist BECIS in executing maintenance tasks. The maintenance schedule typically includes downtime of one to five days per month, during which cleaning and inspection tests are conducted to ensure the system's optimal performance. Various training programmes, such as those focused on safety, fire protection, first aid and operation, are part of the maintenance measures. The project prioritises employing a local workforce. Additionally, the annual maintenance activities are executed by a local vendor.

4

Biofuel Category

4.1. Overview of the Winners

The winners of the Biofuel category are the Pertamina Renewable Diesel (Hydrotreated Vegetable Oil), Waste Solution Approach by Community Ecosystem Creation to Produce Solid Recovered Fuel at Cilegon City, and Biodiesel Production from Used Cooking Oil project. *Pertamina's project* produces high-quality **hydrotreated vegetable oil**. *The Waste Solution Approach* project converts **municipal solid waste into solid recovered fuel** for cofiring, thereby reducing emissions. *The Biodiesel Production* project collects **used cooking oil** and produces biodiesel, promoting low-carbon fuel usage. These initiatives highlight ASEAN countries' commitment to sustainability, addressing environmental challenges while fostering economic development and community engagement.

4.1.1. Winner: Transitioning Indonesia Energy into Greener Fuel: Pertamina Renewable Diesel (Hydrotreated Vegetable Oil) (by PT. Kilang Pertamina Internasional)

Kilang Pertamina International (KPI)'s Green Refinery Cilacap Phase-1 produces hydrotreated vegetable oil (HVO) and has addressed the challenges associated with higher replacement levels of fatty acid methyl ester (FAME) in biodiesel. The HVO offers superior quality and compatibility with fossil diesel, surpassing EURO V diesel standards. This achievement marks the beginning of PT KPI's biofuel business expansion and contributes to the energy transition efforts in various industries, including oil refineries.

The project involved revamping the treated distillate hydro treating (TDHT) unit in Cilacap, initially designed for kerosene-to-jet-fuel treatment. KPI significantly changed the catalyst, fractionation column, equipment metallurgy and infrastructure, enabling the unit to process refined bleached deodorised palm oil (RBDPO) and produce high-quality HVO. With a production capacity of up to 25,000 barrels per day, the revamped TDHT plant holds the International Sustainable Carbon Certification (ISCC) EU, certifying its HVO product's 70% lower greenhouse gas (GHG) emissions than fossil fuel. Furthermore, the plant has obtained commercial and export permits to enter global and domestic markets.

KPI has successfully launched its renewable diesel product, powering diesel generators and producing green electricity during notable events such as Jakarta's Formula-E and Bali's G-20. The company has already exported several cargoes of renewable diesel to initial markets, positioning itself strategically ahead of an anticipated higher biodiesel mandate. As part of its roadmap, KPI plans to expand its production capacity to 26,000 thousand barrels per day, encompassing the production of HVO and other green fuels like sustainable aviation fuel (SAF) and green naphtha for petrochemical feedstock. The project's achievements demonstrate KPI's commitment to advancing sustainable and low-emission solutions in the energy sector.

Figure 4-1 Location HVO / TDHT Plant RU IV Cilacap

4.1.2. 1st Runner Up: Waste Solution Approach by Community Ecosystem Creation to Produce Solid Recovered Fuel at Cilegon City (by PT PLN Indonesia Power)

The "Biodrying Conversion of Municipal Solid Waste into Solid Recovered Fuel (SRF) for Cofiring" project at the Bagendung landfill has yielded impressive results since its commissioning in 2023. The plant produced 70.3 tons of SRF, significantly avoiding approximately 8.07 tCO_2 and 19 tons of methane emissions annually. The project has made substantial strides in reducing greenhouse gas emissions by converting municipal solid waste into SRF and using it for cofiring with biomass at the Suralaya Coal-Fired Power Plant.

To address the challenge of limited biomass supply, PLN's Indonesia Power collaborated with the Environmental Services Agency of Cilegon City to implement the biodrying project at the Bagendung landfill. The process involves collecting and treating municipal solid waste with a bioactivator solvent in a reactor box. After a designated period, the harvested waste is chopped and blended with coal to create SRF. Rigorous laboratory testing ensures that the produced SRF meets national standards for calorific value and compatibility with the coal-fired power plant, guaranteeing optimal performance and compliance with regulatory emission standards.

This innovative project contributes to Indonesia's goal of achieving a 23% RE mix by 2025 and promotes sustainable waste management practices. By converting municipal solid waste into a valuable resource, the project effectively reduces the environmental impact of waste and maximises the utilisation of biomass resources. The project's success highlights the significant potential of alternative biomass sources and underscores the importance of environmental responsibility in pursuing a greener and more sustainable future.

Figure 4-2 BBJP Bagendung Mini Plant

4.1.3. 2nd Runner Up: Biodiesel Production from Used Cooking Oil (by New Biodiesel Co., Ltd)

The New Biodiesel Company has achieved remarkable outcomes and made significant contributions through its "Biodiesel Production from Used Cooking Oil Project". The project addresses the risks associated with reusing cooking oil and aims to improve the health of nearby communities. It collects waste cooking oil from the public, exchanging it for new vegetable oil to be used as feedstock for biodiesel production. This initiative aligns with Thailand's alternative energy promotion strategy, promoting the use of low-carbon fuel in the transportation sector. The company ensures a continuous feedstock supply by purchasing waste cooking oil from the community at a competitive price. The project tackles environmental and health issues and actively involves and benefits the local community.

The production of biodiesel involves a transesterification reaction, with a maximum monthly capacity of 500 tonnes. To ensure the quality of the biodiesel, additional equipment such as filters and moisture evaporators are installed to separate and remove undesirable substances from the waste cooking oil. The biodiesel produced is blended with regular diesel oil at various ratios (B7, B10, and B20) and sold as vehicle fuel. This process enables the project to reduce diesel consumption by over THB 170 million (USD 5 million) annually and decrease the reliance on fossil fuels by 170 TJ annually.

The "Biodiesel Production from Used Cooking Oil Project" has been implemented with a total investment of THB 150 million (USD 4.30 million), entirely funded by the owner. The project's economic indicators showcase an IRR of 17.35% and a payback period of 6.5 years. Establishing this project brings numerous benefits, including mitigating 13,976 tCO_2e emissions per year. Furthermore, people living near the factory receive more than 700 litres of new vegetable oil for cooking each month. Apart from its environmental and health advantages, the project promotes cleaner fuel consumption and fosters environmental consciousness by welcoming residents and visitors to observe the biodiesel production.

