UNIVERSITY OF LJUBLJANA
SCHOOL OF ECONOMICS AND BUSINESS

MASTER’S THESIS

THE FINANCIAL BENEFITS OF IMPLEMENTING SUSTAINABLE PRACTICES IN SECONDARY ALUMINIUM PRODUCTION: A CASE STUDY OF TALUM

Ljubljana, March 2025 EVA VESELIČ

AUTHORSHIP STATEMENT

The undersigned Eva Veselič, a student at the University of Ljubljana, School of Economics and Business, (hereafter: UL SEB), author of this written final work of studies with the title The financial benefits of implementing sustainable practices in secondary aluminium production: A case study of Talum, prepared in collaboration with mentor doc. dr. Marko Budler

D E C L A R E

1. this written final work of studies to be based on the results of my own research;
2. the printed form of this written final work of studies to be identical to its electronic form;
3. the text of this written final work of studies to be language-edited and technically in adherence with the UL SEB Technical Guidelines for Written Works, which means that I cited and / or quoted works and opinions of other authors in this written final work of studies in accordance with the UL SEB Technical Guidelines for Written Works;
4. to be aware of the fact that plagiarism (in written or graphical form) is a criminal offence and can be prosecuted in accordance with the Criminal Code of the Republic of Slovenia;
5. to be aware of the consequences a proven plagiarism charge based on the this written final work could have for my status at the UL SEB in accordance with the relevant UL SEB Rules;
6. to have obtained all the necessary permits to use the data and works of other authors which are (in written or graphical form) referred to in this written final work of studies and to have clearly marked them;
7. to have acted in accordance with ethical principles during the preparation of this written final work of studies and to have, where necessary, obtained permission of the Ethics Committee;
8. my consent to use the electronic form of this written final work of studies for the detection of content similarity with other written works, using similarity detection software that is connected with the UL SEB Study Information System;
9. to transfer to the University of Ljubljana free of charge, non-exclusively, geographically and time-wise unlimited the right of saving this written final work of studies in the electronic form, the right of its reproduction, as well as the right of making this written final work of studies available to the public on the World Wide Web via the Repository of the University of Ljubljana;
10. my consent to publication of my personal data that are included in this written final work of studies and in this declaration, when this written final work of studies is published;
11. that I have verified the authenticity of the information derived from the records using artificial intelligence tools.

Ljubljana, 19.03.2025　　　　　　　　　　　　Author's signature: Veselič

TABLE OF CONTENTS

TABLE OF FIGURES

LIST OF ABBREVIATIONS

ASI - Aluminium Stewardship Initiative

BU - Business unit

CSDDD - The Corporate Sustainability Due Diligence Directive

CSRD - Corporate Sustainability Reporting Directive

ESG – Environmental, Social and Governance

GHG - Greenhouse gas

ISO 14001 - International Organization for Standardization, Environmental Management System

ISO 50001 - International Organization for Standardization, Energy Management System

KPI - Key performance indicator

LCA - Life cycle assessment

LCC - Life cycle costing

LME - London metal exchange

PCR - Post-consumer recycled

ROE - Return on equity

ROS - Return on sales

WBCSD - The World Business Council for Sustainable Development

1 INTRODUCTION

Historically, industrial activity operated under the assumption that natural resources were abundant and their environmental impact was minimal. The increased consumption has revealed the limitations of our finite resources. In response, industries are shifting towards more efficient production processes and resource use. Consequently, the circular economy model has emerged as a solution. The circular economy is defined as "a comprehensive framework where the design of the product, the production process, the distribution channel and every aspect of a firm's operations are organized around minimizing the use of new resources and maximizing the reuse of existing ones" (Aboulamer et al. 2020). This approach encompasses environmental, societal and financial dimensions. Since this transition is particularly evident in industries with high environmental footprints, such as metal production, Talum d.d. - a company that has evolved from primary aluminium production to focusing on secondary processing and aluminium products in recent years - has been used as a case study in this master's thesis.

The focus of the master's thesis is on understanding the broader framework of the circular economy and its relevance to the aluminium industry. According to the De Angelis et al. (2018), the circular economy, as a response to the linear "take-make-dispose" model, emphasizes resource efficiency, waste reduction and value retention. Transitioning to a circular economy model requires reshaping supply chains towards closed-loop systems, integrating conventional and reverse supply chain operations to minimize environmental impacts and maximize resource utilization. This transition has been particularly evident at Talum, especially in the production of slugs and discs, which were the primary focus of the case study in this master's thesis.

The purpose of the master's thesis is to explore the impact of implementing sustainable practices in secondary aluminium production, with a specific focus on the financial performance of Talum. The research is motivated by the important role that aluminium recycling plays in reducing energy consumption, lowering production costs and minimizing environmental impact. According to Smith (2021), aluminium, as a versatile and widely used metal, stands at the forefront of circular economy approach, with increasing emphasis on sustainable practices across its production lifecycle.

The main objective is to identify the challenges and opportunities that arise when adopting sustainable practices in secondary aluminium production. By analysing key metrics such as investment costs, cost savings, revenue growth and risk reduction, this master's thesis aims to contribute to a deeper understanding of the intersection between sustainability and financial performance in the aluminium industry. By combining theoretical insights with practical evidence from Talum's annual reports and a focus group conversation with company representatives, the master's thesis examines the alignment between theory and practice. The goal is to provide a comprehensive assessment of the financial benefits of implementing sustainable practices, while addressing the key obstacles that companies face in implementing such practices. These findings aim to contribute to the broader understanding of sustainable production in the aluminium industry and support the development of effective strategies for balancing financial performance with environmental responsibility.

In this master's thesis, the following research questions are addressed:

R1: What is the financial impact of sustainable practices in secondary aluminium production measured using metrics such as investment costs, cost savings, revenue growth and risk reduction?

R2: What are the challenges and opportunities associated with implementing sustainable practices in secondary aluminium production?

Master's thesis is divided into two parts. The first part is theoretical, focusing on a literature review of the circular economy and supply chain concepts, both in general and specifically within the aluminium production industry in the beginning, followed by the literature review addressing the financial factors associated with the implementation of circular economy practices.

The theoretical part is followed by the case study of Talum. The case study provides an analysis of the transition from primary to secondary aluminium production, examining various aspects, including the history of Talum, environmental responsibility, energy consumption, movement of aluminium's prices, customer demands and industry standards. Special attention is given to the business unit responsible for producing slugs and discs, which serves as a key example of adaptation to circular economy principles in Talum.

In the first part of the case study of Talum, I have compared data between the years of 2018 and 2022. By utilizing data from annual reports, I have prepared descriptive statistics. This time frame was chosen because during this period, the production of electrolytic aluminium at Talum decreased, while the production of slugs and discs increased. Analysis of the data from annual reports was followed by the focus group conversation with key representatives at Talum. Through a focus group conversation, I gathered additional practical insights that, alongside theoretical findings, helped me address the research questions. The final part of the master's thesis discusses recommendations for Talum based on the answers from the research questions.

2 CIRCULAR ECONOMY AND SUPPLY CHAIN

In the past, resources were often perceived as infinite and industrial activities had little interest in the environmental impact of resource extraction. However, with rapid industrialization, a growing world population and more countries joining the middle-income group, the demand for products has risen sharply, resulting in recognition of resources not being infinite according to Aboulamer et al. (2020). This perspective aligns with Govidan &

Hasanagic (2017), who emphasize that the environment faces increasing pressure due to the rising demand for various natural resources. They project that by the year 2050, global resource demand will triple, necessitating significantly greater utilization of natural resources and the adoption of more sustainable practices.

2.1 Circular economy and its dimensions

After conducting a thorough literature review, it became evident that concepts related to sustainability and the circular economy are closely intertwined. Therefore, the following paragraphs will present the most common definitions, which often overlap with each other. The most broad and well-adopted definition of sustainability is that of the Brundtland Commission (World Commission on Environment and Development, 1987, p. 8): "*Development that meets the needs of the present without compromising the ability of future generations to meet their needs*." (Carter & Rogers, 2008).

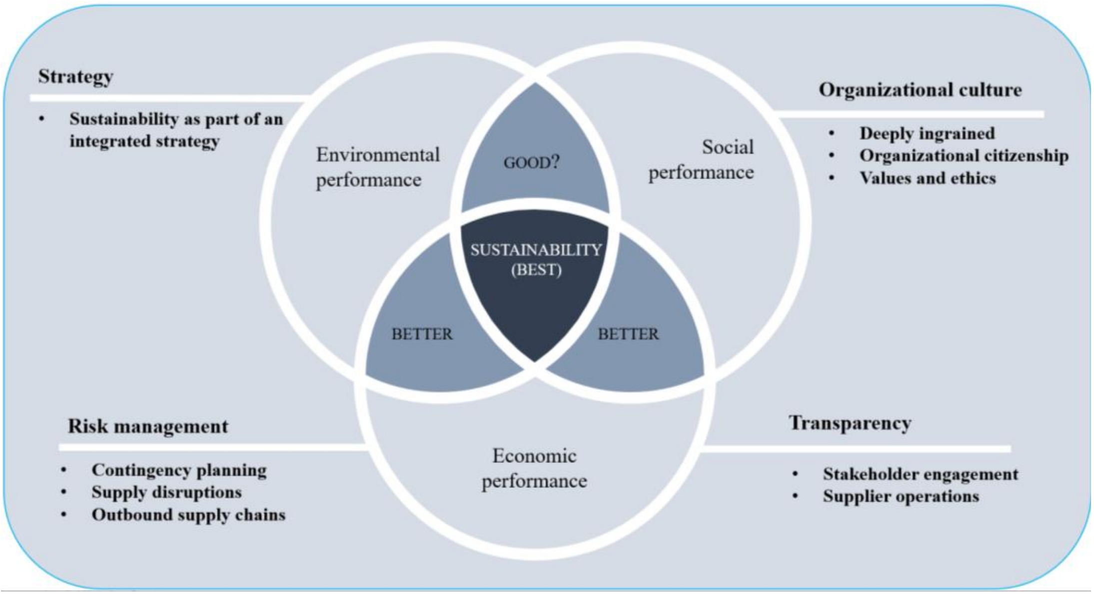
Shrivastava (1995a, p. 955) describes sustainability as "*The potential for reducing long-term risks associated with resource depletion, fluctuations in energy costs, product liabilities and pollution and waste management*." (Carter and Rogers, 2008).

