CIRCULAR ECONOMY AT LNG BONTANG COMPANY: TRANSFORMING ALUMINUM JACKETING WASTE INTO SACRIFICIAL ANODE PRODUCTS

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Abstract. *In the industrial activities of the company, one of the crucial considerations and management aspects is waste. At PT. Badak NGL, an existing environmental issue pertains to aluminum jacketing waste. This waste emanates from the factory's operational activities, thereby presenting an opportunity for waste utilization and subsequent benefits for the company. The primary objective of this research is to convert aluminum jacketing waste into sacrificial anodes, thereby fostering the implementation of a circular economy at PT. Badak NGL. The research methodology employed is descriptive and qualitative. The principal sources of data comprise direct field observations, interviews with relevant stakeholders, and a comprehensive literature review. The integration of circular economy principles into the utilization of aluminum jacketing waste yields economic advantages for the company. To realize this sustainable circular economy, PT Badak NGL collaborates with partner organizations in the process of repurposing aluminum jacketing waste into sacrificial anodes. This collaborative approach aims to facilitate PT Badak NGL in achieving its goal of reducing aluminum jacketing waste by 8 kg/anode. Simultaneously, it endeavors to create employment opportunities for 2 personnel per anode, leading to substantial cost savings in the procurement of sacrificial anodes, amounting to Rp. 406,500.00 per anode.*

Keywords: circular economy, aluminum jacketing, sacrificial Anode.

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1. Introduction

PT Badak NGL, an LNG company located in the city of Bontang, achieved the 11th GOLD PROPER (2010-2021) during the 2021 PROPER event organized by the Indonesian Ministry of Environment and Forestry. This award represents the highest accolade in the realm of environmental management, signifying that the company has exceeded the stipulated requirements (Beyond Compliance). PT Ba-dak NGL's consistent attainment of the 11th consecutive Gold Proper underscores its unwavering commitment to upholding the quality of environmental management and perpetually implementing community development programs. These endeavors yield tangible benefits for both the company and the neighboring community. Drawing upon the KPI (Key Performance Indicator) of Badak NGL Bontang in 2022 about Gold Proper achievements, as well as the Goals & Objectives of the SHEQ Department concerning Proper plan implementation, it becomes evident that addressing Non-B3 waste necessitates the incorporation of community development facets as an appended value within the Proper eco-innovation criterion. The circular economy garners escalating interest from governments, enterprises, communities, and academia, widely acknowledged for its potential to confer environmental, social, and financial advantages [1]. This transformation from a linear economic model to a circular one hinges on heightened resource efficiency, augmented reuse of resources, diminished overall resource inputs, energy conservation, reduced emissions, and curtailed waste leakage. Such measures mitigate adverse environmental consequences while concurrently safeguarding growth and prosperity, thereby fostering a more harmonious equilibrium encompassing the economy, environment, and society [2]. At its core, a circular economy embodies a cyclical system striving to obviate waste by repurposing end-of-life goods into resources for novel products [3]. By sealing the material loop within the industrial ecosystem, sustainable resource utilization emerges as a plausible outcome. The circular economy construct traverses beyond waste management, necessitating optimal resource utilization. Thus, the circular economy offers a potential avenue to reconcile the objectives of pursuing economic expansion and safeguarding the environment [4]. A safeguarded environment in turn catalyzes green growth – a phenomenon predicated on resource-efficient, cleaner economic expansion that in no way impedes the growth trajectory itself. The environment is intrinsically viewed as natural capital, an indispensable production input mandating preservation [5]. Notably, the circular economy concept represents a systematic productivity paradigm that gauges input efficiency while concurrently attending to economic expansion and ecological systems [6].