Figure 4-3 New Biodiesel Plant

4.2. Avoided Emissions

The winners from the biofuel category have made significant strides in reducing carbon emissions and promoting sustainable practices. *KPI's Renewable Diesel Production* significantly reduced primary emissions, with the total potential carbon emissions reduction achieved in 2022 alone was estimated to be 39,285.03 tCO_2e, and an annual estimation of 245,969.25 tCO_2e.

Another impactful endeavour is *PLN Indonesia Power's waste solution approach* to produce SRF implemented in Cilegon City. By converting waste into SRF through a biodrying method, this project has reduced carbon emissions by approximately 8.07 tCO_2 per year. The reduction primarily stems from mitigating primary emissions. Such a significant avoidance of carbon emissions marks a substantial contribution to the overall efforts to reduce the region's carbon footprint.

New Biodiesel's production has made notable progress in reducing carbon emissions. Focusing on using used cooking oil as a feedstock has successfully mitigated primary GHG emissions, reducing them by approximately 13,976 tCO_2e per year. These emission reductions play a crucial role in promoting the use of low-carbon fuels and contribute significantly to the broader efforts of reducing carbon footprints. The project's commitment to environmental sustainability and the promotion of cleaner fuel alternatives is commendable. These projects' impacts extend beyond immediate environmental benefits, contributing to the overall well-being of communities and advancing the transition towards a greener and more sustainable society.

Table 4-1 Avoided Emissions of Biofuel Category

Project Name	Status	Total Potential Carbon Emissions Reduction per year (tCO_2e/yr)
The Hydrotreated Vegetable Oil (HVO) project	*Winner*	245,969.25
Waste Solution Approach to Produce Solid Recovered Fuel Project	*1st Runner Up*	8.07
The Biodiesel Production Project	*2nd Runner Up*	13,976

4.3. Technical Performance

KPI's Renewable Diesel showcases exceptional technical performance. Operating at its designed capacity of 2.5 million barrels per stream day, the refinery ensures the efficient production of renewable diesel fuel. The plant incorporates waste heat recovery technology, enabling steam and electricity generation internally, reducing dependence on external energy sources and enhancing overall energy efficiency. The resulting renewable diesel fuel meets stringent international standards, including EN 15940 and Indonesia National Standard (SNI) 8968:2021, with superior characteristics such as a higher cetane number, lower sulfur content and reduced emissions compared to conventional diesel. Performance comparisons with FAME and fossil diesel, as well as road and voyage tests, further validate the exceptional quality and performance of the HVO product.

PLN Indonesia Power's waste solution approach introduced an innovative biodrying formula and chopping process. Waste processing begins with the arrival of various types of fresh waste, such as municipal waste, market waste and street or park waste. The waste undergoes sorting, weighing, and, if necessary, chipping, especially for large wood components. A bioactivator solvent is prepared by activating dormant bacteria with molasses, which is used for fermentation.

The waste is then placed in reactor boxes, layered, and watered with the bioactivator solvent, undergoing a six-day fermentation process. After fermentation, the waste is finely chopped using a dedicated machine, resulting in SRF or *Bahan Bakar Jelantah Padat (BBJP)* with specific characteristics. This waste-to-fuel technology ensures efficient waste processing, producing refused derived fuel (RDF) with a calorific value of 3,200 kcal/kg. The process takes approximately 20 days, providing an effective waste management and energy generation solution.

New Biodiesel's production uses the transesterification reaction process to produce biodiesel from used cooking oil. The used cooking oil undergoes a separation process to remove contaminants such as waste cooked food, dust and moisture, ensuring the production of high-quality biodiesel—additional equipment, including filters and moisture evaporators, aids in this purification step. Emissions and waste are carefully monitored and controlled throughout production to comply with government regulations. With approximately two years of experience producing biodiesel from waste cooking oil, the company has achieved an impressive methyl ester yield (biodiesel yield) of 98-99%. Moreover, strict control of internal production losses allows for a production efficiency of over 98%. This commitment to quality and efficiency demonstrates the technical prowess of New Biodiesel Co. Ltd. in producing biodiesel as a sustainable alternative fuel source.

4.4. Investment Parameters

KPI's Renewable Diesel required a CAPEX of USD 18.7 million. The monthly O&M cost, excluding fuel, amounts to USD 853,818, while the fuel cost is USD 32,313 per month. With a discount rate of 9.24%, the project demonstrates an IRR of 20.96% and a ROI of 24.44%. The payback period for the project is estimated to be nine years. These investment indicators indicate a favourable financial outlook for the HVO project.

PLN Indonesia Power's waste solution approach required a comparatively lower CAPEX of USD 54,231. The monthly O&M cost, excluding fuel, is USD 3,059. The biomass price is set at USD 43.59 per ton. With 100% equity from PT PLN Indonesia Power, the project boasts an IRR of 21.4%. The estimated payback period for this project is 4.2 years. These investment indicators suggest a relatively quick return on investment and a financially viable venture.

For *New Biodiesel's production*, the total CAPEX amounted to USD 5.75 million. The monthly O&M cost, excluding fuel, is USD 90,000. The fuel cost is set at USD 1.15 per litre. The project's net present value (NPV) is USD 1.93 million, and the IRR is 17.35%. The estimated payback period for this project is 6.5 years. These indicators indicate an average return on investment for the biodiesel production project over a reasonable timeframe.

Table 4-2 Comparison of the Biofuel Category Project Winners' Investment Parameters

Parameters	Project Name		
	The Hydrotreated Vegetable Oil (HVO) Project	Waste Solution Approach to Produce Solid Recovered Fuel Project	The Biodiesel Production Project
	Winner	*1st Runner Up*	*2nd Runner Up*
Total CAPEX	USD 18,728,752	USD 54,231	USD 5,750,000
O&M costs (excluding fuel)	USD 853,818	USD 3,059	USD 90,000
IRR	20.96%	21.40%	17.35%
ROI	24.44%	N/A	N/A
NPV	N/A	N/A	USD 1,930,000
Payback Period (years)	9	4.2	6.5

Table 4-2 underlines that KPI's Renewable Diesel demonstrates a significant initial investment but offers favourable returns with a relatively shorter payback period of nine years. PLN Indonesia Power's waste solution approach requires a lower initial investment and shows promising returns, with a payback period of 4.2 years. *New Biodiesel's* production has a moderate initial investment, reasonable returns and a payback period of 6.5 years. These investment indicators provide insights into each project's financial viability and potential returns.

