

Integrating LCA and Carbon Accounting for Gate-to-Gate Sustainability Improvement: Evidence from Liquid Nitrogen Injection in KBR Purifier Unit for Liquid Ammonia Production

Integrasi Life Cycle Assessment (LCA) dan Akuntansi Karbon untuk Peningkatan Keberlanjutan Gate-to-Gate: Studi Kasus Injeksi Nitrogen Cair di KBR Purifier Unit untuk Produksi Amonia Cair

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ABSTRAK

Penelitian ini mengintegrasikan *Life Cycle Assessment (LCA)* dan Akuntansi Karbon untuk mengukur peningkatan kinerja keberlanjutan dalam proses produksi amonia. Fokus analisis ini ditempatkan pada batas *gate-to-gate* pada fase *start-up* unit *purifier*, di mana penggunaan energi sangat tinggi. Secara umum, proses *start-up* unit *purifier* pada pabrik amonia berlangsung selama 20–25 jam dan memerlukan volume besar gas alam serta *steam*, yang menghasilkan emisi karbon signifikan dan ketidakefisienan energi. Penelitian ini memaparkan penerapan teknologi Injeksi Nitrogen Cair (*Liquid Nitrogen / LIN*) yang dimanfaatkan untuk mempercepat proses pendinginan (*cooling down*) unit *purifier* suhu antara -100 sampai -186 °C, dan terbukti mampu mengurangi waktu *start-up* sekitar 10,56 jam. Standar ISO 14064-1 dan SNI 7724:2011 digunakan dalam analisis ini, dan dilakukan perhitungan neraca massa gas, energi, dan emisi. Hasil penelitian menunjukkan bahwa penerapan Injeksi LIN dapat menurunkan konsumsi gas alam sebesar 23,94 MMSCF, *steam* sebesar 899,56 ton, serta total energi mekanik (Mech/ημ) pada siklus *start-up* sebesar 28.009,61 GJ. Pengurangan ini setara dengan penurunan emisi sebesar 1.568,43- 1.610,06 Ton CO₂e. Pendekatan dekarbonisasi yang berorientasi pada proses ini mendukung sistem MRV (*Measurement, Reporting, and Verification*), yang memungkinkan pendaftaran kredit karbon sesuai dengan kerangka pasar karbon Indonesia (IDX Carbon).

Kata kunci — Amonia Cair, Efisiensi Energi; KBR Purifier Unit; *Life Cycle Assessment (LCA)*; *Measurement, Reporting and Verification (MRV)*.

ABSTRACT

This research combines *Life Cycle Assessment (LCA)* and Carbon Accounting to quantify sustainability performance improvements in ammonia production. Emphasis is placed on *gate-to-gate* in the *start-up* phase of the *purifier* unit where energy use is high. Typically, start up in ammonia plants is a 20-25 hour long process that consumes large volumes of natural gas and steam resulting in substantial carbon emissions and inefficiency. This statement presents the technology of LIN (*Liquid Nitrogen*) Injection, which is used to accelerate the cooling process of *purifier* units at a temperature between -100 to -186 °C, reduces *start-up* duration by an estimation about 10.56 hours. ISO 14064-1 and SNI 7724:2011 standards were used, a gaseous mass, energy, and emission balance was carried out. Results also indicate that LIN Injection reduces natural gas consumption of 23.94 MMSCF, steam with a factor of 899.56 tons and total energy Mech/ημ using *start-up* cycle 28,009.61 GJ. This is equivalent to 1,568.43- 1,610.06 tons of CO₂e emission reduction. This process-oriented decarbonization supports the MRV system, which enables carbon credit registration according to Indonesian's IDX Carbon market framework.