2. Literature Review

2.1 Circular Economy

There exist several definitions of the circular economy. Ellen [7] characterizes the circular economy as a system capable of addressing global challenges like climate change, biodiversity loss, and heightened waste and pollution. It achieves this through economic activities that minimize waste and pollution, facilitate the circulation of products and materials at their utmost value, and foster the regeneration of nature. Meanwhile, according to Shirvanimoghaddam [8], the circular economy represents an alternative to the conventional economy. It involves conducting economic activities while conserving resources for as long as possible, sustaining their value during use, and repurposing them to generate new products after their lifecycle. Furthermore, Mishra [9] defines the circular economy as a system aspiring to optimize the entire product lifecycle. This optimization encompasses resource selection, production, consumption, and disposal. It is promoted through practices such as zero-waste design, reutilization, repair, and resource sharing. These aforementioned definitions illuminate the circular economy as a substitute for the linear economy concept. A linear economy follows a "take-make-use-dispose" cycle, wherein resources are extracted from the earth (take), processed into products (make), utilized (use), and discarded when the product's utility diminishes (waste) [10]. Conversely, the circular economy acknowledges the "take-make-use-return" cycle [10], wherein resources are responsibly extracted (take), transformed into products (make), employed to sustain value (use), and ultimately repurposed into new products upon reaching their lifecycle's end (return) [8]. This contrast is further illustrated by the linear economic model depicted in Figure 1 and the circular economic model illustrated in Figure 2.

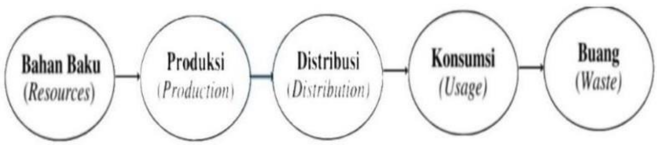

Figure 1. Linear economy

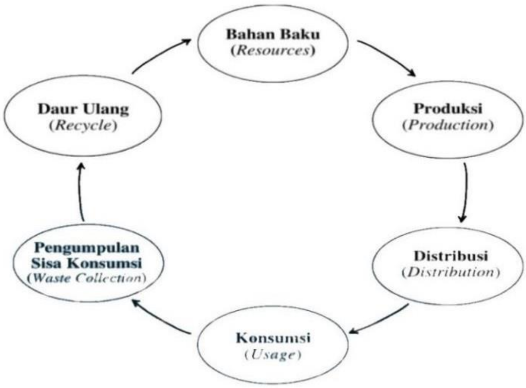

Figure 2. Circular economy

2.1.1 Circular Economy Approach

As per Ellen [7], the circular economy approach is recognized as the 5R principle, encompassing five key elements, namely: Reduce, Reuse, Recycle, Refurbish, and Renew. The elucidation of each element within this principle is provided in detail in Table 1 below:

Table 1. Circular economy approach (5R principle)

Principle	Definition
Reduce	- Morseletto [11] Reduced use of natural resources which will further reduceenergy inputs, raw materials, and waste. - Reike [12], Dematerialization of products by replacing raw materials fromnature with other alternatives that have the same utility for users. - Ellen [7], Reduce wastage during the manufacturingphase through more efficient use of resources. - Ellen [7], Reducing waste generated in the supplychain. - Ellen [7], Redesigning products to use fewer inputs orresources.
	- Morseletto [13] Minimize waste generated. - Shirvanimoghaddam [8], Reduce energy consumed in the manufacturing process. - Shirvanimoghaddam [8], Reduced use of materials and natural resources.

Reuse	- Morseletto [11], Reusing a product while maintaining its function andcharacteristics. - Ellen [7], Using existing assets together (such ashouses, cars, and other equipment). - Fheng, Z [14] Repeating the use of the product by not changing the shape of theproduct.
Recycle	- Ellen [7] Recycling products or components intonew materials. - Reike [12], Achieve minimum use of new resources by recycling materials. - Morseletto [13], Processing materials to obtain the same new material (e.g.through shredding, melting, etc.). - Morseletto [13], Collects materials and processes them into a certain form that can be reused and can be used as raw materials for making new products.
Refurbish	- Morseletto [11], Maintain or care for the product so that it can functionproperly. - Ellen [7] Repair, refurbish and replace components toextend product life.
Renew	- Ellen [7], Prioritizing the use of renewable andenvironmentally friendly energy and materials.