4.5. Operation and Maintenance

KPI's Renewable Diesel operates continuously 24/7, and 330 days a year. The operation is divided into three shifts to ensure round-the-clock production. The biorefinery plant has run smoothly for 431 days in HVO mode, jet A-1 mode and high-grade diesel mode without any interruptions or significant issues. The refinery follows a maintenance scheme involving internal resources and business partners' support. The maintenance tasks are divided among various departments, including reliability, maintenance planning and support, maintenance execution, workshop and procurement. The Project employs various maintenance strategies, such as risk-based inspections, condition-based monitoring, online asset performance monitoring and digital twin asset modelling. Training is provided to ensure compliance with international sustainability standards and to equip the production and operation teams with the necessary skills.

The BBJP of *PLN Indonesia Power's waste solution approach* operates from 8 am to 4 pm, six days a week, for approximately 288 days per year. The maintenance scheme primarily focuses on the chopping machine, ensuring optimal performance by addressing issues like waste sticking to the sharp areas. Daily, weekly and monthly maintenance activities are conducted to keep the working area clean and the machine in good working condition. PT PLN Indonesia

Power also provides assistance and training to the local labour appointed by the Cilegon Government. The aim is to impart knowledge and skills related to biodrying and conversion into SRF. The researchers gather information while simultaneously training the local workforce. PLN Indonesia Power's Education and Training Center includes a syllabus on converting waste into SRF, enabling replicating SRF mini plants across different locations.

As for *New Biodiesel's production*, the operation hours extend to 24 hours per day and 300 days per year. The technical staff is responsible for checking and maintaining the machines and equipment before daily operations. If malfunctions are detected, immediate repairs or replacements are carried out to prevent production disruptions. The maintenance plan is annually revised, incorporating work instructions and considering any modifications to the production line. The company places a strong emphasis on capacity building and knowledge management. Senior-level workers coach and transfer their production-related operational expertise to newcomers. On-the-job training is also provided to new staff members to gain hands-on experience. This focus on skills development ensures a capable workforce that can effectively handle the production process and replace retired staff members.

In summary, *KPI's Renewable Diesel* operates continuously with three shifts, following a comprehensive maintenance scheme incorporating various strategies and training programmes. *PLN Indonesia Power's waste solution approach* operates during specific hours. It emphasises routine maintenance, accompanied by assistance and training for the local workforce. *New Biodiesel's production* operates round-the-clock and implements a maintenance plan with regular checks and staff development programmes. These operation and maintenance schemes ensure smooth and efficient production processes in each project.

5

Combined Heat and Power Category

5.1. Overview of the Winners

The Combined Heat and Power (CHP) category shortlisted three winners. *Eastern Sugar and Cane (ESC)'s Baggase Combined Heat and Power Plant* in Sa Kaeo, Thailand efficiently produces electricity and steam by harnessing **biogas** derived from 120,000 tons of bagasse annually, significantly reducing carbon emissions and achieving impressive returns on the USD 14.22 million investment. ESC's integrated approach sets a high standard for environmental impact reduction and resource efficiency, demonstrating its commitment to sustainability.

The first runner-up, *Suralaya Power Generation Unit* in Cilegon, Banten, Indonesia, effectively combines **biomass** with coal to reduce CO_2 emissions, achieving energy savings and a high profit margin. They have been recognised for their exemplary environmental management and community contributions. The second runner-up is the *Sei Pagar Biogas Cofiring Boiler Pilot Project* in Indonesia which efficiently uses POME as the **biogas** feedstock to reduce emissions, providing dual benefits of clean energy and financial incentives while aligning with various SDGs.

5.1.1. Winner: Bagasse Combined Heat and Power Plant for Energy Self-Sufficiency (by Eastern Sugar and Cane Public Company Limited and ES Energy Co., Ltd. (Wang Sombun))

ESC has achieved remarkable sugar production and distribution outcomes. Operating two sugar factories with a daily capacity of 46,000 tons of cane, ESC maximises value by utilising by-products to generate electricity, ethanol, biogas and fertilizer. Their ES Energy Bagasse Combined Heat Power Plant uses 120,000 tons of bagasse annually, producing steam and electricity. While 52% of the steam is used for sugar cane crushing, the remaining 48% generates approximately 19.2 GWh of electricity.

This innovative RE production has successfully replaced fossil fuel usage, substantially avoiding over 13.4 million tCO_2e emissions yearly. Over the 25-year lifespan of the project, this equates to more than 335 million tCO_2e avoided. The project's investment value of USD 14.22 million has yielded impressive returns, with an IRR of 17.91% and a payback period of 4 years and 11 months. ESC's unwavering commitment to efficient sugar production and the use of by-products reflects its dedication to sustainability and the optimisation of operational value.

ESC's integrated approach contributes to the sugar industry and sets an exemplary environmental impact reduction and resource efficiency standard. By leveraging by-products and making substantial investments in renewable energy infrastructure, ESC is paving the way for a sustainable future in the industry. Their initiatives benefit their operations and have a positive environmental impact, showcasing ESC's dedication to profitability and environmental stewardship.

Figure 5-1 ES Energy (Wang Sombun) Bagasse Combined Heat Power Plant

5.1.2. 1st Runner Up: Implementation Biomass Cofiring In Suralaya Coal Co-Generation Plant (by PLN Indonesia Power Co., Ltd. (Suralaya Power Generation Unit))

The Suralaya power generation unit is making major strides in meeting the electricity demand of the Java-Bali region, contributing 12% of the national electricity demand in 2022. Using 12.8 billion kg of coal and 132 million kg of biomass as fuel, it has generated an impressive total production of 23,351.6 TWh. Employing co-firing technology and operating a desalination plant that produces 824,380 m3/year of fresh water, the unit efficiently utilises resources to meet both electricity and water needs.