Keywords — Energy Efficiency; KBR Purifier Unit; *Life Cycle Assessment (LCA)*; Liquid Ammonia; *Measurement, Reporting and Verification (MRV)*

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1. Introduction

Socioeconomic change towards sustainability is increasingly being determined by the meeting point of eco-innovation, climate responsibility and standardized carbon accounting toolkits. With the global industry closer to a net-zero pathway, process-level innovations that contribute to less energy depth and emissions have become an important levers for attaining the SDGs [1]. The ammonia industry with its strong reliance on fossil-based feedstock and energy, is one of the most promising sectors to showcase how eco-innovation can materialize into real carbon reduction and operational flexibility.

Eco-innovation involves the development of new technologies and products and processes and management systems which help decrease environmental harm. The OECD defines eco-innovation as innovations which create actual environmental benefits together with economic worth [2]. The system operates through three elements which include technological efficiency and resource circularity and system-level transformations. The LIN Injection system operates as an eco-innovative process improvement which enhances operational flexibility and sustainability during ammonia production. This system is implemented within the KBR Purifier Unit, a synthesis gas purification section that removes impurities such as methane, argon, and excess nitrogen through an advanced cryogenic separation process. As a result, the unit produces synthesis gas with an optimized hydrogen-to-nitrogen ratio, ensuring ideal feed conditions for subsequent ammonia synthesis [3]. The LIN Injection system replaces conventional process-gas cooling with cryogenic nitrogen at $-196\text{ }^{\circ}\text{C}$ to achieve faster temperature decreases during purifier startup which results in reduced natural gas and steam consumption. The Liquid Nitrogen (LIN) Injection innovation represents a significant advancement in process eco-efficiency because it unites technological advancements with environmental protection. The intervention reduces energy usage by 28,009.61 GJ during start-up operations while decreasing carbon emissions between 1,568.43-1,610.06 tCO₂e per occurrence which aligns with industrial decarbonization targets.

This study uniquely integrates Life Cycle Assessment (LCA) with corporate carbon accounting to connect micro-level process optimization with macro-level carbon management. Within this framework, the KBR Purifier™ Ammonia Process embodies the principles of the circular economy by promoting energy recovery, emission reduction, and resource efficiency. Through advanced cryogenic purification and mild reforming technologies, the system produces a cleaner synthesis gas with precise H₂/N₂ ratio control, achieving low specific energy consumption of approximately 6.3 Gcal/MT. These improvements contribute to lower fuel demand, reduced inert gas formation, and decreased maintenance requirements. Consequently, the process enhances operational efficiency, minimizes waste generation, and extends equipment lifespan—further reinforcing industrial circularity. By providing transparent and traceable quantification of emission reductions, the system enables the creation of verifiable carbon assets that can participate in domestic and international carbon trading under the Economic Carbon Values framework. Furthermore, its measurable contributions to Sustainable Development Goals (SDGs) 7 (Affordable and Clean Energy), 9 (Industry, Innovation, and Infrastructure), 12 (Responsible Consumption and Production), and 13 (Climate Action) illustrate how technological innovation can simultaneously advance environmental sustainability, economic performance, and climate accountability. Through MRV-based verification, the KBR Purifier™ approach effectively links process efficiency, carbon market readiness, and circular economy value creation within an integrated low-carbon industrial model.

Specifically, with gate-to-gate LCA analyses, you can literally see what's going on - from materials to energy, while carbon credits take the environmental impact and give them actual value as carbon credits that companies can trade on carbon markets such as IDX's carbon market in the Indonesian context. Through the lens of our project and by utilizing this pair of methodologies, the reality of eco-innovation being ultimately a means of improving one's own efficiency and then becoming a much broader



sustainability platform that's positive for the environment and for one's profits, as with the vision of GS4GG. Therefore, this study contributes towards advancing the dialogue towards making sustainability a reality by:

1. Determining where LIN injection can be genuinely classified as a successful form of industrial eco-innovation, with evidence sourced from hard LCA data;
2. Ensuring that carbon accounting procedures are carried out correctly by using the actual standard of ISO 14064 and SNI 7724:2011; and
3. How reducing system-level emissions relates to global goals (GS4GG) - to aid understanding of a more encompassing view of what sustainability means.