In essence, sustainability is a broader concept that encompasses social, environmental and economic considerations, often referred to as the three pillars of sustainability (Ellen MacArthur Foundation, 2013). The viewpoint of the three pillars of sustainability aligns with the concept of the triple bottom line, which is a concept, developed by Elkington (2004) and it simultaneously considers and balances economic, environmental and social goals from a microeconomic standpoint and is primarily used by businesses to assess and report their performance in terms of economic, social and environmental point of view (Carter & Rogers, 2008).

Carter & Rogers (2008) state that organizations can engage in activities at the intersection of social, environmental and economic performance that positively impact both the natural environment and society, while also yielding long-term economic benefits and a competitive advantage for the company. When a company has strong performance on traditional measures of profit and loss in addition to a broader understanding of performance that encompasses social and environmental considerations, we can consider the company as sustainable (Pagell & Wu, 2009).

As industries face increasing environmental, social and economic challenges, the need for a holistic approach to sustainability is needed (Budler & Lunder, 2024). Achieving true sustainability requires balancing these three pillars through initiatives such as embedding sustainability into integrated strategies, promoting organizational culture based on values and ethics, ensuring transparency in stakeholder engagement and managing risks effectively. This approach aligns with long-term sustainability goals. The sustainability model framework that integrates environmental, societal and financial dimensions into organizational strategies is visualized in the figure 1 below.

Figure 1: Sustainability model



Source: Adapted from Carter & Rogers (2008)

Circular economy which is seen as a pathway towards achieving sustainability goals by promoting more efficient resource use and reducing environmental impact, concentrates on redesigning economic systems to minimize waste and maximize resource efficiency (Ellen MacArthur Foundation, 2013).

One of the most recent definitions of the circular economy is the one from European Commission (2015): "*In a circular economy the value of products and materials is maintained for as long as possible; waste and resource use are minimized and resources are kept within the economy when a product has reached the end of its life, to be used again and again to create further value*."

The circular economy is gaining popularity in political and business circles as a means of addressing the limitations of traditional linear models. To stay competitive, businesses are becoming more interested in using resource-efficient practices due to the changing macro-economic, regulatory and ecological landscape (De Angelis et al., 2018).

According to Genovese et al. (2017) the circular economy advances environmental sustainability by promoting the transformation of products in ways that create a balance between protecting the environment and supporting economic growth.

As industries recognize the limitations of traditional approaches and the need for sustainability, the concept of circular economy is gaining momentum. To fully implement circular economy principles, companies must rethink the way they manage their supply chains (Govidan & Hasanagic, 2018). The next chapter explores how businesses are shifting from traditional, linear supply chains to more circular supply chains.

2.2 Transition from traditional to circular supply chains

The linear economy model has dominated industrial development for 150 years. This traditional approach involves producing goods from raw materials, selling products and eventually disposing of them as waste, following the take-make-use-dispose paradigm. The model prioritizes maximizing production output and efficiency, often by scaling operations to produce larger volumes of goods at the lowest possible cost (Govidan & Hasanagic, 2018).

While the concept of circular economy is not new, it increased its recognition from the business community only in recent times. This can be attributed to current macro-economic, regulatory and ecological trends that make resource-efficient business practices more attractive and competitive (Govidan & Hasanagic, 2018).

In response to environmental concerns and product lifecycle issues, companies have started to develop a circular supply chain. The circular model seeks to eliminate waste by keeping materials in use through recycling, refurbishing and remanufacturing, creating a closed-loop system where products can circulate multiple times. Circular supply chains focus on collaborative value capture, where companies work together across the supply chain, including suppliers, manufacturers and customers to maximize the value of materials and products over their lifetime. The emphasis is on quality and durability over quantity. Circular supply chains emphasize localized production, recycling and consumption to reduce the carbon footprint and transportation costs (De Angelis et al., 2018). The figure 2 below illustrates the difference between traditional and circular supply chains.

Figure 2: Traditional versus circular supply chain.

	Traditional supply chains	**Circular supply chains**
Structure	Linear and open	Closed and short loops
Focus	Efficiency	Collaborative value capture
Scale	High volume	Medium to low volume
Scope	Global	Regional and local

Source: Adapted from De Angelis et al. (2018)

2.3 Barriers in implementation of circular economy

Although the shift from traditional to circular supply chains brings certain advantages, such as reducing waste and improving resource efficiency, it also comes with challenges. Even though the circular economy model is gaining more attention, industries like aluminium production still face significant obstacles that slow down the adoption of these practices. Govidan & Hasanagic (2018) classify eight clusters of barriers connected to implementation of the circular economy. The barriers aluminium producers face when they try to implement circular practices in the aluminium industry are presented in the figure 3 below.

Figure 3: Barriers to implementing circular economy concepts

Title of Issue	Description of the issue in connection with aluminium industry
Governmental issues	Absence of standardized performance assessment systems, ineffective recycling policies and poorly coordinated new laws, need to promote secondary aluminium production and optimize scrap collection systems.
Financial and economic issues	High costs of recycling technologies and volatile scrap aluminium prices.
Technological issues	Challenges in maintaining product quality during the recycling process, technological constraints in remelting and dealing with mixed metal alloys.
Knowledge and skills issues	Lack of reliable information, inadequate public awareness, insufficient skills and limited consumer understanding of refurbished products.
Management issues	Lack of support from top management and low priority given to circular economy initiatives
Circular economy framework issues	Difficulties with the circular economy framework, where alternative approaches may seem more viable, leading to the persistence of linear models.
Cultural and social issues	Lack of enthusiasm for the circular economy, negative perceptions of recycled products, especially in industries focused on quality and aesthetics, like automotive or packaging industries, which reduce demand for remanufactured aluminium products.
Market issues	External market factors like ownership regulations and the absence of refurbishment standards, hindering the full potential of circular economy practices.

Source: Adapted from Govidan & Hasanagic (2018)

2.4 Overcoming barriers in circular economy implementation

After looking at the barriers to implementing circular economy practices, it is important to consider the methods that can help industries address these challenges. Some of the concepts and methods that could help to overcome such barriers are the eco-efficiency concept and the life cycle assessment (LCA) method which could help companies to better understand the environmental and economic benefits of adopting circular practices.

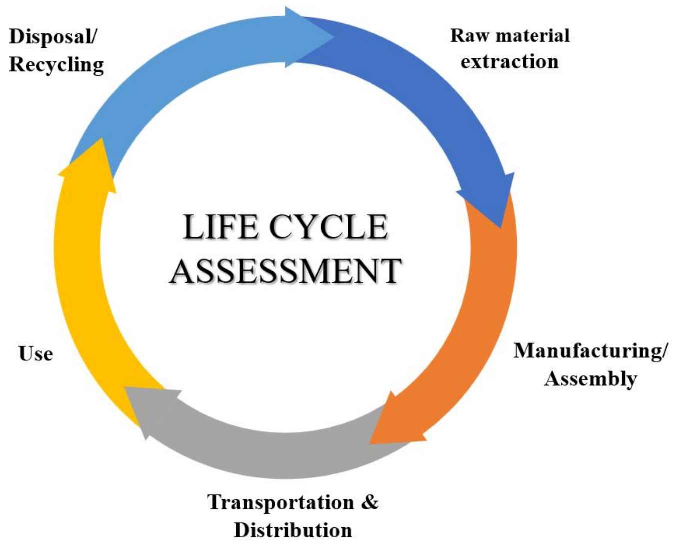
Eco-efficiency and LCA are interconnected through their focus on sustainability and resource optimization. Eco-efficiency links environmental impacts with economic performance. The World Business Council for Sustainable Development (WBCSD) defines eco-efficiency as: "*The delivery of competitively priced goods and services that satisfy human needs and bring quality of life, while progressively reducing ecological impacts and resource intensity throughout the life cycle to a level at least in line with the Earth's estimated carrying capacity*".

Eco-efficiency indicators measure and compare the eco-efficiency of sectors within and across different countries. Focusing on eco-efficiency can improve economic and environmental performance. However, the social dimension is often overlooked despite its importance to reach the goals of sustainable development (Caiado et al., 2017). Zhu et al. (2007) explain that with certain innovative approaches environmental risks could be reduced, while enabling organizations to benefit both in profitability and market share. This enhances eco-efficiency, creating a win-win scenario for companies.

Frischknecht (2010) explains eco-efficiency as "*making more with less*". By focusing on eco-efficiency, higher recycling targets and reduced greenhouse gases emissions can be achieved. The concept connects the environmental impact of an industrial activity to the economic value it generates.

To address the environmental impact of a product, supply chains must consider all the by-products that are created during the life cycle of a product. LCA assess environmental impacts of a product in different phases, from raw material extraction, manufacturing, transportation, evaluating the impact of the product during its operation life to measuring the environmental impact of product's disposal or recycling (Paraskevas et al., 2015) LCA is one of the methods that can be used to identify strategies for reducing the environmental impact of a product over its usable life and beyond and is widely used in the aluminium industry. (Linton et al., 2007). In the figure 4 below phases of the LCA are illustrated.