To prioritize sustainable energy practices, the unit has strongly emphasised increasing the utilisation of biomass waste as a fuel mixture, significantly reducing CO_2 emissions. Their commitment to energy efficiency has yielded remarkable outcomes, including substantial energy savings of 6,567.4 TJ and a noteworthy reduction of 4.8 million tCO_2e emissions through their environmental emissions reduction programmes. The Suralaya Generating Unit has demonstrated prudent financial management, maintaining a 55% profit margin with an operating cost of USD 943,194.22, where 5% is allocated for operation and maintenance. Their exemplary environmental management performance has been acknowledged by the Indonesian Ministry of Environment, receiving the prestigious gold category recognition in 2022. Additionally, the unit actively contributes to the local community's well-being by providing employment opportunities and extending benefits to the surrounding area.

In summary, the Suralaya power generation unit is a vital contributor to meeting the electricity demand of the Java-Bali region. Through their commitment to green energy initiatives, including the increased utilisation of biomass waste and a focus on energy efficiency, they have successfully reduced CO_2 emissions while ensuring a sustainable and efficient use of resources. Their exceptional environmental management performance has been duly recognised, and their positive impact extends beyond energy production to the local community, providing employment opportunities and fostering community benefits.

Figure 5-2 Suralaya Power Generation Unit

5.1.3. 2nd Runner Up: Implementation of Biogas Cofiring in Biomass Cogeneration Power Plant at the Sei Pagar Palm Oil Mill (by PT Perkebunan Nusantara V)

The Biogas Cofiring Boiler Pilot Project at Sei Pagar Palm Oil Mill (POM) in PTPN V has achieved outstanding outcomes and addressed environmental challenges. By efficiently utilising POME as feedstock, the project significantly reduces emissions. Methane gas, captured and processed from POME, replaces palm shells in the boiler, substantially decreasing GHG emissions. Additionally, the surplus palm shells can be sold, providing an additional income stream for the mill. This project represents a significant improvement over the previous practice of releasing POME into the atmosphere, contributing to air pollution and global warming.

The steam generated in the boiler plays a dual role in the project's success. Firstly, it is used to drive a turbine, producing electricity that powers the sterilisation process. Sei Pagar POM has successfully reduced its GHG emissions by implementing this initiative. It becomes eligible to receive incentives from the International Sustainability Carbon Certification (ISCC) for certified palm oil sales. Furthermore, this project aligns strongly with various SDGs, including affordable and clean energy, industry and innovation, responsible consumption and production, climate action, and life on land. Its multifaceted approach benefits the company financially and actively contributes to pursuing sustainability goals.

In conclusion, the *Biogas Cofiring Boiler Pilot Project* at Sei Pagar POM is a highly profitable and sustainable initiative. It exemplifies the mill's commitment to environmental responsibility and advancing sustainable practices in the palm oil industry. By effectively utilising POME as a renewable energy source and significantly reducing GHG emissions, the project demonstrates the positive impact of innovative solutions on profitability and sustainability. It is a successful model for other palm oil mills seeking to optimise financial performance while actively contributing to environmental stewardship.

Figure 5-3 Biogas Cofiring Boiler at Sei Pagar POM

5.2. Avoided Emissions

ESC's Baggase Combined Heat and Power Plant can potentially reduce carbon emissions by 13.4 million tCO_2e annually. This project promotes cleaner and more sustainable energy generation by addressing primary greenhouse gas emissions like carbon dioxide, methane, nitrous oxide and CFCs. Over its 25-year lifetime, the estimated total potential carbon emission reduction reaches 335 million tCO_2e.

Suralaya Power Generation Unit holds great promise for carbon emissions reduction, potentially 235 million tCO_2e annually. Integrating biomass as an additional fuel source alongside coal effectively curbs primary greenhouse gas emissions, mitigating the environmental impact of coal-based power generation.

On a smaller scale, the *Sei Pagar Biogas Cofiring Boiler Pilot Project* reduces carbon emissions by 7,152 tCO_2e per year by using biogas produced from POME as feedstock, supporting a more sustainable and environmentally friendly operation within the palm oil industry.

Table 5-1 Avoided Emissions of CHP Category

Project Name	Status	Total Potential Carbon Emissions Reduction per year (tCO_2e/yr)
The Bagasse Combined Heat and Power Plant Project	*Winner*	13,400,000
The Implementation of Biomass Cofiring in the Suralaya Coal Co-Generation Plant Project	*1st Runner Up*	235,000,000
The Development of Biogas Cofiring at Sei Pagar Palm Oil Mill Project	*2nd Runner Up*	7,152

As highlighted in Table 5-1, *ESC's Baggase Combined Heat and Power Plant*, *Suralaya Power Generation Unit*, and *Sei Pagar Biogas Cofiring Boiler Pilot Project* all contribute to reducing carbon emissions and mitigating climate change effects. While the first two projects showcase significant potential for large-scale emission reductions, the smaller-scale biogas cofiring project at the palm oil mill still contributes to sustainable practices. Together, these endeavours demonstrate the commitment to combatting climate change and fostering a more environmentally conscious approach to energy generation and industry.

5.3. Technical Performance

ESC's Baggase Combined Heat and Power Plant stands out with its notable capabilities. The plant efficiently harnesses resources with an installed capacity of 10 MW for electricity and 130 tons/h for steam and a net capacity of 8 MW for electricity and 115 tons/h for steam. It generates substantial energy, producing 277,000 tons/year from steam and 19.2 GWh/year from electricity. The plant maximises its potential by consuming 120,000 tons/year of biomass with a biomass heat input of 7,350 kJ/kg. With a capacity factor of 80%, it ensures efficient utilisation of available resources.

Suralaya Power Generation Unit operates on a significant scale. The plant boasts an installed power capacity of 4 x 400 MW and a 3 x 600 MW net capacity. It achieves its objectives through a fuel combustion rate of 12.8 million tons/year of coal and 132,941 tons/year of biomass. The coal and biomass are skillfully mixed, with a rate of 199.5 tons of biomass per 1 MW per day. Additionally, the project relies on water consumption of 824,380 m^3/year sourced within the project area to support its operations effectively.

Sei Pagar Biogas Cofiring Boiler Pilot Project excels in two main aspects: biological process performance and palm shell saving. Its boiler capacity ranges from 100 to 120 Nm^3 of biogas per hour, maintaining a pH in the continuously stirred tank reactor of 7.0 to 7.2 and a temperature of 36°C to 40°C. The biogas boasts a methane content exceeding 60% while removing chemical oxygen demand achieves over 90% efficiency.