Through this, our study offers a way for companies to make themselves more agile, more transparent, and more effective by following a cleaner manufacturing process that contributes to less carbon emissions for the company and actual certified credits for a cleaner environment that every person can agree on.

2. Methodology

2.1. Research Design and Analytical Framework

This paper uses a hybrid method of analysis for environmental systems that makes use of quantitative LCA and carbon accounting at a business enterprise degree that makes use of approaches of *Measurement, Reporting, and Verification* (MRV). Where the innovation of the methodological method of this paper might lie could be at the point wherein environmental assessments at a set degree that contain gate-to-gate existence cycle tests are blended with organizational level GHGs that adhere to techniques of ISO 14064-1 and SNI 7724:2011.

This methodological method may be explained for evaluation at three levels:

1. Manner stage intervention quantification – measurement of heat energy reduction and emission avoidance for the Liquid Nitrogen (LIN) injection manner for the duration of the cleaner begin-up.
2. Existence Cycle impact evaluation (LCIA) – analysis of environmental overall performance with appreciate to categories of

impact (GWP, CED, ADP-fossil), with boundary of which is

3. Integration of carbon accounting and MRV – translating GHG emissions avoidance into carbon credits that may be demonstrated to demonstrate fulfillment of the necessities of ISO 14064-1:2018 and the Gold widespread for the worldwide dreams (GS4GG).

This method enables a guaranteed coherence between innovation era, environmental overall performance dimension, and value of reduced emissions which till now have been vastly unexplored with reference to the ammonia industry.

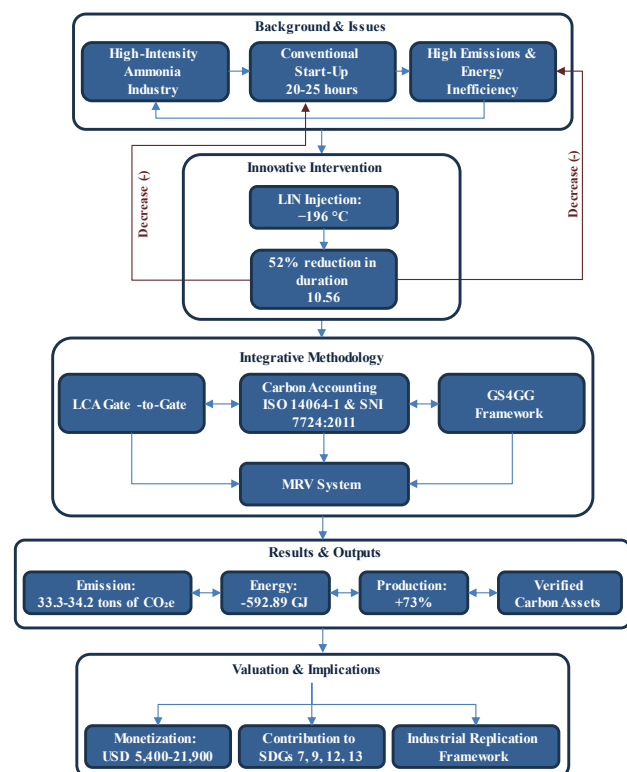


Figure 1. The analytical coherence between technological innovation, environmental performance quantification, and economic valorization

2.2. System Boundary and Functional Unit

A system boundary can also be pointed out to be gate-to-gate that encompasses the most effective begin-up unit of the cleanser package determined inside the ammonia plant. This level was picked since it signifies a vital and power-dense transition unit that has contributed disproportionately to the plant's aggregate emissions despite its short-term period.