2.1.2 Implementation of Circular Economy

The implementation of the circular economy concept typically varies across countries, owing to the diverse array of factors that can influence its execution. Fheng, Z [14] discovered that the application of a circular economy in different global regions can be contingent upon the specific circumstances and conditions prevalent within each area. This phenomenon is exemplified by the instances outlined in Table 2 below:

Table 2. Implementation of Circular Economy in the World

Country	Circular Economy Implementation
Japan, Singapore, and Korea	Implementation of the green city (eco-city), implementation of responsible consumer character.
German	An environmental policy with issues of sustainability of raw materials and natural resources.

China	Creating an eco-industrial park, technology development, product development, and production management.
England, Denmark, Switzerland and Portugal	Zero waste
North America and Europe	Collaborative research and application of reduce, reuse, and recycle principles every day.

Based on the data presented in Table 2, each country formulates its concept and method for implementing the circular economy in alignment with its existing economic conditions and ongoing economic activities. The diverse range of implementations depicted in Table 2 above serves to illustrate that the notion of a circular economy can evolve and be integrated based on temporal and spatial considerations. In the UK, Denmark, and Portugal, the focus of circular economy implementation centers around waste management. This emphasis on waste management forms the cornerstone for conceiving the circular economy framework, which involves meticulous scrutiny of every energy source utilized in product management and a comprehensive examination of each constituent component of the product. It involves categorizing consumed products based on the timeframe required for waste decomposition and distinguishing between long-term and short-term waste. Products that remain usable can then be recycled and repurposed as foundational elements for subsequent production endeavors. Elevating waste as a pivotal element in the design of circular economy development necessitates a meticulous evaluation of each employed product component and a deliberate focus on the energy sources deployed for these components.

2.1.3 Impact of Circular Economy in Indonesia

Indonesia, with a population of 275 million in 2022, ranks as the fourth most populous country globally, underscoring its bustling economic nature. Consequently, this dynamism can lead to significant waste generation, necessitating effective management to bestow beneficial value upon the environment and society. Drawing on data from the National Waste Management Information System (SISPN), achievements in 2021 spanned 241 districts/cities across Indonesia. The total waste generated amounted to 30,335,308.50 tons annually, signifying a reduction of 15.6% from the preceding year, equivalent to 4,732,595.18 tons annually. The successful execution of waste handling stood at 49.14% per year, corresponding to 14,906,818.15 tons annually. Among these figures, managed waste constituted 64.4%, totaling 19,639,413.34 tons yearly, while unmanageable waste accounted for 35.26%, equivalent to

10,695,895.16 tons annually. In response to these challenges, the government has introduced several policies aimed at waste reduction emanating from production, consumption, and industrial sources. Notably, these include strategies like curbing plastic bag usage for shopping and entailing levies on each plastic bag employed in mini-markets, supermarkets, and malls. Additionally, the government ratified a waste management law through Government Regulation No. 27 of 2020, stipulating provisions in Article 4, Paragraph 1 concerning waste reduction regulations, as well as paragraphs addressing waste management. To facilitate the implementation of a circular economy in Indonesia, a collaborative effort involving local governments, the general populace, entrepreneurs, environmental activists, and academics is imperative. This multi-stakeholder engagement aims to foster an enhanced developmental trajectory. The proposed policy model is outlined as follows:

1) Reward and Punishment approach
   The substantial volume of unmanaged waste within each region renders this policy essential, particularly in light of the community's limited awareness regarding waste management. Thus, it becomes imperative to duly recognize the significance of fostering awareness concerning waste management. This recognition is vital for enhancing the community's mindset and fostering a heightened sense of responsibility toward safeguarding the environment.
2) Local Wisdom Approach
   The customary law approach stands as a significant method that should persistently be employed to enhance community participation, ensuring their direct involvement and accountability for the waste they generate.
3) Mentoring and training on collaboration among government officials, the community, and relevant stakeholders must be enhanced to establish enduring cooperation. This entails mentoring and training in proper waste management practices, along with raising awareness about the ensuing impacts. Additionally, providing guidance and support to Micro, Small, and Medium Enterprises (MSMEs) in producing eco-friendly goods, while minimizing the utilization of environmentally and health-detrimental materials through the implementation of the Green Production concept, is essential.