The availability of fresh fruit bunches and the smooth operation of POM are crucial in acquiring palm shell savings. It also led to a substantial reduction, decreasing the emissions from 414.23 $kgCO_2e$/dry ton CPO to 262.16 $kgCO_2e$/dry ton CPO. This reduction represents a 37% decrease, contributing to environmental preservation. However, the limited biogas cofiring system's capacity, representing only 25% of Sei Pagar POM's production potential, accounts for the reduction falling short of 100%.

5.4. Investment Parameters

ESC's Baggase Combined Heat and Power Plant showcases promising investment indicators. With CAPEX of USD 14.2 million, the project yields an IRR of 17.91%, a ROI of 6% and a payback period of 4.92 years. These indicators indicate the project's financial viability and potential to generate favourable returns.

Similarly, *Suralaya Power Generation Unit* presents strong investment indicators. With CAPEX of USD 20.3 million, the project exhibits an impressive IRR of 28.38%, a ROI of 12% and a payback period of 4.88 years. These indicators highlight the project's financial attractiveness and potential for significant returns.

In contrast, *Sei Pagar Biogas Cofiring Boiler Pilot Project* demonstrates relatively lower investment indicators. The project involves a CAPEX of USD 916,466 and exhibits an IRR of 8.39%, a ROI of 3.64% and a payback period of nine years. These investment indicators indicate a moderate financial performance, with a longer payback period and relatively lower returns than the other projects.

Table 5-2 Comparison of the CHP Category Project Winners' Investment Parameters

Parameters	Project Name		
	The Bagasse Combined Heat and Power Plant Project	The Implementation of Biomass Cofiring in the Suralaya Coal Co-Generation Plant Project	The Development of Biogas Cofiring at the Sei Pagar Palm Oil Mill Project
	Winner	*1st Runner Up*	*2nd Runner Up*
Total CAPEX	USD 14,160,000	USD 20,300,000	USD 916,466
O&M costs (excluding fuel)	USD 516,493	USD 26,897	USD 27,494
IRR	17.91%	28.38%	8.39%
ROI	6.00%	12%	3.64%
NPV	USD 890,363	N/A	USD 110,001
Payback Period (years)	4.92	4.88	9

Table 5-2 compares the projects' investment parameters. Both *ESC's Baggase Combined Heat and Power Plant* and the *Suralaya Power Generation Unit* display favourable investment indicators, including higher IRR, ROI and relatively shorter payback periods. These projects are attractive in terms of financial performance and offer the potential for significant returns on investment. By contrast, *Sei Pagar Biogas Cofiring Boiler Pilot Project* presents lower investment indicators, with a comparatively lower IRR, ROI and a longer payback period. However, it is essential to consider each project's specific context and objectives when assessing their investment attractiveness.

5.5. Operation and Maintenance

ESC's Baggase Combined Heat and Power Plant have a well-defined system. The plant operates for specific hours yearly, aligned with the sugar factory's energy usage and production season. Maintenance activities are scheduled during the sugar melting season and off-season to coincide with the annual plan. A dedicated team of 18 personnel maintains the plant's steam and electricity production, working closely with the sugar factory's production and maintenance departments. Training programmes and knowledge-sharing are emphasised, and effective maintenance measures such as condition-based and preventive maintenance are implemented.

Suralaya Power Generation Unit follows a comprehensive maintenance scheme. The plant operates continuously, 24 hours a day for most of the year, with maintenance performed by a dedicated maintenance service unit and in-house staff. The preventive maintenance scheme prioritises the needs of the machines, scheduling major maintenance or overhauls after a specific number of operating hours or years. The project adheres to quality management standards, implements regular preventive maintenance, and places importance on developing the competence and knowledge of the workforce through training programmes.

Sei Pagar Biogas Cofiring Boiler Pilot Project has a straightforward maintenance scheme. The biogas production operates continuously throughout the year, with real-time monitoring and control facilitated by a SCADA system. The mill's maintenance team handles minor repairs, while major repairs are outsourced to vendors. Preventive maintenance checks ensures that regular maintenance activities are carried out. The absence of complex equipment in the biogas cofiring plant eliminates the need for extensive overhauls. Training programmes, benchmarking visits and knowledge-sharing initiatives are provided to operators and maintenance teams to ensure effective operation and maintenance.

6

Special Submission Category

6.1. Overview of the Submissions

There were three special submissions for this year. The first one is the implementation of *geothermal analysis engineering software (GAES) at the Kamojang POMU geothermal power plant*, which resulted in significant outcomes, improving efficiency, reducing costs and optimising power generation capacity. Next, *the electrification project by H2 Energy and the Ministry of Health Malaysia* showcased the viability of **hydrogen energy storage systems**, providing uninterrupted electricity supply in rural areas through a hybrid system powered by solar PV and fuel cells. The last special submission comes from *Thailand (Delta Electronics (Thailand) PCL.)*, which integrated **solar energy** with automation to enhance productivity, reduce labour requirements and promote sustainable farming practices. Although these projects exemplify the pursuit of innovative and environmentally friendly solutions in various sectors, no winners were selected for this category. Nevertheless, these commendable projects deserve recognition and play a significant role in tackling environmental challenges. The next sections delineate each project's performance, outputs and operational mechanisms.

6.1.1. 1st Special Submission: Smart Application for Excellent Geothermal Power Plant Performance (by PLN Indonesia Power)

GAES at Indonesia's Kamojang POMU geothermal power plant has yielded remarkable outcomes. The software, designed to address operational challenges such as scaling, erosion and corrosion, has significantly improved the plant's efficiency and financial performance. The equivalent availability factor of critical systems, including the turbine washing system and cooling tower, increased from 90.94% to 96.85% in 2021. The production cost decreased by IDR 85.51 (USD 0.0054)/kWh, resulting in a financial benefit of USD 5 million.

GAES's integrated modules monitor geothermal steam quality and analyse generator performance, enabling better decision-making. This innovative application reduces costs, improves overall performance and maximises the absorption of a steam price discount of one cent dollar. GAES empowers the Kamojang POMU GPP to achieve economic gains and optimise power generation capacity by effectively tackling operational challenges and enhancing decision-making processes.

Implementing GAES has significantly improved the Kamojang POMU geothermal power plant. The software has mitigated scaling, erosion and corrosion issues through enhanced monitoring and analysis, increasing efficiency and decreasing production costs. GAES's contribution to better decision-making processes has improved the plant's overall performance and economic benefits.