During the start-up phase of the ammonia purification unit, the process gas possesses high intrinsic energy, characterized by elevated pressure (approximately 47 kg/cm²G) and moderate temperature gradients of 3–4 °C. From a thermodynamic perspective, gas expansion leads to a reduction in both pressure and temperature according to the first law of thermodynamics, where adiabatic expansion of high-pressure gas results in a proportional enthalpy decrease. In the conventional operation, this pressure reduction is facilitated solely through the purifier expander, gradually lowering the temperature to approximately –186 °C. However, this approach is time-intensive, requiring an extended stabilization period before reaching cryogenic steady-state conditions.

To enhance thermal transition efficiency, Liquid Nitrogen (LIN) is strategically injected into the process stream within the intermediate temperature window of –100 °C to –186 °C. The injection is performed under controlled thermal gradient limits of 100–125 °C per hour, ensuring that temperature variation does not exceed 25 °C per hour to prevent rapid-cooling-induced thermal stress or cracking within the metallic surfaces of the purifier assembly. This cryogenic intervention functions as a thermal booster, accelerating the rate of temperature decline while maintaining structural integrity and process safety.

Simultaneously, the expander's mechanical energy generated from the controlled depressurization is converted into electrical energy via a coupled generator system, contributing to the plant's auxiliary power supply. The integrated thermodynamic pathway—comprising LIN-assisted cryogenic cooling and energy recovery through the expander-generator set—optimizes both the thermal and energetic performance of the start-up cycle:

1. Baseline situation (conventional startup machine): organized predominantly by technology gas expansion for cooling; common c programming language of 20.33 hours.
2. improved scenario (LIN Injection): usage of the cryogenic cooling technique by injection

of Liquid Nitrogen (–196°C) among –100 °C and –186 °C with a lessened duration of 10.56 hours.

This boundary design enables the right implementation of environmental and active upgrades for the LIN Injection innovation without being affected by methods that follow thereafter (for instance, the synthesis cycle and ammonia liquefaction).

2.3. Data Inventory and Mass–Energy Balance Modeling

The Life Cycle Inventory (LCI) was developed using verified operational data from PT Panca Amara Utama (PAU) plant records and energy management reviews (2019–2024). Data validation followed a two-stage verification process: internal cross-checking of plant operations and external confirmation through third-party audited environmental records and supplier invoices for gas and steam use. The use of KBR's Purifier™ Ammonia Process ensures low energy consumption, reduced inert gas formation, and extended equipment lifespan—key drivers of circular resource efficiency [5]. Verified performance data further enable transparent emission quantification, supporting the company's participation in carbon trading schemes and strengthening its contribution to Indonesia's carbon economic values (NEK) framework. On-site observations to test the accuracy of automated readings for periodic inspections for sensor calibration assessments have been carried out (Table 1).

Table 1. Primary Data Inventory for Mass – Energy Balance Modeling

Parameter	Baseline (Conventional)	LIN Injection	Δ Change
Duration (h)	20.33	10.56	–9.78
Natural gas (MMSCF/cycle)	49.78	25.84	–23.94
Steam (ton/cycle)	1870.67	899.56	–899.56



Liquid Nitrogen (ton/cycle)	—	14.00	+14.00
Energy consumption (GJ)	58,304.80	30,267.52	– 28,037.28
CO₂e emission-tier-2 (Ton CO₂e)	3,361	1,745	–1,616

Source: PT Panca Amara Utama (2024)

Modelling of mass and energy balance applied a regular country differential method with a normalizing procedure for all material and energy inflows and outflows on a patterns consistent with the begin-up cycle (functional unit). LIN's heat value was calculated using the latent heat of vaporization at -196°C (199 kJ/kg at -196°C). Prevented combustion energy of PAU's natural gas was then calculated. Steam savings analyses accounted for a demand for a total of 899.56 tons every cycle of heat energy for the operational power plant turned into converted to strength equivalences according to standard thermodynamic properties. This strict validation approach enhances confidence inside the accuracy of the dataset to deliver valid effects for LCA and carbon budget analyses [4], which accurately reflect actual performance underneath actual PAU operations for the ammonia plant. Prevented combustion energy of PAU's natural gas turned into computed by way of equation:

$$E_{\text{saved}} = m_{\text{NG,saved}} \times LHV_{\text{NG}}$$

Where $LHV_{\text{NG}} = 54.28 \text{ MJ/kg}$.