Figure 4: Life cycle assessment



Source: Adapted from Paraskevas et al. (2015)

Frischknecht (2010) classifies two different approaches in metal recycling that are currently used in daily LCA. They focus on different parts of the product lifecycle and allocate environmental impacts differently:

Recycled content approach: This approach is used in the production phase and considers the proportion or amount of recycled metal used in the production of a product. This method compares the environmental impact of a product with a certain percentage of recycled material content to one made fully from the primary material. (Frischknecht, 2010).

End-of-life recycling approach: This approach focuses on the final disposition or fate of the metal at the end of its useful life, emphasizing the recycling of materials to reduce the need for new raw material extraction. This method assesses the environmental impacts associated with waste processing and recycling activities (Frischknecht, 2010).

In the figure 5 below both recycling approaches are compared in the aspect of lifecycle stage, focus of the approach, environmental credit and application of the approach.

Figure 5: Comparison of recycled contant approach and end-of-life recycling appproach

Aspect	Recycled content approach	End-of-life recycling approach
Lifecycle stage	Production phase	End-of-life phase
Focus	Use of recycled materials as inputs	Recycling of materials at the product's end-of-life
Environmental credit	Immediate reduction in raw material demand	Future reduction in primary material use due to recycling
Application	Promotes using recycled content in design	Encourages better waste management and recycling

Source: own work

During end-of-life recycling approach, significant difficulties are presented, due to mixing of metals and their alloys that occurs without control during different phases of a product's life cycle, along with limitations in melt purification during remelting (Paraskevas et al., 2015).

If we use the end-of-life recycling approach in case of aluminium recycling, primary aluminium production is the most eco-efficient. This is because at the end of its life aluminium products made from primary aluminium can be effectively recycled and reused, preserving much of the value of the material. On the other hand, if we use the recycled content approach, the most eco-efficient way to produce aluminium is by using sorted aluminium scrap. This method minimizes energy consumption and environmental impact, as recycling scrap requires significantly less energy than producing aluminium from raw materials. Finally, the eco-efficiency of recycling aluminium is substantially higher as compared to the production of aluminium from bauxite (Frischknecht, 2010).

Luthin et al. (2021) note that LCA is an established methodology to evaluate the environmental performance of products, but that for comprehensive sustainable decision-making, the economic and social perspectives are also important. Economic performance can be evaluated with life cycle costing (LCC). LCC is a methodology to evaluate the total cost of a product, system or service over its entire lifespan, including acquisition, operation, maintenance and disposal, for better long-term decision-making. LCC complements LCA by examining the financial aspects. By combining both LCA and LCC, it becomes possible to obtain valid statements about sustainable performance since improving environmental performance often results in trade-offs with economic efficiency. Therefore, a joint assessment of both LCA and LCC is essential for a comprehensive understanding of sustainable performance and can be used as a tool for decision making. A general framework on LCA and LCC integration and the approach to identify trade-offs in the entire production process for both primary and secondary aluminium has not been developed yet.

After examining eco-efficiency and LCA as a concept and a method available for solutions to the barriers in implementing circular economy practices, it is essential to focus on the materials at the core of these processes. The following chapter will explore aluminium as a production material, its properties and its importance in various industries, while also discussing the environmental impact of its production and the growing significance of aluminium recycling in the circular economy.

3 CIRCULAR ECONOMY IN ALUMINIUM PRODUCTION

Aluminium is a silvery-white light metal, which is widely used due to its material properties, such as high electrical and thermal conductivity, low density, high resistance to environmental influences and high strength-to-weight ratio. Aluminium ranks as the third most frequent element involved in the structure of the crust of the Earth and is the most important non-ferrous working metal in today’s industry (Vasters & Franken, 2020).

3.1 Supply chain of aluminium production

The supply chain of the aluminium production involves two main processes: primary production and secondary production. Primary aluminium production begins with mining bauxite ore, which is processed into alumina. This alumina is refined into aluminium through an energy-intensive method called the Hall-Héroult process, requiring approximately 15,000 kWh of electricity per ton. This process not only consumes a lot of energy but also generates significant carbon emissions, especially if electricity comes from fossil fuels (Ferretti et al., 2007).

In contrast, secondary aluminium production focuses on recycling scrap aluminium, such as used cans and industrial waste. This method is significantly energy-efficient, using only about 5% of the energy needed for primary production, thereby saving around 14,000 kWh per ton. The process involves collecting, cleaning and melting scrap and then forming it into new products. Recycling aluminium reduces the need for mining, conserves resource, minimizes waste and results in much lower carbon emissions. Choosing the most suitable process for the aluminium supply chain depends on the specific needs of the industry. Primary production is essential for creating high-quality aluminium for industries such as aerospace and electronics. Meanwhile, secondary production efficiently supplies aluminium for products like packaging and cars (Ferretti et al., 2007).

3.2 Primary aluminium

Following the discovery of aluminium as an element, a standardized process for primary aluminium production from bauxite was quickly established. This involved several stages, including bauxite mining, alumina production, electrolysis and ingot casting (Luthin et al., 2021). The primary aluminium production requires a significant consumption of electrical energy, leading to negative consequences on the overall cost of final products (Ferretti et al., 2007).

Aluminium is used in construction, transportation, machinery, packaging, consumer durables, electrical transmission lines and many other applications. Demand for aluminium increased especially because of the trend towards lightweight construction in the automotive industry, which offers environmental benefit, such as fuel savings and lower GHG (greenhouse gas) emissions, but its production causes greater environmental impact than materials like steel. It contributes significantly to GHG emissions, consuming over 3.5% of global electricity (Luthin et al., 2021).

In 2022, the total production of primary aluminium across the globe was 68.461 million metric tonnes. The majority of all the aluminium produced, which in 2023 accounted for 1.5 billion tonnes, around 75%, remains actively utilized. Every year, more than 30 million tonnes of aluminium scrap is recycled globally, which makes it one of the most recycled materials on the planet (International Aluminium Institute, 2023).

Understanding widespread use of aluminium and its environmental impact highlights the need to explore its supply chain into detail.

3.3 Secondary aluminium

The secondary aluminium refers to a metallic alloy acquired through the recycling of manufacturing scraps and the recovery of used products. This approach enables financial savings in both raw materials and energy, specifically by reducing electricity usage (Ferretti et al., 2007). This goes in line with Wallace (2011), who defines the term "secondary aluminium" as aluminium that is derived from recycled sources, encompassing diverse forms of aluminium scrap such as new production off-cuts, machining swarf, drosses or obsolete end-of-life aluminium products. From the start of commercial production, aluminium has been subjected to recycling, initially driven by both commercial and environmental motives. Recycling aluminium does not compromise its quality, since it can be recycled multiple times, but still maintains its significant scrap value. The primary objective of all secondary facilities is to minimize the cost of raw material.

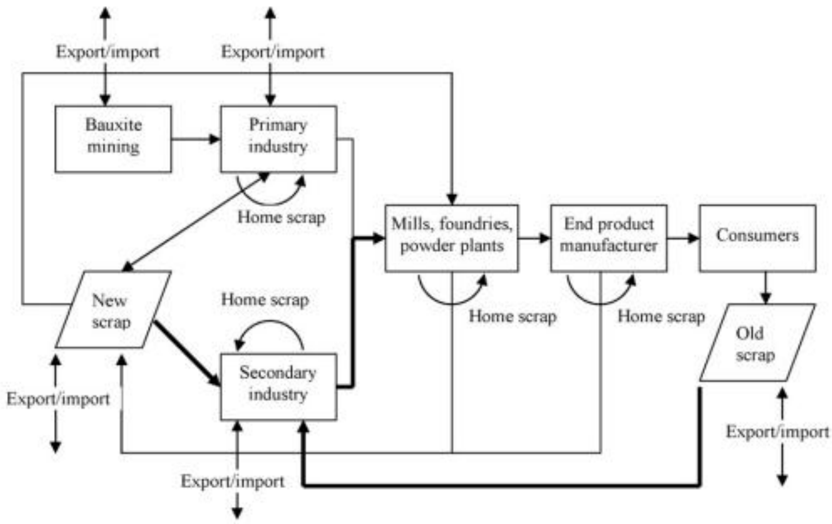
The next chapter will delve into the flow management of secondary aluminium, examining how the collection, processing and transportation of aluminium scrap contribute to a more sustainable and efficient supply chain.

3.3.1 Flow management of secondary aluminium

There exist two categories of secondary aluminium production. The first one involves refiners who manufacture casting alloys and deoxidized aluminium by utilizing both old and new scrap, providing them in ingot or molten form and at the same time enhancing its quality. This is done through the elimination of oxides, intermetallics and dopants like magnesium and calcium. The second one involves remelters who produce wrought alloys, primarily sourced from clean and sorted wrought alloy scrap, supplying them as rolling slabs, extrusion billets or master alloys (Wallace, 2011).

According to Blomberg & Söderholm (2009) the overall stock of aluminium is growing faster than production of secondary aluminium, from which it can be concluded that the expenses of recovery and recycling will diminish over time. With the growth of stock, secondary refiners will find it less difficult to acquire good quality scrap. While scrap prices directly influence the costs of producing secondary aluminium, the availability of old scrap indirectly affects these expenses. Increased stock improves the chances of obtaining high-quality scrap, while reducing production costs. In the figure 6 below flows of primary and secondary aluminium in the economy are illustrated.