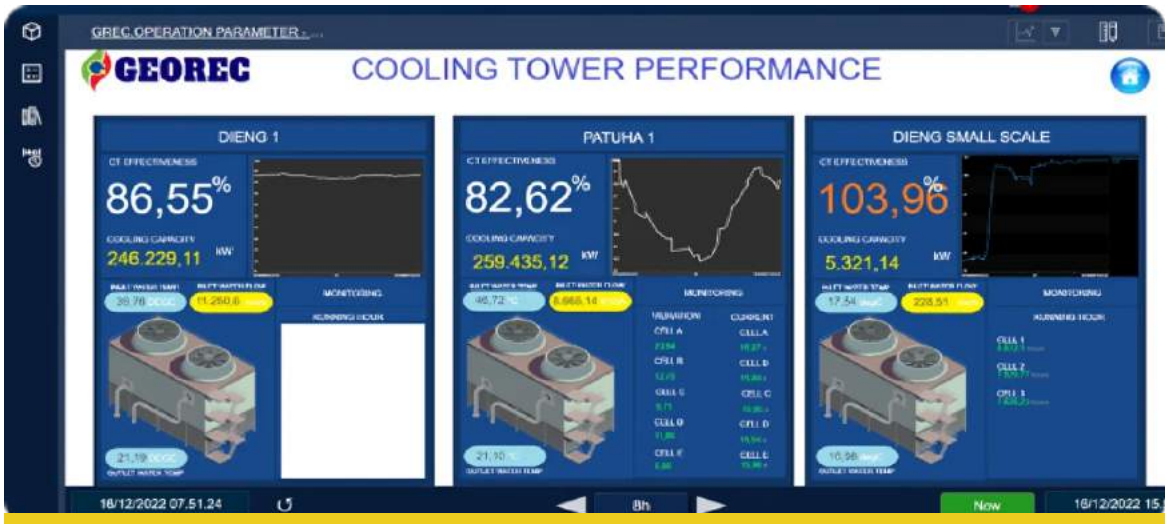


Figure 6-1 Software Interface of the Geothermal Analysis Engineering Software (GAES)

6.1.2. 2nd Special Submission: Solar + Hydrogen Green Energy Powered by H2E System at Klinik Kesihatan Long Loyang, Marudi, Sarawak (by H2 Energy Sdn. Bhd.)

The electrification project, a collaboration between H2 Energy Sdn Bhd (H2Energy) and the Ministry of Health Malaysia (MOH), demonstrated the viability and reliability of hydrogen energy storage systems for providing uninterrupted electricity supply to healthcare clinics in rural areas. The pilot test clinic in Long Loyang, a remote village in Sarawak Borneo, is a successful example, as it lacks access to the national power grid.

The project's system infrastructure consists of a solar PV system that meets the daytime demand of approximately 5 kWp, and a fuel cell designed to deliver up to 2.5 kWp of electrical energy at night. Hydrogen gas is generated through an onsite electrolyser module and stored at 500 NL per hour. The generated hydrogen gas is stored in four units of gas cylinders compressed to 35 bars. This hybrid system has proven effective, particularly in operational environments in rural and remote areas of Sarawak. It offers several advantages over diesel generators, including sustainability, cleanliness and providing uninterrupted power supply.

The H2E System, a decentralised renewable energy solution, was successfully installed and launched in August 2022 to cater to the clinic's electricity needs on a 24/7 basis. It supplies the required power during operating hours and a minimal base load for refrigeration and other essential electrical/medical appliances during non-operating hours. H2Energy has developed modular, compact and highly mobile systems that are easily transportable, and scalable/customisable to accommodate different load profiles. The H2E system, which uses solar PV panels, an electrolyser and hydrogen storage tanks, provides a daily supply of 25-30 kW, with a peak load of 2.88 kWp. The project also has potential for broader applications in various rural settings, such as settlements and schools, which H2Energy is exploring through collaborations with relevant government agencies.

Figure 6-2 H2E System Powerhouse at Long Loyang Clinic

6.1.3. 3rd Special Submission: Delta's Smart Factory Farm (by Delta Electronics (Thailand) PCL.)

Delta's Smart Factory Farm project has achieved noteworthy outcomes and achievements in addressing the impacts of climate change on agriculture and food production. By promoting sustainable and adaptive farming practices, the project aims to address reduced yields, low-quality produce, and increased the incidence of pests and diseases, thereby contributing to long-term resilience in the food system.

Delta Electronics (Thailand) PCL is actively developing Delta's Smart Factory Farm to foster sustainable growth in local areas and communities. The project introduces innovative smart farming practices that enhance the value of local products while offering efficient food production solutions and improved food security. The project's reliance on renewable energy sources aligns with Delta's commitments to sustainability and reduced environmental impacts.

The Delta Smart Factory Farm integrates automation and RE solutions to monitor weather conditions, control interior greenhouse climates, maintain water quality and optimise plant nutrition. The project has achieved significant outcomes by leveraging automation technologies, including improved efficiency, reduced labour requirements and water conservation. The implemented solutions include a solar rooftop system with a capacity of 5.4 kWp, ensuring 100% operations powered by renewable energy.

The hydroponics greenhouse provides precise control over plant growth and quality. A water recirculation treatment system using reverse osmosis technology reduces water loss. A nutrient control system ensures the highest availability of essential nutrients for optimal plant growth. The project also incorporates temperature and humidity control systems to create the most efficient atmospheric conditions. Air ventilation control aids in the distribution of CO_2, while lighting control ensures the provision of suitable levels of photons for the plants. These advancements enhance farm productivity and contribute to resource efficiency, making the Delta Smart Factory Farm a model for sustainable and technologically advanced agriculture practices.

Figure 6-3 Delta's Smart Factory Farm Green House

6.2. Avoided Emissions

GAES of Kamojang POMU Geothermal aims to reduce carbon emissions by ensuring the optimal performance of geothermal power plants. While specific details have not been provided, the project focuses on predicting and preventing derating issues and monitoring generator performance. These practices can be implemented within the PLN Group to support their commitment to reducing carbon emissions.