2.2 Aluminium

Aluminum resides within Group IIIA in the chemical elements of the periodic table, possessing an atomic number of 13 and an atomic weight of 26.98 grams per mole. Upon oxidation, aluminum forms a thin layer of corrosion-resistant oxide (Al_2O_3) when exposed to air. This oxide layer contributes to its resilience. Notably, aluminum is reactive to both acidic and basic substances [15]. Being one of the most frequently utilized metals alongside steel and iron, aluminum holds a prominent position among non-ferrous metals. PT. Badak [16] highlights its commendable corrosion resistance and effective electrical conductivity. However, the aluminum available in the market is seldom entirely pure; it typically incorporates residual elements. These remnants manifest in the form of trapped gas bubbles resulting from the melting or casting process, or due to imperfect temperature control owing to subpar raw materials or mold quality. The purest aluminum available for purchase is around 99% pure, as exemplified by aluminum foil [16].

2.2.1 Aluminum Characteristics

Aluminum's structure differs from that of typical metals due to its robust chemical bonding with oxygen. Aluminum compounds, particularly oxides in diverse degrees of purity and hydration, are prevalent. In terms of abundance, aluminum ranks as the second most plentiful metallic element on Earth, following silicon, comprising approximately 27.5% of the composition. It is estimated that aluminum constitutes around 8% of the Earth's crust [16]. According to PT. Badak [16], the properties of aluminum can be outlined as follows:

a) Tough at Low Temperatures
b) Tough at High Temperatures
c) Lightweight
d) Good Electrical Conductivity
e) Corrosion Resistant
f) Easily Recyclable
g) Nontoxic

2.3 Sacrificial Anodes

The sacrificial anode cathodic protection system stands as one of the corrosion control techniques employed for metals within piping systems and other stationary equipment across various industries, including shipping, construction, and more. This method involves connecting sacrificial anodes to the material being protected. Magnesium, Zinc, and Aluminum represent common metals used for sacrificial anodes. However, these metals are no longer used in their pure forms; rather, they are utilized as mixed metals (alloys) to enhance their efficacy in cathodic protection. In a broader context, magnesium finds application in soil and freshwater environments. Zinc is favored for use in seawater, brackish water, sea mud, and soil locations with a soil resistivity of no more than 1500 ohm-cm. Meanwhile, aluminum is employed for locations encompassing seawater, brackish water, and sea mud.

Table 3. Selection of Anodes Cathodic Protection

Type	Potential* (volts)	Current Capacity (A-hrs/lb)	Consumption Rate (lb/A-yr)
Magnesium			
H-1C AZ-63D Alloy	-1.4 to -1.5	250 to 470	19 to 36
High Potential Alloy	-1.7 to -1.8	450 to 540	16 to 19
Zinc			
ASTM B418-01			
Type I (saltwater)	-1.1	354	24.8
Type II (soil)	-1.1	335	26.2
Aluminum			
Mercury Alloys	-1.10	1250 to 1290	6.8 to 7.0
Indium Alloys	-1.15	1040 to 1180	7.4 to 8.4

Sumber: US Army Engineer, 2001

The efficiency of galvanic anodes is contingent upon the alloy composition and the installation environment of the anode. Zinc alloys and aluminum alloys are predominantly favored due to their higher efficiency. Extensive research has examined the performance of these two types of sacrificial anodes, employing galvanic corrosion tests conducted within a simulated seawater environment. Performance metrics encompass protection potential, galvanic current, anode capacity, anode efficiency, anode consumption rate, induction time, and anode corrosion pattern. The outcomes revealed that aluminum alloy sacrificial anodes exhibited superior galvanic current and anode capacity compared to their zinc alloy counterparts. Furthermore, the efficiency of aluminum alloy surpassed that of zinc alloy, and its consumption rate proved to be lower.