Figure 6 The flows of primary and secondary aluminium in the economy



Source: Blomberg & Hellmer (2000)

3.3.2 Logistics of secondary aluminium

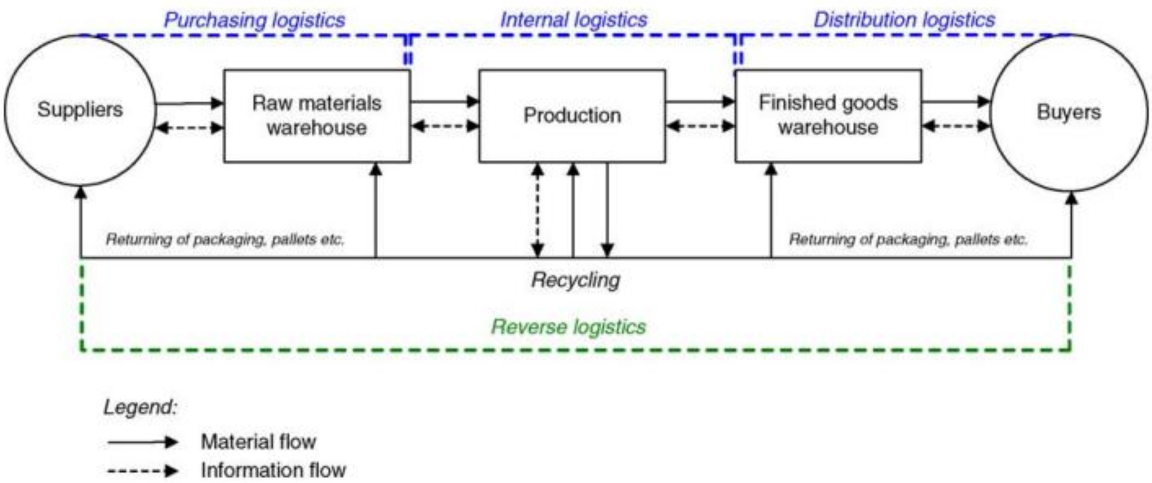
Traditional logistics systems focused mainly on minimizing costs and maximizing profits, with less emphasis on environmental impacts. In contrast, circular supply chains integrate environmental considerations into their operations (Logožar et al., 2006).

The economic efficiency of aluminium recycling relies heavily on the costs incurred at various stages of the recycling process. Transportation expenses present a significant portion of the overall cost structure. Optimal logistics and transport processes are crucial to ensure time and cost-effective recycling, while lowering environmental impact. (Logožar et al., 2006)

According to Logožar et al. (2006) approximately 25% of the energy required for secondary aluminium production is attributed to transportation and scrap preparation. Since transportation between different technologic operations is needed, optimizing the in-plant aluminium recycling logistics scheme is essential. The objective is to find the most economical transportation model that adheres to restrictions related to the collected scrap volumes, reprocessing unit capacities and internal transport route availability. Reverse logistics, as a component of circular supply chains, refers to the practice of relocating goods from their usual end point to extract value or ensure appropriate disposal.

Hence, it is crucial to carefully analyse the investment choices concerning transport methods and scrap collection locations to optimize fixed costs, which could increase the competitive advantage of the company. With this case Logožar et al. (2006) confirm that aligning environmental and economic objectives can lead to minimal transport costs and emissions. In the figure 7 below reverse logistics in comparison with traditional logistics is illustrated.

Figure 7 Reverse logistics in comparison with traditional logistics subsystems.



Source: Logožar et al. (2006)

In contrast to the mostly regional logistics of secondary aluminium, primary aluminium production requires transporting bauxite and alumina usually over long distances, often by sea, rail and road. This complex logistics chain can contribute significantly to the total production costs.

After examining the logistics involved in secondary aluminium production, the next step is to understand the broader context of aluminium recycling itself. The next chapter will focus on the recycling process, highlighting its advantages, challenges and the role it plays in extending the lifespan of aluminium.

3.4 Aluminium recycling

Metals are highly recyclable compared to other materials due to several factors. Firstly, metals possess high economic value. Secondly, large quantities of metal scrap are available for recycling, enabling economies of scale. Thirdly, metals exhibit excellent recyclability, a distinctive feature compared to other materials (Paraskevas et al., 2015).

Recycling non-renewable resources like metals extends their lifespan, as processed scrap materials or secondary metals are generally cheaper than primary metals. This is because the initial costs for exploration, mining and refining have already been incurred and the energy requirements for recycling are lower (Blomberg & Söderholm, 2009). Therefore, the demand for sustainable raw materials and products throughout the entire supply chain has increased (Luthin et al., 2021).

Recycled metal retains its original properties, such as ductility and conductivity, making it a nearly perfect substitute for primary metal. Aluminium recycling and secondary aluminium production began shortly after the industrial production of primary aluminium was established. Secondary aluminium production is far less energy intensive than primary production, even down to 5% of the energy requirement of primary smelting (Blomberg & Söderholm, 2009). This aligns with Luthin et al. (2021) and Wallace (2011) who also state that secondary production consumes just 5% of the energy required for primary aluminium production. These factors provide strong justification for the nickname of aluminium, which is “green metal”. The environmental benefits of aluminium recycling are both direct such as the recycling process itself and indirect, like the promotion of lighter vehicles (Ferretti et al., 2007).

Aluminium recycling lacks a standard process due to the variety of scrap compositions requiring different recycling methods and furnace technologies. Aluminium recycling can be roughly divided into scrap collection, processing and melting by remelters or refiners. However, tracking secondary aluminium production is much more challenging than primary production (Luthin et al., 2021).

A significant limiting factor in recycling of aluminium is the accumulation of foreign elements in aluminium streams at various life cycle stages. The limited options for purifying the melt, which refers to removing impurities from a molten metal, contribute to contamination and potentially result in quality loss. Efficiently controlling the composition of material streams before remelting is crucial, since out of the 45 common alloying and impurity elements found in aluminium, only a limited number of six elements, magnesium and zinc for example, can be partially removed (Paraskevas et al., 2019).

The process of aluminium recycling can vary depending on the type of recycling method used. To better understand how aluminium is recycled and the challenges it faces, the next chapter will explore the differences between open-loop and closed-loop recycling.

3.4.1 Open-loop recycling of aluminium

The methods of recycling metals can vary and are typically divided into two main approaches: open-loop and closed-loop recycling. Open-loop recycling is more common for metals than closed-loop recycling (Paraskevas et al., 2015).

Open-loop recycling involves converting a product or material into a different type of product at the end of its useful life. In this process recycled materials flow into other product systems, such as old aluminium scrap. Although aluminium theoretically allows for infinite recycling, downcycling due to not clearly separated alloys must be considered. There are various types of material losses, such as loss of original functional quality, dissipation of scarce resources and the final need for dilution of the resulting metal impurities with primary materials (Paraskevas et al., 2015).

3.4.2 Closed-loop recycling of aluminium

Closed-loop recycling refers to the process where a product or material is recycled into the same product without significant degradation in quality. Close-loop recycling is more suitable if we want to keep the quality of recycled material, according to Niero & Olsen (2016). Paraskevas et al. (2019) agrees that transitioning from open recycling loops to more compositionally precise closed loops is crucial for the long-term sustainability of the aluminium recycling process. This shift aims to maximize the overall efficiency of material resources within the system.

The transition to a circular economy, including recycling, comes with both opportunities and challenges that impact the financial performance of companies. The next chapter will explore the role of financial factors in adopting circular economy concepts, highlighting the potential financial challenges and benefits for the manufacturing industry.

4 FINANCIAL FACTORS WITHIN THE CONTEXT OF CIRCULAR ECONOMY

Organizations can effectively pursue their business goals and lower their environmental footprint at the same time. Nevertheless, it should be noted that although waste and pollution reduction are aligned with the traditional goals of operations management, not all environmental practices lead to cost savings. In fact, certain practices may raise additional costs, particularly in the short term (Pagell & Wu, 2009). According to Sarfraz et al. (2023)

implementation of circular economy within an organization can be challenging, since certain sustainability driven innovations come with higher costs that can directly impact financial performance of the company.

4.1 Balancing financial performance and sustainability

According to Linton et al. (2007) several studies have found that prioritizing sustainability in the supply chain is related to lower costs and can have a neutral or positive effect on overall value. This is in line with findings by Larsen et al. (2018), who argue that circular supply chain activities, which manufacturers have traditionally considered an expensive inconvenience, can strengthen a firm's financial performance in two ways, either with increasing revenue or reducing costs.

The revenue of the firm can be increased by recovery and resale of end-products, which are products that were refurbished, repaired or remanufactured back to a usable and saleable condition. Reselling recovered products or product's components can also create a challenge for low-cost competitors attempting to enter the market, since recovered products represent a direct competitor. However, with a supply chain expansion, the supply chain becomes more complex, with new strategic and operational challenges. This can also result in increased costs, at least in the short term, which can reflect the transfer of external costs from society to supply chain partners (Larsen et al., 2018).

According to Sarfraz et al. (2023) it follows that the advantages of transitioning to a circular economy are commonly realized by companies in the long run. It is crucial for a company's strategy to not only address social and environmental risks but also properly consider their financial impact to maximize the synergies of implementing a circular economy.

The decision of a company to move towards a circular economy is largely influenced by the choice of its management. To align the business model with the principles of circular economy, management may need to be incentivized through internal bonus payments or compelled by external pressure from capital markets and non-compliance costs imposed by governments (Sarfraz et al., 2023).

Based on Sarfraz et al. (2023) research resumed on G7 European members (Germany, France, Italy and United Kingdom), concluded that advanced economies have the most significant advancement towards adopting a circular economy and achieving sustainable economic growth. This goes in line with Gonçalves et al. (2022), who states that when it comes to recycling and circularity of materials, the European Union's index is slightly higher than that of the rest of the world.

As stated by Charlo et al. (2013) even though businesses acknowledge the significance of the social aspect, they may not be willing to bear the financial costs associated with implementing socially responsible practices. Companies are more likely to act responsibly when they view responsible behaviour as a competitive advantage.