The steam saving was derived from the operational boiler feedwater demand reduction (≈ 899.56 tons per cycle), and its energy equivalence was expressed as:

$$E_{\text{steam}} = m_{\text{steam,saved}} \times H_{\text{Sup}}$$

Where $H_{\text{Sup}} = 3,165.06 \text{ kJ/kg}$ (enthalpy at a superheat temperature of 385°C and pressure of $47 \text{ kg/cm}^2\text{G}$).

2.4. Carbon Accounting Methodology

Quantification of greenhouse gas (GHG) emissions became conducted in alignment with

ISO 14064-1:2018 and SNI 7724:2011 standards, employing a hybrid method combining pastime information with emission factors. The have a look at considered the three principal GHGs applicable to ammonia production: carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O), with their worldwide warming potentials (GWPs) averaged over a 100-year horizon based totally on IPCC AR6 pointers [5].

Key assumptions made concerning emission factors include:

- Emission thing for carbon dioxide from fuel combustion altered to permanent at $56.1 \text{ kg CO}_2/\text{GJ}$ due to the default values recommended by the IPCC and the Indonesian carbon accounting manual.
- Emissions of CH_4 and N_2O by combustion have been planned by utilizing emission elements of 1 kg of CH_4/GJ and 0.1 kg of $\text{N}_2\text{O}/\text{GJ}$.
- Procedure emissions specifically from ammonia synthesis and begin-up activities had been calculated the usage of an emission element of 1.5 lots CO_2 in step with ton of ammonia produced, derived from validated literature for Indonesian ammonia flowers [6].
- Emissions of steam technology encompassed the indirect emissions for fuel use with gasoline-specific emission factors that can be similar to that of the United States of America's inventories.

$$E_{\text{total}} = \sum (A_i \times EF_i \times GW P_i)$$

Where:

A_i = activity data (e.g., fuel used in GJ)

EF_i = emission factor (kg GHG/GJ)

$GW P_i$ = Global Warming Potential for gas i ($\text{CO}_2 = 1$, $\text{CH}_4 = 27.9$, $\text{N}_2\text{O} = 273$)

The avoided emission ($\Delta\text{CO}_2\text{e}$) between scenarios was calculated as:

$$\Delta\text{CO}_2\text{e} = E_{\text{baseline}} - (E_{\text{project}} + E_{\text{LIN}})$$

Where E_{LIN} represents the embodied emission from LIN production and distribution, estimated using industrial nitrogen life cycle data ($0.18 \text{ kg CO}_2\text{e/kg LIN}$).



All of the emission factors have been confirmed against information provided by Indonesian authorities' inventories and peer-reviewed scientific literature to ensure appropriateness for context [7]. This specified level of granularity of the emission thing assumption complements the level of complexity of the carbon accounting analysis assessment tool, providing a convincing background for Size, Reporting, and Verification (MRV) methodologies [8].

2.5. Life Cycle Impact Assessment (LCIA)

The OLS was applied by the LCIA to implement the midpoint indicators consistent with the CML-IA baseline approach for classes that directly indicate energy and fossil fuel dependencies [9]:

1. Global Warming Potential (GWP) with unit
2. Cumulative strength call for (CED, MJ)
3. Abiotic Depletion potential—Fossil (ADP-fossil, MJ)

Comparing 2019 to 2024 was normalized to remove differences due to variations of the scale of production of each country's population [10]. Annual minute changes are studied by applying a delta effect to display stability.