2.3.1 Aluminium Sacrificial Anodes

Aluminum alloys are used primarily in marine environments and those rich in chloride compounds, such as offshore petroleum platforms, underwater pipelines, and saltwater tanks. There are two types of aluminum alloys: one that uses mercury and another that uses indium to reduce the passivation effect caused by the formation of an oxide film (Al_2O_3) on the aluminum surface. The aluminum anode is never used in freshwater environments, except for the impressed current ground bed, and cannot be used for ground location. In the market, there are three types of aluminum alloy products, namely:

- Galvalum type I, use in seawater environments.
- Galvalum type II, use in salt mud environments.
- Galvalum type III, use in seawater, brackish water, and salt mud environments.

Due to the mercury content that pollutes the environment, Galvalum I and Galvalum II are rarely used anymore. The chemical composition of aluminum anodes is shown in the table below, which is referred to as Type 3 alloy in DNV-RP-B401.

Table 4. Chemical Composition of Sacrificial Anode

Element	Type 1	Type 2	Type 3
Zn	0.3 – 0.5	0.3 – 6	2.5 – 5.75
In	-	-	0.015 – 0.04
Si	0.11 – 0.21	0.11 – 0.21	Max 0.12
Fe	Max 0.13	Max 0.13	Max 0.09
Cu	Max 0.006	Max 0.006	Max 0.003
Cd	Max 0.002	Max 0.002	Max 0.002
Al	Remainder	Remainder	Remainder

Sumber: DNV-RP-B401

2.3.2 Sacrificial Anodes at PT Badak NGL

The PT Badak NGL refinery is situated on the seacoast of Bontang City, directly exposed to the air and seawater environment, which necessitates the use of sacrificial anodes for corrosion protection. Approximately 90% of the sacrificial anodes utilized are made of aluminum. Preventive maintenance is conducted every 6 months, 1 year, or 5 years, depending on the equipment being protected. This maintenance routine includes internal cleaning, testing, and replacement of sacrificial anodes. As a result, sacrificial anodes are among the fast-moving materials highly demanded at PT Badak NGL.

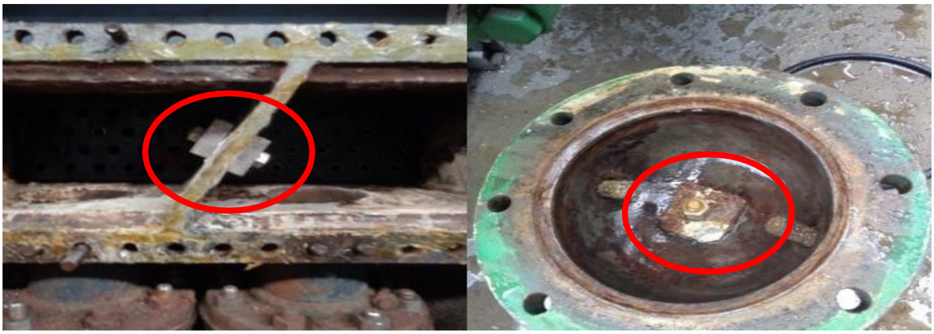

Figure 3. Application examples of sacrificial anodes on equipment at PT Badak NGL

The supply of sacrificial anodes at PT Badak NGL is procured from external parties. At the time this report was prepared, the price of sacrificial anodes was USD 33.06, equivalent to IDR 471,500 per unit.