H2E System at Klinik Kesihatan Long Loyang demonstrates significant emission reductions. The clinic is estimated to avoid 13 to 33 tCO_2e annually compared to diesel-powered alternatives. By phasing out carbon-emitting diesel generators, an estimated annual reduction of 9,334 $kgCO_2e$ is achieved across the clinic's operations, improving air quality and reducing sound pollution.

Delta's Smart Factory Farm integrates a solar energy system that covers the greenhouse's electricity demand, resulting in a net-zero greenhouse. This system generates 20 kWh/day or 8,000 kWh/year of green electricity, avoiding the emission of approximately 4 tCO_2e annually.

Table 6-1 Avoided Emissions of Special Submission Category

Project Name	Total Potential Carbon Emissions Reduction per year (tCO_2e/yr)
Smart Application for Excellent Geothermal Power Plant Performance	N/A
Solar + Hydrogen Green Energy Powered by H2E System	13
Delta's Smart Factory Farm	4

Table 6-1 indicates that these projects have made notable efforts to mitigate carbon emissions. The geothermal power plant project aims to improve overall performance. In contrast, the solar and hydrogen-powered clinic and smart factory farm projects achieve significant emission reductions through renewable energy sources.

6.3. Technical Performance

GAES of Kamojang POMU Geothermal helps predict and prevent derating, and also monitor generator performance. This innovation has increased the equivalent availability factor for the turbine washing system and cooling tower performance from 90.94% to 96.85% in 2021. The project demonstrates the potential for improving the performance of geothermal power plants and reducing carbon emissions.

H2E System at Klinik Kesihatan Long Loyang uses solar PV panels and an electrolyser to generate and store hydrogen gas for electricity supply. Specific technical details on performance are limited, but the system supplies 25-30 kW daily, with a peak load of 2.88 kWp. The energy storage capacity of the hydrogen gas is designed to yield 38 kWh when converted back to electricity. The project highlights the use of renewable energy sources and demonstrates the potential for reducing carbon emissions and dependence on diesel generators.

Delta's Smart Factory Farm incorporates various technical systems for efficient plant growth. The hydroponics greenhouse system enables control and adjustment of system parameters affecting plant growth and quality. The greenhouse design maximises space efficiency and enables the growth of 270 plants in just 18 m2. The project also includes a water recirculation treatment system that conserves water and ensures efficient nutrient delivery. A nutrient control system maintains the necessary nutrient levels, while temperature and humidity control, air ventilation control and lighting control create optimal growing conditions. The automation systems are managed by a programmable logic controller and the DeltaGrid Energy IOT system facilitates the overall energy management. The project is powered by a renewable energy solution consisting of a 5.4 kWp solar system, further enhancing its sustainable and technologically advanced approach.

6.4. Investment Parameters

GAES of Kamojang POMU Geothermal does not provide specific details about the initial investment cost. However, the installation cost per unit is estimated at approximately USD 130,000, which includes infrastructure, software development, the basic GAES system and engineering design services. The project has demonstrated significant financial benefits, yielding USD 5 million. The restoration of electricity supply and profit from software sales contributed the most to this financial gain.

H2E System at Klinik Kesihatan Long Loyang does not provide information on the investment cost. However, though these costs are not quantifiable in monetary terms, the H2Energy system has the lowest environmental and social costs compared to other alternatives. In terms of the levelised cost of energy (LCOE), the H2Energy system has the lowest LCOE of RM 11.32 (USD 2.4) over 20 years, based on a capacity of 40 kWh. Additionally, compared to diesel generators and solar batteries, the H2Energy system has the lowest downtime and maintenance costs of RM 20,000 (USD 4,250) every five years.

Delta's Smart Factory Farm invested USD 85,000 in greenhouse construction, farming utility systems, hydroponics systems, automation solutions (including sensors and controllers) and a solar energy system. The smart factory farm can grow 270 plants in just an 18 m2 area, which would require over 54 m2 in a traditional farm to achieve the same level of productivity. High-precision control technology minimises culture time and contributes to efficient plant growth. Implementing a solar energy system also reduces energy costs, resulting in annual savings of over USD 1,000. Additionally, the smart greenhouse generates revenue for the community, with each crop worth USD 850, as it offers high-quality, pesticide-free lettuce products targeted towards health-conscious individuals.

Table 6-2 Comparison of the Special Submission Category Project Winners' Investment Parameters

Parameters	Project Name		
	Smart Application for Excellent Geothermal Power Plant Performance	Solar + Hydrogen Green Energy Powered by H2E System	Delta's Smart Factory Farm
	1st Submission	*2nd Submission*	*3rd Submission*
Investment Cost	N/A	N/A	USD 85,000
Installation Cost	USD 130,000	N/A	USD 218,062

As indicated in Table 6-2, *GAES of Kamojang POMU Geothermal* and *H2E System at Klinik Kesihatan Long Loyang* do not provide detailed information on their respective investment costs. However, they have demonstrated significant financial benefits and cost advantages, such as the restoration of the electricity supply and low LCOE.

6.5. Operation and Maintenance

GAES of Kamojang POMU Geothermal does not provide detailed information about its maintenance scheme. However, GAES has proven to be an effective tool for smart analysis and solving operational problems in geothermal power plants. By addressing issues such as scaling, erosion and corrosion of turbines, as well as the decrease in cooling system effectiveness, GAES has significantly improved the plant's performance, increasing the equivalent availability factor from 90.94% to 96.85% in 2021. The project aims to reduce economic losses, improve generation availability, minimise energy losses and reduce maintenance costs.

The current ownership and financing responsibilities of the *H2E System* lie entirely with H2Energy. However, there are plans for transferring ownership to Malaysia's Ministry of Health (MoH). H2Energy conducts periodic routine maintenance to ensure the system's full functionality. Operative training sessions have been undertaken with on-site staff and representatives from the local health authorities. Different arrangements, such as sale or lease types, may be considered for future projects.

After the installation and implementation phase of *Delta's Smart Factory Farm*, the expert engineers supported local businesses through training and customer service. This ensures that the farm operates smoothly and efficiently and that any operational or maintenance issues are addressed promptly with the help of Delta's technical expertise.

7

Conclusions and Recommendations

7.1. Conclusions

ASEAN RE Awards 2023 has seen a remarkable surge, with 35 submissions from all categories. This increase in the number of submissions can be attributed to the in-person organisation of the judging and awarding processes. The guideline improvement may also contribute to the overall increase in submissions. As for the geographical distribution aspect, the submissions for the RE Awards continue to be dominated by Malaysia and Indonesia, followed closely by Thailand.