There is a trade-off between short-term profitability and long-term environmental sustainability which encompass uncertainty and risk. Pagell & Wu (2009) assume that owners and managers will focus on profitability, but members of the community will pay more attention to overall liveability of the community and environmental impact from production. When it comes to trade off decisions in the organization, particularly when environmental costs or benefits are uncertain, the organization would usually decide for the option that is best aligned with their core values, mission and business strategy.

This goes in line with Linton et al. (2007) who explain that emphasis on optimizing operation has shifted from focusing on individual facilities or organizations to a holistic view of the entire supply chain. To maximize value across the entire supply chain, organizations need to prioritize performance over cost, even if it means operating less efficiently in terms of cost efficiency. On the other hand, there may be certain conflicts between what is economically advantageous for members of the supply chain and what is beneficial for the larger system or population.

4.2 Financial challenges in circular economy concept implementation

For a company to pursue the objectives of circular economy, the supply chain needs to be redesigned, which can present various challenges. Uncertainties around the quantity, quality and timing of product returns in circular supply chains can impact capacity planning for renovation activities like remanufacturing. Economic and financial viability challenges, such as time mismatch between revenue and cost streams, financial risk, operational risk and return flows uncertainty arise, when companies are redesigning their supply chain for the circular economy (Bressanelli et al., 2018). According to Ethirajan et al. (2020) financial risk is the most vulnerable risk category in circular supply chains.

Gonçalves et al. (2022) also emphasize financial barriers for companies that adopt the objectives of the circular economy. Financial barriers are related to several factors, including the size of the business and the initial investment cost, challenges faced by micro and small businesses, the need for a more complex business structure and increased risk exposure. They view the initial costs of investment as possible barriers to implementing circular economy initiatives. They also emphasize the significance of public financial incentives such as subsidies, which not only reduce the risk exposure but also ensure the profitability of specific projects.

Next to initial investment cost, the size of a business plays a crucial role in the adoption of a circular model. When the size of the company decreases, the challenge of obtaining investments intensifies, thereby heightening the level of risk involved. In the end, they point out that for micro and small companies the country in which the business operates is the main factor in determining the success of circular initiatives. (Gonçalves et al., 2022)

The lack of financial, organizational and national metrics to evaluate the progress of diverse circular businesses is another significant challenge that prevents the implementation of the circular economy. To achieve financial success, it is crucial to analyse the costs of products across all stages of production, considering various resources such as reuse, recycling and product design. Accounting for process costs is essential as resources for different products can have varying lifecycles. Thus, financial incentives, project subsidies and heightened awareness among nations, companies and consumers are vital factors for advancing the objectives of the circular economy. (Gonçalves et al., 2022)

Despite these challenges, companies must strive towards sustainability. As Carter & Rogers (2008) point out, some companies have already exhausted the easy sustainability initiatives and are now facing longer-term investments where financial and environmental criteria are not always compatible.

Lastly, according to Hervani et al. (2005) it can be challenging to measure performance results of one specific entity among multiple vendors, manufacturers, distributors and retailers that are spread globally over the whole supply chain. Even though measuring the performance of a specific entity can be useful, Pagell & Wu (2009), state that achieving sustainability requires more than assigning responsibility to a separate entity within the organization, but it must be integrated into every aspect of the company. The goal should be to internalize sustainability objectives so that they become critical to the company's growth and financial performance. This means that financial goals and environmental goals are aligned and sustainability becomes an integral part of the business strategy, incorporated into every aspect of the supply chain.

4.3 Financial benefits in circular economy concept implementation

Possible financial benefit in addressing environmental and social concerns proactively is the ability to influence future government regulations, which can lead to a competitive advantage of the company, as the company is better prepared to comply with future regulations and avoid costly penalties (Carter & Dresner, 2001).

Additional financial benefits of implementing sustainable practices in the manufacturing company, according to Carter & Rogers (2008) are reduced costs, shorter lead times and better reputation, because implementing sustainable practices can enhance the attractiveness of an organization to both suppliers and customers.

According to Sarfraz et al. (2023) some studies show that by optimizing the use of resources, costs can be reduced, which leads to higher profits and a stronger market position. This provides a competitive edge for businesses from a long-term perspective, which goes in line with Gonçalves et al. (2022) who state that apart from the societal advantages, the implementation of circular economy principles can also bring economic benefits to companies, which results in a positive impact on social, environmental and financial aspects.

It appears that empirical data regarding the comprehensive costs and benefits of adopting a circular economy business model in relation to its impact on the financial performance of firms is still insufficient, as highlighted by Sarfraz et al. (2023). This finding is consistent with the Gonçalves et al. (2022), who suggest that the correlation between the circular economy and finance has not been fully investigated yet. They conclude that there is a need for additional research in this area as it is a new and critical aspect for the advancement of the circular economy.

After discussing the financial challenges and benefits of implementing circular economy concepts in manufacturing, the next step is to see how these factors influence real world business decisions. The following chapter will provide a case study of Talum, a company that has transitioned from primary to secondary aluminium production. Through this case study, we will see how Talum has leveraged sustainability to drive financial performance, mitigate risks and explore new opportunities in the market. Additionally, the case highlights the strengths and weaknesses identified through a SWOT analysis, offering a view of how the circular economy can create both challenges and opportunities for companies like Talum.

5 CASE STUDY OF TALUM

This master's thesis adopts a qualitative case study methodology as outlined by Yin (2003), who emphasizes its suitability for answering complex "how" and "why" questions, particularly when the researcher has limited control over events and when the phenomenon is embedded in a real-life context. The case study method is appropriate in this research because it enables an in-depth understanding of Talum's transition from primary to secondary aluminium production. Yin (2003) argues that case studies are especially useful when contextual conditions are integral to the phenomenon, which applies directly to Talum's strategic shift in response to energy prices and environmental regulations.

This research is designed as a single-case study, focused on one organization, Talum d.d., as a unique and informative case of sustainable transition in the aluminium industry. The case is bounded by time (2018–2022) and location (Slovenia). It combines multiple data sources, including annual reports, internal company materials and a focus group with Talum representatives, ensuring methodological rigor through data triangulation.

Following Yin's (2003) guidance, this case study is primarily descriptive and explanatory. It describes the financial and operational changes in Talum's production model and explains how these changes align with sustainability goals. The descriptive component captures the evolution of production volumes, energy use and cost structures, while the explanatory aspect uncovers why and how Talum's strategic decisions were made and what implications they had for business performance. The study also uses embedded units of analysis such as the business unit Slugs and Discs, which plays a key role in Talum's circular economy approach.

By employing Yin's case study methodology, this research allows for a holistic analysis that embraces the complexity and interconnectedness of sustainability practices, industrial economics and real-world decision-making. This approach supports the study's objective of generating insights that may be transferable to other companies navigating similar transitions.

5.1 Company overview and history

The aluminium factory began construction in 1942 in Kidričevo. In 1954, the first electrolytic furnaces were started, enabling the production of around 10,000 tonnes of aluminium per year. Regular production of alumina and aluminium began in 1955. The factory's capacity was 45,000 tonnes of alumina and 15,000 tonnes of aluminium per year (Talum, 2022a).

In 1981, the production of narrow and wide aluminium strips and wires began and in 1982, a facility for evaporators, slugs and discs was opened. In the early 1990s, environmental protection changes influenced production, leading to the discontinuation of electrolysis A and the production of metallurgical alumina in 1991. In 2003, a modern foundry for cast alloys was built and production increasingly started to incorporate secondary aluminium (Talum, 2022a).

In 2006, the newly established work unit Castings cast the first piece using a gravity casting machine. In 2008, they obtained an environmental permit issued by the Environmental Agency of the Republic of Slovenia. The financial and economic crisis reached its peak in 2009, causing a drastic deterioration in conditions in the global aluminium market. They responded to this situation by reducing primary aluminium production by 60%. (Talum, 2022a).

In 2015, the high-pressure die-casting project for aluminium started and they began increasing the sales of coils and casts. Talum established a strategy to achieve higher added value through innovation and development partnerships in 2018. Key strategic directions included sustainable development with increased added value, as well as digitization and the transformation of business models. Financial goals within the strategy include appropriate ROE (return on equity), growth of value added per employee, liquidity and financial stability which are measured with financial KPIs (key performance indicators) such as ROE and ROS (return on sales) (Talum, 2022a).

Today the group Talum consists of the managing company Talum d.d. Kidričevo and subsidiary companies in which Talum d.d. Kidričevo is the only shareholder (100% share). Internally, the company Talum d.d. Kidričevo is organised within BU (business units) and services: BU Aluminium, BU Foundry, BU Service and engineering, BU Casting, BU Slugs and discs and BU Logistics (Talum, 2022a).

Today Talum's strategic vision revolves around energy-efficient and environmentally friendly aluminium production and processing. The company produces a wide range of aluminium products such as primary aluminium, billets, castings, slugs, discs, evaporators and heat exchangers. With an annual production volume of 115,000 tonnes of aluminium products, Talum has been transitioning from primary aluminium production to aluminium processing in recent years (Talum, 2022a).

They have tried to maintain their own production of primary aluminium in electrolysis in very difficult conditions on the European energy market. In the first half of 2022, due to the high cost of energy, they kept the production capacity in electrolysis at only one third of what they had leased the necessary energy for. In Q3, they further reduced the production of electrolytic aluminium to 22% of their production capacity and ended the year with 12% of all the operating production capacity in electrolysis (Talum, 2022a).

Talum was in terms of specific electricity consumption per tonne of electrolytic aluminium, firmly in the top 10% of the most successful aluminium producers in the EU, with an average consumption of 13.90 MWh per tonne of electrolytic aluminium produced over the last 6 years. (Talum, 2022b). However, at the beginning of 2023, the company announced that, after 60 years, it would be shutting down its electrolysis furnaces for aluminium production in April 2023. This decision was primarily driven by the increased normative consumption of electricity and the inability to secure additional electricity at an affordable price, making continued production at the current scale unsustainable both technically and economically (Talum, 2022a).