Table 5. Data on The Number of Sacrificial Anode Replacement Jobs

Period	Number of Sacrificial Anode Replacement Jobs	Annual Average Jobs	Monthly Job Averages
2019	206		
2020	157	173	5
2021	155		
2022 (Jan – Oct)	109	109	11

2.4 Implementation of Circular Economy

The Circular Economy process involves the utilization of aluminum jacketing waste to produce sacrificial anode products. The first stage entails PT Badak NGL collecting aluminum jacketing waste, which is then sent to the company's fostered partner workshop, under the supervision of PT Badak NGL. The waste is processed through smelting to create sacrificial anodes. Once the product is finished, the activation of the sacrificial anodes is tested and documented. Subsequently, the sacrificial anode products produced by the fostered partners are sent and sold to the company PT Badak NGL.

Figure 4. Circular Economy Process of Aluminum Jacketing Waste Optimization

3. Methods

A research design is a structured plan or framework used as a guide in conducting research. It outlines the procedures for collecting information necessary to address the formulated problems. To ensure high-quality research, certain steps must be followed during the research process. The sequence of steps for this research is as follows:

a) Problem Identification
In identifying problems that exist at PT Badak NGL, the authors conduct direct observations in the field, especially during activities that produce aluminum waste.

b) Data Retrieval
The data collected is related to the average amount of aluminum waste generated each year from maintenance activities at the PT Badak NGL refinery.

c) Data Processing

- Define
"Define" is the first step in the DMAIC quality improvement program. The steps included in the Define phase consist of determining or defining the project's objectives, creating a company business overview, project statement, identifying problems, and specifying objectives for quality improvement.

- Measure
After the Define phase, the next phase is Measuring. In this phase, the problems that have been identified are measured to determine the magnitude of their effects. The measurement phase holds significant importance in quality improvement, as it provides insights into the company's current state based on existing data, serving as a benchmark for analysis and enhancement. This study will measure the amount of aluminum waste generated and explore its potential to be utilized as a useful product, along with identifying improvement opportunities in terms of Quality, Cost, Delivery, HSSE (Health, Safety, Security, and Environment), and Morale.

- Analyze
The next phase is the Analysis phase. During this stage, the various root causes of the problem are inventoried and analyzed, starting from the dominant cause, considering factors such as man, machine, environment, method, and material using a fishbone diagram. Causal factors and alternative solutions are analyzed, and an ROI (Return on Investment) analysis is conducted to assess the feasibility of the chosen solution.

- Improve

  After the analysis, the Improvement phase is carried out. The purpose of this phase is to determine how to utilize aluminum waste and transform it into sacrificial anodes, starting from the design phase to the testing process, to produce the best results according to the required product specifications.
- Control

  In this phase, all the existing improvement efforts are controlled (via simulation or technical achievement), and then all the efforts are documented and socialized to all relevant employees in the company.

3.1 Data Sources

The types and sources of data used in this research are primary data and secondary data. Primary data is obtained directly from individual sources, such as the results of interviews or filled-out questionnaires. In this study, primary data is gathered through interviews with relevant workers, namely those in the SHE&Q department, the Maintenance department, and members of the Telihan Recycle fostered partner group. On the other hand, secondary data refers to data or information that has been further processed and presented by primary data collectors or other parties. The secondary data collection used in this study includes company profiles, Company LCA (Life Cycle Assessment) results in reports, Telihan Recycle daily reports, research journals, websites, and E-Books/Textbooks.

3.2 Data Collection Method

This research employs several techniques in data collection, which are:

a) Direct observation

   Direct observation is a data collection method that is conducted directly in the field, within the company's business processes. This observation aims to understand and obtain the primary data needed for the research.

b) Interview

   The interview is a data collection technique used to identify and explore the problem under study. Interviews are conducted by asking questions to related parties within the company, fostered partners, and the surrounding community, who are relevant to the research object, to obtain the necessary data.

c) Literature study

   A literature study is a data collection method that involves studying related theories in books, scientific papers, websites, articles, and other literature relevant to the object and topic of the research.