2.6. Integration with Gold Standard for the Global Goals (GS4GG)

The methodological strength of this commentary performs a seamless synchronization with gold general for global requirements (GS4GG) to ensure the achieved cuts of emissions and savings of electricity for LIN Injection are simultaneously measurable, reportable, and verifiable (MRV), according to ISO 14064-1 and SNI 7724:2011 requirements while being at the same instant linked to a number of Sustainable Development Goals (SDGs 7, 9, 12, and 13) [1]. This verification system with multi-layer triangulation assessment that demonstrated operational records with plant data, ensured thermodynamic modeling purity with Aspen HYSYS 2024 computation modeling, and employed objective 1/3 impartial verification of GHGs according to ISO 14065 requirements was further refined with Monte Carlo uncertainty analysis with 10,000 iterations to achieve error bands of less than $\pm 3\%$ for GHG

depth and $\pm 2\%$ for energy accuracy. In addition to methodological energy requirements for accuracy, methodological strength of this study's contribution to existing knowledge at the point of convergence of three-fold integration approach with gate-to-gate LCA method approach, Business carbon accounting calculator system, and further synchronization with GS4GG points to three-fold blue innovation of generator-scale blue innovation to deliver weathering of the validatable, financierable, and SGD-linkage facilitating carbon globalized cost of the decarbonized carbon globalized economy [11]. This triple approach to methodological strength offers a blue innovation playbook strategy for the energy hubs industry to decouple science for decarbonized operations that continue to rise with the carbon globalized economy.

3. Results and Discussion

3.1. Reduction in Energy and Emission Intensity

An emission reduction of approximately 1,568.43- 1,610.06 tCO₂e per startup cycle, as quantified through Life Cycle Assessment (LCA), reflects a significant improvement in environmental efficiency achieved by the KBR Purifier™ Ammonia Process. The integration of cryogenic purification, mild reforming, and optimized hydrogen-to-nitrogen ratio control effectively reduces fuel consumption, energy intensity, and inert gas formation, thereby establishing a closed-loop operational efficiency consistent with circular economy principles. These verified emission reductions, compliant with ISO 14064-1 and SNI 7724:2011 standards, are eligible for Measurement, Reporting, and Verification (MRV) as tradable carbon assets under Indonesia's Economic Carbon Values and IDX Carbon Exchange frameworks. With an indicative carbon price range of USD 5–20 per tCO₂e, the intervention presents potential financial benefits of approximately USD 5,400–21,900 per operational cycle. This outcome underscores the economic feasibility of low-carbon industrial transformation and demonstrates that environmental innovation can



directly translate into measurable economic value through participation in emerging carbon markets.

Further on, this integration approach encompasses innovation-process technology progress with sustainability management for system sustainability and demonstrates the double benefit of eco-innovation on productivity and sustainability. The evidence of minor changes of GWP and CED values across annual observations (2019-2024) provides evidence of stable behavior reliability to emphasize the strength of effecting results. normal, this testifies that this study demonstrates the application of lifestyles Cycle analysis integration with carbon accounting of a company to analyze carbon emission performance of a company to advance a concept of cleaner manufacturing technology [12].

3.2. Gate-to-Gate LCA Results

Table 2. Annual fluctuations LIN production, overall GWP and CED

Impact Category	2019	2020	2021	2022	2023	2024	Δ (2019– 2024)
CED (MJ)	18.	18.	18.	18.	18.	18.	–0.0 001
	55	55	55	55	55	55	
	35	35	34	34	36	34	
ADP- fossil	18.	18.	18.	18.	18.	18.	–0.0 001
	55	55	55	55	55	55	
	17	17	17	17	18	16	
GWP (kg)	3.9	3.9	3.9	3.9	3.9	3.9	–0.0 083
	45	45	41	40	37	37	
	8	8	8	5	5	5	

Although minor year-to-year fluctuations associated with LIN production were observed, the overall Global Warming Potential (GWP) and Cumulative Energy Demand (CED) exhibited a declining trend, indicating that the intervention led to an improvement in environmental performance within the defined gate-to-gate system boundary [13]. Such variations are plausibly attributable to upstream

processes, including raw material extraction and processing activities [14].