5.2 Talum's transition from primary to secondary aluminium production

The basis of the circular economy is that aluminium and its processing enable an unlimited re-use of return raw materials with the preservation of its primary characteristics. Talum is increasing the share of secondary raw materials and developing technological procedures accordingly. They are investing in increasing the melting capacity for recycling. They have established feedback loops with customers to increase the processing of secondary raw materials and they reuse aluminium obtained from slag (Talum, 2022c).

According to Talum’s Annual Report (2022a) there are several reasons for the strategic decision to stop the production of electrolytic aluminium and focus on purchased primary aluminium, recycling aluminium and secondary aluminium production, which are explained in the next paragraphs.

Talum prevents and manages the significant impacts of its activities, aluminium products and services on the environment by upholding an environmental management system aligned with the ISO 14001 standard and an energy management system aligned with the ISO 50001 standard. Moreover, the company's environmental and social standards and practices are rooted in the ten principles and objectives of sustainable development outlined in the United Nations Global Compact and the Sustainable Development Goals, as stated in the Talum Annual Report (2022a).

In 2021 Talum initiated the process the ASI (Aluminium Stewardship Initiative) performance standard. The ASI standard defines environmental, social and governance principles and criteria to address sustainability issues in the aluminium value chain. This involves the ambitious implementation of activities with intensive reductions in energy consumption, lowering CO2 emissions and a significant shift towards the use of secondary aluminium. Talum followed a strategy of restructuring programs with innovation towards sustainable transformation, circular economy and the path to carbon neutrality by 2040. As a result, Talum reduced their total carbon footprint from direct CO2 emissions by 79% in 2020, compared to the reference year of 1990 (Talum, 2022a).

Talum is committed to addressing climate change within the framework of the Paris Agreement. This commitment entails reducing direct and indirect GHG emissions throughout the aluminium production process and across product life cycles to facilitate decarbonization. Consequently, it is important to utilize electricity with guaranteed origins, incorporating electricity from our renewable sources and increasing the utilization of recycled aluminium (Talum, 2022a).

As an energy-intensive company it is important for Talum to manage electricity, heat, natural gas and compressed air rationally and efficiently, in accordance with the set standards and legal requirements. Emissions of substances into the air and the quality of the ambient air are regularly monitored and controlled so that the emissions meet the set standards and legal requirements. In 2020, Talum significantly reduced their electro-intensity by reducing the amount of energy consumed in relation to total revenue generated by 60%, compared to 2005. Their electricity consumption went from 2,000 GWh to less than 600 GWh (Talum, 2022a).

Demands for decarbonization and green energy are adding new and additional concerns for energy-intensive primary aluminium production. Export protectionist limitations and rising costs of gas and electricity are indeed threatening the viability of primary production. One of the goals of Talum’s continuous improvement is increasing the use of recycled aluminium, but quality is the driving force behind all their activities. Their guiding principle is the realization of the non-fault strategy, timely supply strategy and the introduction of complex aluminium products with the deployment of process digitalization and with circular economy (Talum, 2022c).

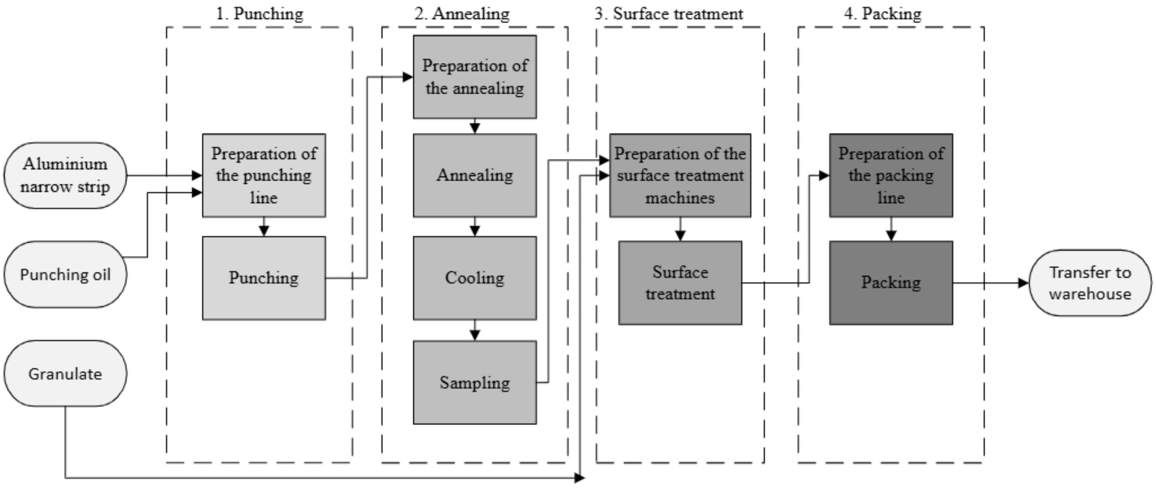
Those were several reasons for strategic decisions to stop the production of electrolytic aluminium in 2023 and focus on purchased primary aluminium, recycling aluminium and secondary aluminium production.

5.3 Business unit slugs and discs

In the case study the particular focus will be on the business unit Slugs and discs, where benefits of secondary aluminium are particularly visible. Talum decided to actively expand and develop the BU Slugs and discs program for the pharmaceutical, cosmetic, food and packaging industries. Talum is already manufacturing coils for containers made from 100% recycled aluminium, reducing the carbon footprint by 75%. Demand for slugs and discs which are produced from the so-called PCR (post-consumer recycled) material is increasing (Talum, 2022a).

In 2022, 41,274 tonnes of scrap aluminium were purchased, including production residue and 72 tonnes of slag. The quantities of recycled aluminium are increasing from year to year and this affects the reduction of specific amounts of energy used per product unit (Talum, 2022b). In 2022 Talum launched the "Slugs and discs 70,000 t" project, with which they are establishing production capacity to produce 60,000 tonnes of slugs and discs and 10,000 tonnes of new products (cold-rolled strip, discs for Teflon-coated pans and slugs and discs for technical parts). In the following figure 8, the production process of slugs is illustrated with a flowchart.

Figure 8 Flowchart of slug production process



Source: own work

Talum is already the largest manufacturer of slugs and discs in the world. In the future, they want to increase the sales of the current sales program and establish the production and sale of new products with higher added value and with an even lower carbon footprint (Talum, 2022a).

6 METHODOLOGY

6.1 Research design and approach

For analysing potential financial benefits of circular economy initiatives of Talum, certain data of the company was gathered. Research methodology combines quantitative and qualitative methods. The quantitative approach consists of collecting financial data about the company from their annual reports. Next to quantitative data collection, qualitative approach consists of analysing data from company reports and a focus group conversation. The purpose of this methodology is to address the following research questions:

R1: What is the financial impact of sustainable practices in secondary aluminium production measured using metrics such as investment costs, cost savings, revenue growth and risk reduction?

R2: What are the challenges and opportunities associated with implementing sustainable practices in secondary aluminium production in financial terms?

6.2 Data collection and analysis

In the quantitative analysis of the case study of Talum, I have compared data between the years of 2018 and 2022. This time frame was chosen because during this period production of electrolytic aluminium at Talum decreased, while the production of slugs and discs increased. The aim was to observe the correlation between implementation of circular economy, financial performance and the reason for Talum’s decision to shift focus from primary aluminium production to purchased primary aluminium, aluminium recycling and increasing the amount of secondary aluminium.

The next step of the research was a focus group conversation, which helped to get a deeper understanding of respondents’ opinions, perspectives and experiences. The purpose of data collecting from the focus group conversation was to provide a framework to the data collected from the annual reports of the company. The main objective of this methodology was to analyse the data and to identify correlations, similarities and differences between the theoretical findings and the empirical data.

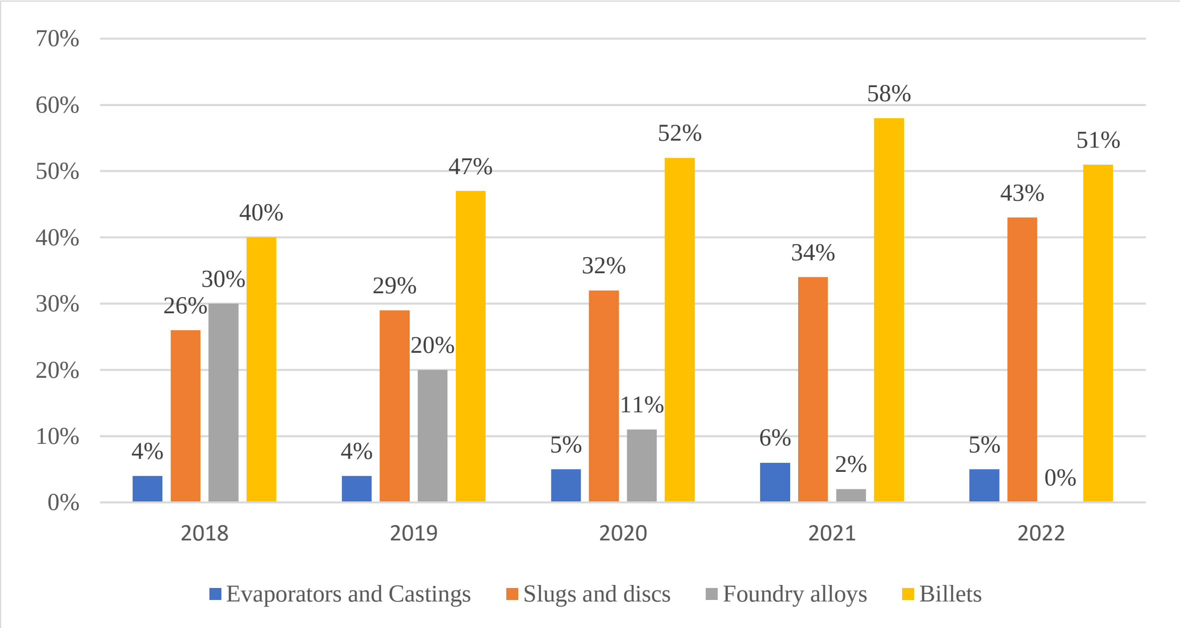
7 RESULTS

7.1 Business performance overview

Every primary aluminium product starts with electrolytic aluminium, which is the reason that this was the first object of observation when analysing annual reports of the company. The production of electrolytic aluminium in 2018 was at 80,511 tonnes, at company's full capacity. Only 4 years later, in 2022, Talum’s initial plan was to produce electrolytic aluminium at 34% of their production capacity. However, due to unfavourable conditions on the energy market, they decreased the production even further. By July 2022, the production was operating at 22% capacity, reaching only 12% capacity in Q4 of 2022. Talum produced 19,211 tonnes of electrolytic aluminium in 2022, representing a 31% shortfall from their planned production, a 49% decline compared to 2021 and 77% decline compared to 2018 (Talum, 2022a).