3.3 Data Processing Method

After successfully collecting the data, the data processing is conducted using the DMAIC Method, which stands for Define, Measure, Analyze, Improve, and Control. Each of these stages serves as a framework for determining the final decision to optimize the product, aligning with sustainable development goals.

4. Results

These sacrificial anode products have not yet been certified by the competent authority, but they have the potential to replace the current supplies of sacrificial anodes at PT Badak NGL. Therefore, the sacrificial anode products have the following potential benefits:

a) Anode from Procurement by PT Badak NGL:
- ➢ Anode weight: 5 kg
- ➢ Price: IDR 471,500, - per anode

b) Anode from Telihan Recycle per 5 kg:
- ➢ Materials

Table 6. Calculation of Material Cost

No	Material	Quantity (in units)	Price
1.	Aluminum waste	8 kg	-
2.	Zinc	200 gr	Rp 24.800, -
3.	Indium	2 gr	Rp 1.800, -
4.	Fuel	2 liter	Rp 2.000, -
5.	Electricity for blower	2 jam	Rp 3.000, -
	Total		Rp 31.600, -

➢ Manpower:
- Melting Duration: 24 minutes per anode
- Manhour Price: Rp. 48,000,- / hour
- Number of laborers: 2 people
- Total labor cost: Rp. 38.400,- per anode

- Total cost per anode = Material cost + Labor cost
  = Rp. 31,600,- + 38,400,-
  = Rp. 70,000 per anode

Based on that calculation, the price of anode procurement by PT Badak NGL can be compared to Rp. 471,500 per unit, while the Telihan Recycle anode is priced at only Rp. 70,000. This potential price difference results in savings of Rp. 401,500 per anode for PT Badak NGL. Additionally, there is the potential to boost the economy of PT Badak NGL's fostered partners who have successfully transformed waste into usable products and enhanced their competence in creating certified products.

5. Conclusions

Aluminum jacketing waste is one of the byproducts generated from activities at the Badak LNG refinery. The lack of utilization of aluminum jacketing waste presents a problem that needs to be addressed by repurposing it as a raw material for making sacrificial anodes. These sacrificial anodes have been tested and proven effective in protecting materials from corrosion. Moreover, this research has successfully transferred competence to Badak LNG's fostered partners, enabling them to utilize aluminum jacketing waste in the production of sacrificial anodes with economic value. This newly acquired competence enhances the CSR (Corporate Social Responsibility) value of Badak LNG and has the potential to boost the economy of Badak LNG's fostered partners.

6. References

1. Andersen, M. S. (2007). *An introductory note on the environmental economics of the circular economy.Sustainability Science, 2*(1), 133-140.
2. Korhonen, J., Honkasalo, A., & Seppälä, J. (2017). Circular Economy: The Concept and its Limitations.*Ecological Economics, 143*, 37-46.
3. Stahel, W. R. (2014). Reuse Is the Key to the Circular Economy. European Commission. Dipetik September 26, 2017, dari http://ec.europa.eu/environment/ecoap/about-eco-innovation/experts-interviews/reuse-is-the-key-to-the-irculareconomy_en .htm
4. Ellen MacArthur Foundation. (2015). *Growth Within: a circular economy vision for a competitiveEurope. Ellen MacArthur Foundation.* UK: Cowes.
5. Ellen Macarthur Foundation. (2012). *Towards the Circular Economy.* Dipetik September 26, 2017, darihttp://www.ellenmacarthurfoundation.org/business/reports
6. Kementerian PPN/Bappenas, Embassy of Denmark Jakarta, dan UNDP (2021), “The Economic, Social, and Environmental Benefits of a Circular Economy in Indonesia”, Report, Januari 2021.
7. Ellen Macarthur Foundation (2021), “Circular Economy Glossary”, Glossarium