More than that, an interesting pattern emerges within the specific types of submissions. For example, the off-grid category had a noticeable upward trajectory, particularly within the thermal sector. This signals a growing interest in decentralised and thermal-based renewable energy solutions.

In the off-grid category, the winners predominantly hailed from Indonesia, followed by Malaysia and Thailand as runners-up. By comparison, Indonesia and Thailand dominated the on-grid category, showcasing their leadership in grid-connected renewable energy projects. Indonesia emerged as the frontrunner in biofuel and CHP award-winning projects. A significant trend within this category was the utilisation of used or waste feedstocks, such as used cooking oil and other recovered fuels, showcasing an innovative approach to sustainability.

Lastly, while the special submission category did not produce any winners, all of the submitted projects demonstrated a substantial impact through diverse approaches and focal points. The scale of these projects varies widely, ranging from individual plant setups to initiatives spanning specific areas or regions. This diversity reflects the wide range of actions being taken to promote and enhance renewable energy adoption across different scales and contexts.

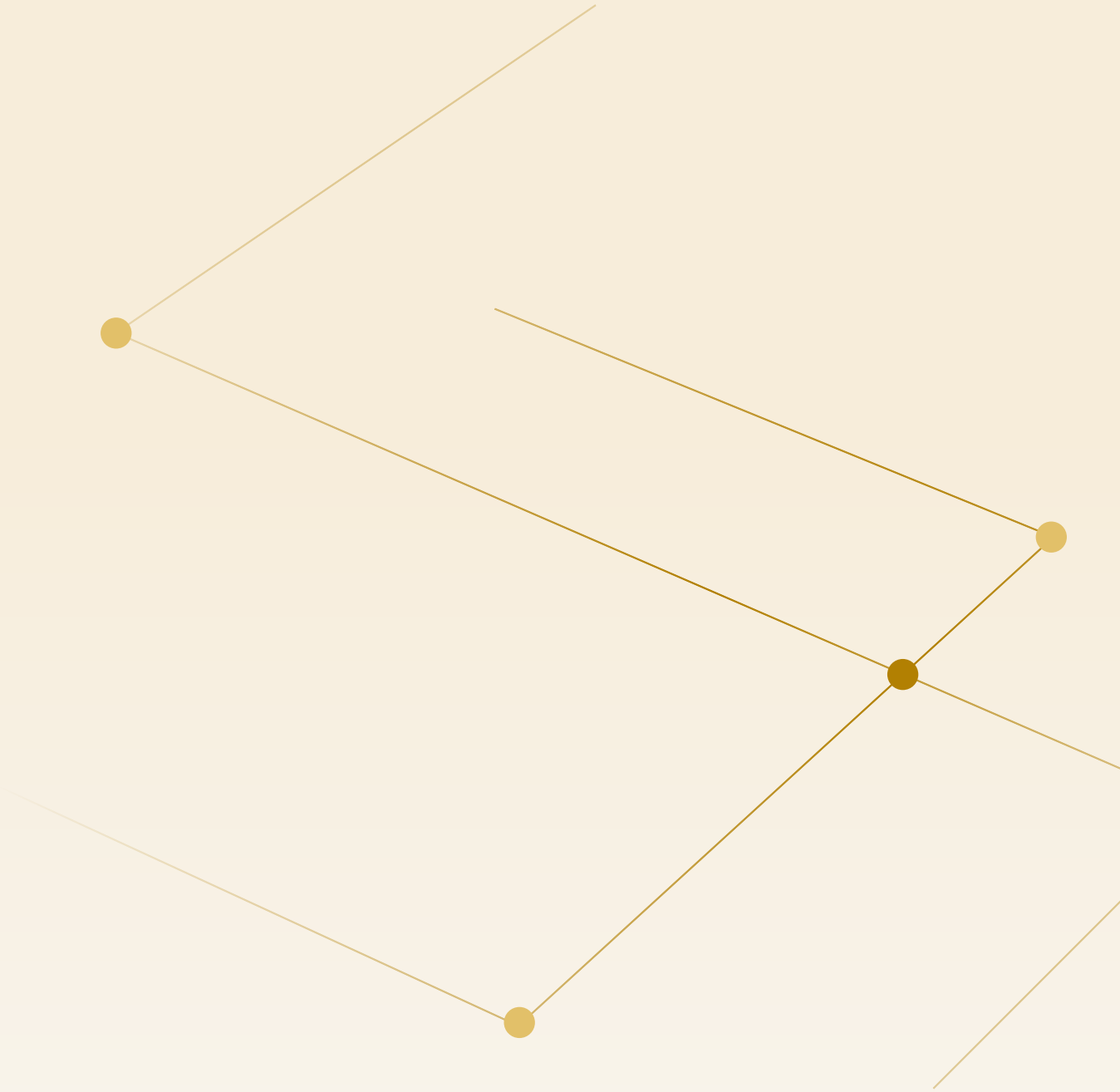
7.2. Recommendations

Several enhancements made to the ASEAN RE Awards 2023, such as more detailed descriptions and scoring criteria, increased the total number of participants. This shows that by promoting a broader range of projects and approaches, the ASEAN Energy Awards can inspire more extensive and more diverse cross-sector collaboration and innovative thinking which transcends traditional boundaries.

Several projects highlighted the importance of combining RE with conventional fuel or other RE technologies. For example, the CHP category winners presented the value of co-firing biomass in existing coal-fired plants. This approach reduces emissions and showcases the potential of harmonising renewable sources with conventional energy systems. Emphasising such integration can foster greater acceptance and RE adoption among various stakeholders.

The winning projects also demonstrated how involving local communities not only drives acceptance but also enhances the sustainability of projects. Additionally, several projects that highlighted the adoption of new and innovative technologies underscored the importance of investing in technologies that improve operational efficiency and address challenges. Encouraging the exploration and integration of local stakeholders and capacity-building initiatives to the project will drive the industry forward and ensure long-term impact.

Lastly, the winners serve as a powerful examples. Their achievements go beyond carbon emissions reduction to broader environmental benefits. These projects show that addressing multiple environmental concerns simultaneously is achievable and highly advantageous. This point aligns closely with the purpose and objective of the RE Awards: to both motivate and represent a testament to the unwavering commitment of the region to advance renewable energy solutions.



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