3.3. Integration with Carbon Accounting and MRV

LCA-obtained net emission reduction of approximately 1,568.43- 1,610.06 tCO₂e for one startup cycle was further operationalized into organization-level carbon accounting indicators according to the Measurement, Reporting, and Verification (MRV) procedure structured by means of ISO 14064-1:2018, SNI 7724:2011, and National Registry system for control of climate change (SRN-PPI) [15]. Under this validated accounting system, every unit of reduced CO₂e can be traced back as a carbon asset [16] that can eventually be traded on the IDX Carbon Exchange with an estimated monetary value of between USD 5,400 to 21,900 per cycle, depending on current market values of tCO₂e at a pricing range of between USD 5 to 20 per tCO₂e [17].

This convergence of methodologies portrays a science-informed translation of decarbonization at the process stage to a carbon value with monetary expression, carving out a space between technology-mediated emission mitigation and corporate decarbonization finance [18]. by incorporating the life cycle assessment (LCA) outcome into a MRV-compliant accounting system, the LIN Injection tool validates environmental value addition by a cogent, auditable, and market-verified method. furthermore, by being compliant with the gold standard of the global goals (GS4GG) validation system, the credence of accomplished emission savings goes beyond compliance indicators to directly associate the innovation with global sustainability goals (SDG 7, SDG 9, SDG 12, and SDG 13). Hence, this convergence resets the sustainability paradigm of eco-innovation from a system optimization tool to a sustainability accelerator for a carbon-competitive future by developing a replicable pattern where LCA-driven evidence supports carbon market activity, corporate disclosure, and global sustainability-aligned value addition. This innovation tool henceforth sets a trailblazing paradigm shift to quantify the efficiency of emission savings to a verified climate value that supports commercial

sustainability and economic resilience in a nascent carbon economy order.

3.4. Process-Level Learning and Agility

The implementation of Monitoring Reporting and Verification (MRV) systems based on ISO 14064-1 [19] and SNI 7724:2019 requirements [20] creates an obvious framework which enables effective validation of greenhouse gas emission reductions. The alignment between these standards ensures that LIN Injection process reductions become eligible for carbon credit schemes through verifiable and credible discount tracking. The Gold standard for the global goals (GS4GG) [21] social and environmental advantages which support essential Sustainable development goals [1] including affordable and reliable energy and business innovation and responsible consumption [22] and climate protection.

The research proves its expertise by implementing the MRV-GS4GG framework at method level in business energy-in-depth environments. The LIN Injection demonstrates method-level adaptability through its use of -196°C cryogenic cooling during critical startup phases which speeds up thermal changes to cut start-up time by 52% without compromising product quality or gas-phase stability. The system provides two benefits through its ability to reduce emissions to 1,568.43- 1,610.06 tCO_{2e} and energy consumption to 28,009.61 GJ per cycle while boosting production output by 73%. The system extends conventional assignment-based testing by integrating eco-innovative solutions into a complete sustainability framework which converts operational efficiency gains into measurable carbon assets that comply with international standards.

4. Conclusion

This study demonstrates that integrating gate-to-gate Life Cycle Assessment (LCA) with carbon accounting provides a robust framework for quantifying sustainability improvements in ammonia production. The implementation of Liquid Nitrogen Injection in the KBR Purifier™ unit reduced start-up energy consumption by 28,009.61 GJ and achieved a verified emission

reduction of 1,568.43- 1,610.06 tCO_{2e} per start-up cycle, with uncertainty levels below 3% for GHG intensity and 2% for energy balance based on 10,000 Monte Carlo iterations. These results confirm that the intervention delivers measurable improvements in process efficiency and carbon performance. The quantified emission reductions comply with ISO 14064-1 and SNI 7724:2019, supporting their eligibility for MRV-based carbon monetisation under Indonesia's Economic Carbon Values and IDX Carbon Exchange frameworks.

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