8. Shirvanimoghaddam, K., Motamed, B., Ramakrishna, S. dan Naebe, M. (2020). "Death by waste: Fashion and textile circular economy case", Science of The Total Environment, Vol. 718, https://doi.org/10.1016/j.scitotenv.2020.137317.
9. Mishra, S., Jain, S. dan Malhotra, G. (2021). "*The Anatomy of Circular Economy Transition in the Fashion Industry", Social Responsibility Journal Vol. 17 No. 4, https://doi.org/10.1108/SRJ-06-2019- 0216*
10. Ritchie, K.J. dan Freed, E.C. (2021). *Circular Economy for Dummies, United States: Wiley.*
11. Morseletto, P. (2020). "Targets for a Circular Economy" Resources, Conservation and Recycling. Vol.153, https://doi.org/10.1016/j.resconrec.2019.104553
12. Reike, D., Vermeulen, W.J. dan Witjes, S. (2018). "The Circular Economy: New or Refurbished as CE 3.0? — Exploring Controversies in the Conceptualization of the Circular Economy Through A Focus On.
13. Morseletto, P., 2020. *Restorative and Regenerative: Exploring the Concepts in the Circular Economy.Journal of Industrial Ecology* 24(4):763–73.
14. Fheng, Z., & Yan, N. (2007). Putting a circular economy into practice. *Journal of Sustainability Science,2*(1), 95-101.
15. Birat, J. P. (2015). *Life-cycle assessment, resource efficiency, and recycling. Metallurgical Research &Technology, 112*(2), 206.
16. PT. Badak NGL (2021) *annual*, https://badaklng.com/images/pdf/annual-report-badak-lng-2021.pdf
17. Ren, J., Manzardo, A., Toniolo, S., & Scipioni, A. (2013). *Sustainability of hydrogen supply chain. PartI: identification of critical criteria and cause-effect analysis for enhancing sustainability using DEMATEL. International journal of hydrogen energy, 38*(33), 14159-14171.
18. History And Resource Value Retention Options." Resources, Conservation and Recycling, Vol.135, https://doi.org/10.1016/j.resconrec.2017.08.027
19. Scott, J. T. (2017). The Sustainable Business: A Practitioner's Guide to Achieving Long-term Profitability and Competitiveness. Routledge.
20. Anggono, J. Citro, S. dan Palapessy, V. R. (2000) Studi Perbandingan Kinerja AnodaKorban Paduan Aluminium dengan Paduan Seng dalam Lingkungan Air Laut, Jurnal Teknik Mesin, Fakultas Teknologi Industri, Universitas Kristen Petra, Surabaya, Volume 2 Nomor 1, pp. 89 – 99.
21. Qolbi. R. A., and M.L. Singgih, 2022, Circular Economy Framework in Cigarette Filter Company (CFC) Using Material Circularity Indicator (MCI), The 3rd International Conference on Management of Technology, Innovation, and Project, Interdisciplinary school of Management and Technology, Institut Teknologi Sepuluh Nopember Surabaya, 2022.
22. Prabowo, I.E and M.L. Singgih, 2022, Circular Economy In Recycled Paper Company, In Proceedings of the International Conference on Engineering and Information Technology for Sustainable Industry (ICONETSI), ICONETSI, September 21, 22, 2022, Alam Sutera, Tangerang, Indonesia © 2022 Association for Computing Machinery, 2022.
23. Muhammad Rosiawan, Moses Laksono Singgih and Erwin Widodo, 2019, Measurement of Cost & Benefit for Implementation of Risk Management in the Production Process, IPTEK Journal of Proceedings Series No. (5) (2019), ISSN (2354-6026), The 1st

International Conference on Business and Management of Technology (IConBMT), August 3rd 2019, Institut Teknologi Sepuluh Nopember, Surabaya, Indonesia.

24. Niwedya.N. and Moses Laksono Singgih, 2015, Analisis Dampak Lingkungan Kegiatan Operasional Hotel dengan Pendekatan Life Cycle Assessment (LCA) dan Environmental Management Accounting (EMA) (Studi Kasus: Hotel Yasmin Makassar), Prosiding Seminar Nasional Manajemen Teknologi XXIII, Surabaya 1 Agustus 2015.