The Talum Group business plan for 2023 was based solely on a 10% occupancy of the production capacity in the C electrolysis and a slightly higher volume of total goods production compared to 2022, which were achieved through increased recycling and processing of aluminium. In the beginning of 2023, the company revealed that after 60 years, they will be shutting down their electrolysis furnaces for aluminium production in the beginning of April 2023 (Talum, 2022a). In figure 9 the trend between the years of 2018 and 2022 for all the individual aluminium products is visible (Talum, 2022a).

Figure 9 Structure of the physical volume of sales by individual aluminium products in percentage between year 2018 and 2022



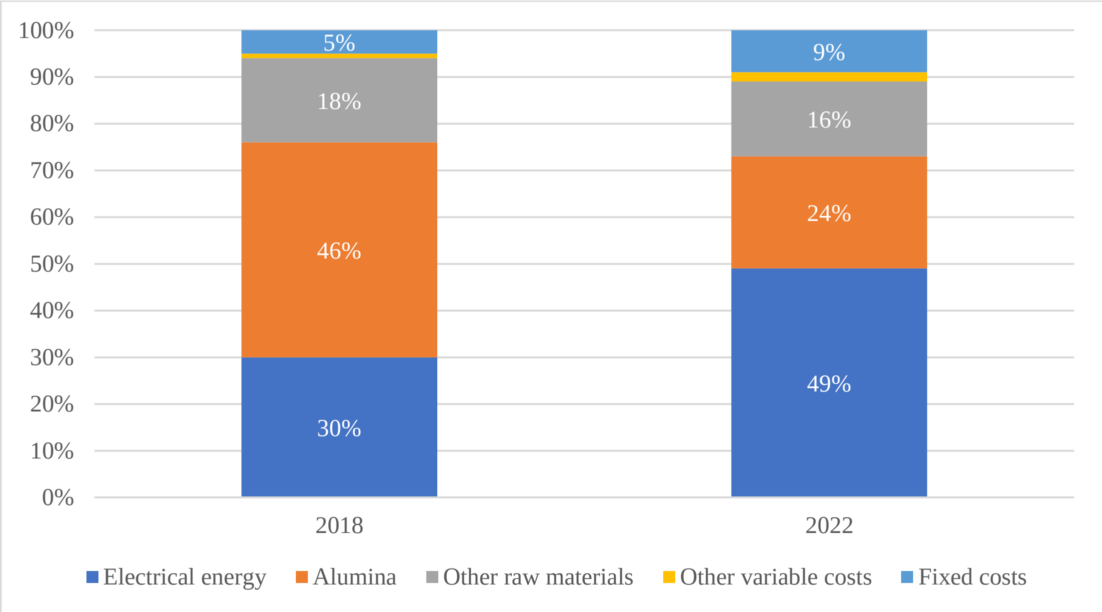
Source: own work

In figure 9 we can see that due to the decrease of electrolysis aluminium production, the percentage of physical volume sale of foundry alloys decreased from 30% to practically 0%. The physical volume of sale of individual products that increased the most are slugs and discs, increasing from 26% in 2018 to 43% in 2022.

In terms of specific electricity consumption per tonne of electrolytic aluminium, Talum was firmly in the top 10% of the most successful aluminium producers in the EU, with an average consumption of 13.90 MWh per tonne of electrolytic aluminium over the last years.

To understand the transition from primary aluminium production to the usage of secondary aluminium, the change of structure of the production cost of primary aluminium from 2018 to 2022 is presented in figure 10. The main driver of the change in cost structure was the significant increase in the price of electrical energy. Energy cost represented 30% of the structure in 2018 and in 2022 energy cost presented almost half the production cost of aluminium (Talum, 2022a).

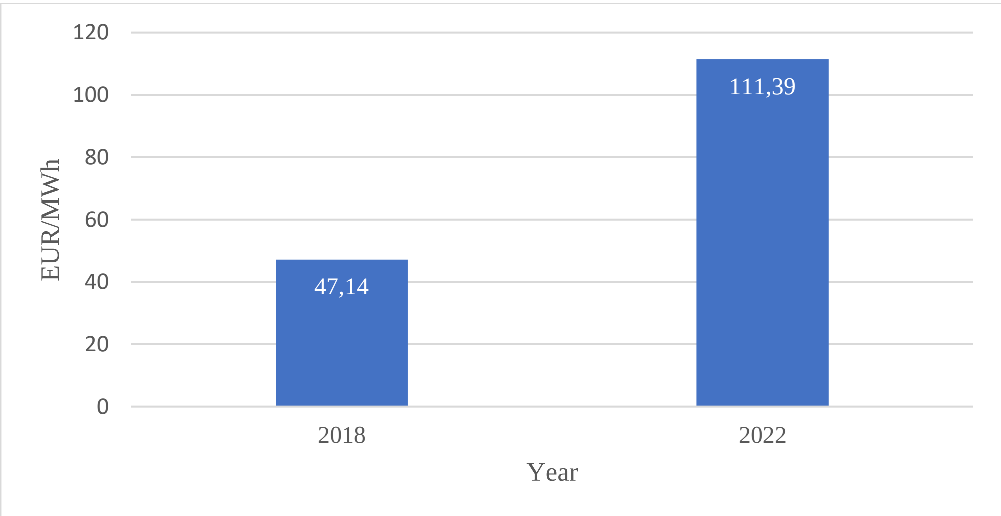
Figure 10 The structure of the production cost of electrolytic aluminium in percentage in year 2018 and year 2022



Source: own work

The reason for the percentile increase of electrical energy in the cost structure of the price for electrolytic aluminium production could be explained with the electricity price increase between years 2018 and 2022. In 2017, Talum purchased 1,401,600 MW of electrical energy for the period 2019-2021 at an average price of 47.14 EUR/MWh. In 2022, due to the decrease in electrolysis, the amount of electricity used was lower, but the average electricity price was much higher, at 111.39 EUR/MWh (Talum, 2022a). In figure 11 we can observe the difference in average electricity cost between the years of 2018 and 2022.

Figure 11 Average electricity price in year 2018 and 2022



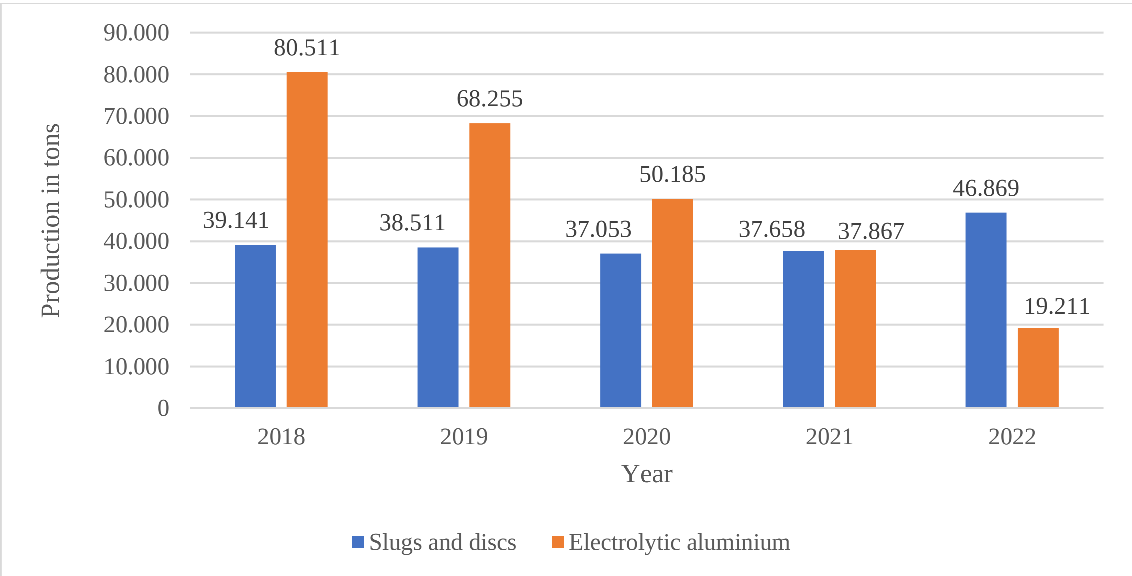
Source: own work

For Talum, reducing aluminium production and thus electricity consumption was a very big short-term adaptation challenge. The reduction in electrolytic aluminium production has led to an increased reliance on acquiring various types of aluminium, including primary and scrap. Consequently, the total volume of aluminium purchased in 2022 reached 69,277 tonnes, which consisted of 46,565 tonnes of primary external aluminium and 22,712 tonnes of scrap aluminium. This amounts to around 33% of purchased aluminium in 2022, consisting of mainly high-quality profiles and electrical materials (Talum, 2022a).

With the focus on the business unit Slugs and discs, the evident advantages of secondary aluminium will be presented. Customers for slugs and discs include manufacturers of aluminium packaging for the pharmaceutical, food and cosmetic industries, as well as producers of premium aluminium pans and pots for household use.

In the structure of created production of aluminium products in 2018, slugs and disc represented only 26%, 39.141 tonnes out of 150.123 tonnes of all the products produced. In 2022 slugs and discs represent 43% of the aluminium products created in Talum, 46.869 tonnes, out of 108.204 tonnes. Their market share in Europe exceeds 22% and it surpasses 50% in the field of slugs and discs for pans and pots. This makes Talum the largest slugs and discs manufacturer in Europe since 2017. The plan for production in the next years is to increase the volume of the slugs and disc, so the trend of increasing will continue. On the other hand, the amount of electrolysis aluminium in 2022 (19.211 tonnes) was only 24% compared to the amount in 2018 (80.511 tonnes) (Talum, 2022a). In the figure 12 below, the trend of the slugs and disc quantity increase and electrolytic aluminium decrease is presented.

Figure 12 Quantity of electrolytic aluminium and slugs and discs between year 2018 and year 2022



Source: own work

In 2022, Talum faced a strong and consistent demand for slugs and discs. Similarly, there was a demand for the so-called PCR slugs and discs, where Talum achieved growth. In 2022, PCR coils accounted for more than 20% of the share of slugs and discs sold, forming the foundation for future growth of slugs and discs sales. Due to the diversification of their portfolio across various industries, the essential roles of these industries in providing essential goods, such as pharmaceutical, cosmetic and food packaging and due to the additional dispersion of sales across different markets, the volume of sales of slugs and discs is expected to grow in the future (Talum, 2022a).

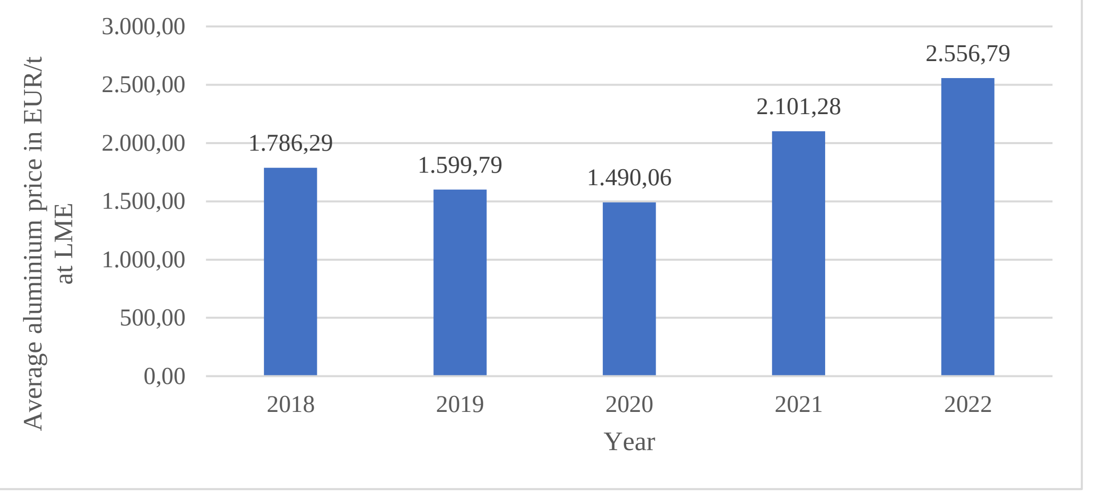
The next essential note is the price of aluminium. Average aluminium price in EUR/t at LME (London Market Exchange) in 2022 was 2.556,79 EUR/t, while average aluminium price in 2018 was lower, at 1.786,29 EUR/t according to LME (Talum, 2022a).

The fluctuations in aluminium prices between 2018 and 2022 can be attributed to various factors, including trade tariffs, geopolitical tensions, economic conditions, environmental regulations, supply chain disruptions, currency fluctuations, demand from key industries and investor sentiment. In 2018, the average aluminium price on the LME was 1.786,29 EUR/t, influenced by trade tariffs imposed by the Trump administration, particularly targeting aluminium imports from major producers like China, which created uncertainty and price volatility. In the following year, the average price dropped to €1.599,79 EUR/t due to ongoing trade tensions between China and the US, which led to global economic slowdown concerns. Additionally, stricter environmental regulations and lower demand from key industries like automotive and construction contributed to the decrease in prices. In 2020, the average aluminium price further decreased to 1.490,06 EUR/t. This decline was primarily driven by the COVID-19 pandemic, which caused widespread disruptions in production and supply chains. Lockdown measures and economic slowdowns around the world led to reduced demand for aluminium, which led to the price drop (Talum, 2022a).

However, in 2021, the average aluminium price rebounded to 2.101,28 EUR/t, driven by post-pandemic economic recovery efforts, particularly in industries like construction and automotive industry. Additionally, supply chain disruptions and higher production costs due to environmental regulations contributed to the rise in prices. The year 2022 witnessed further price increases, with the average aluminium price reaching €2,556.79 per tonne. This uptrend was driven by several factors, including geopolitical tensions such as the conflict between Russia and Ukraine, which led to concerns about supply disruptions. Additionally, inflationary pressures, tightening monetary policies and fears of a global recession contributed to higher prices. (Talum, 2022a)

Overall, these fluctuations reflect the dynamic nature of the global aluminium market, influenced by a complex interplay of factors affecting both short-term volatility and long-term trends. The trend of average aluminium price in EUR/t is visible in figure 13 below.

Figure 13 Average aluminium price in EUR/t at LME between year 2018 and year 2022



Source: own work

7.2 Focus group analysis

To complement the case study approach, a focus group conversation was conducted with key representatives from Talum. As Yin (2003) suggests, the use of multiple sources of evidence is essential in case study research to enhance validity, and focus groups serve as a valuable qualitative tool within this framework. In total five respondents participated in the focus group, which was held in person and moderated by me to ensure a productive and insightful discussion. In the beginning the purpose of the session and the structure of the conversation was introduced. 13 pre-determined open-ended questions served as a starting point of the conversation with the experts in the area of aluminium production, slugs and discs, financial and environmental topics. The questions were developed to support the answers to the research questions of this master's thesis and are presented in an Annex.

The participants of the focus group were 5 individuals: Director of BU Slugs and Discs, Head of Sales of BU Slugs and Discs, Director of BU Aluminium, Purchasing Manager for Scrap Aluminum and Environmental Representative. The participants were selected for their extensive experience, which is in line with the research questions of my master's thesis, as well as their involvement in strategy development and decision-making processes concerning Talum's future business. With employment at Talum ranging from 10 to 30 years, they have held positions across various business units within the company, giving them diverse backgrounds and perspectives.

The focus group methodology contributed to collective input, discussion and interaction among participants, offering valuable insights and perspectives on the research topic. I facilitated the conversation to allow participants to freely share their experiences and perspectives. Active listening and follow-up questions were used to clarify and deepen responses. The interactions between the participants were the main advantage of the focus group methodology. Due to synthesizing respondent viewpoints, I managed to obtain comprehensive feedback. The focus group conversation lasted for one hour. During the focus group conversation, notes were taken, which were used to provide a framework to the data already collected from Talum reports and to answer the research questions. The interview was held in Slovene. After the focus group conversation, answers were translated into English.

Questions were split into two sections. The purpose of the first section was to provide a framework for the information about Talum's sustainability goals, which was already obtained from Talum Group's Sustainable Development Report and Talum Sustainability Policy. Additionally, we delved into discussing financial and environmental performance in the first section of the conversation. In the second section responders were asked about the challenges, risks and opportunities in the regular production of primary aluminium, compared to the production and usage of secondary aluminium. The goal was to relate the answers to the research questions and to the information that was presented in the theoretical part of the master's thesis.

For the focus group 13 pre-determined open-ended questions served as a starting point of the conversation. From the answers, it was possible to identify 15 categories and 6 themes. In the first section of the conversation, which focused on obtaining answers that would help address the first research question, the information obtained related to the sustainable practices at Talum. Additionally, financial and environmental performance metrics used at Talum were discussed. The answers from the first section correspond to themes from 1 to 3. In the second section of the focus group conversation, which served as a basis for providing insights to answer the second research question, respondents addressed the challenges, opportunities and risks associated with regular production of primary aluminium compared to the production of secondary aluminium, corresponding to the themes from 4 to 6. Identified themes and categories are presented in the figure 14 below.

Figure 14 Themes and Categories

Research Question	Theme	Category
1	**1 Sustainable practices**	1.1 Timeline of shifting focus to secondary aluminium for Talum
		1.2 Secondary aluminium and aluminium scrap
		1.3 Sustainable packaging
	2 Financial metrics	2.1 Cost of investments
		2.2 Cost savings
		2.3 Revenue growth
	3 Environmental metrics	3.1 Carbon footprint
		3.2 "Green" slugs
2	**4 Challenges**	4.1 Procurement and supply chain challenges
		4.2 Logistics and distance from sorting centres
		4.3 Investment and restructuring
	5 Opportunities	5.1 Increasing demand for sustainable packaging
		5.2 Innovation and additional value creation
	6 Risks	6.1 Risks of primary aluminium production
		6.2 Risks of secondary aluminium production

Source: own work

7.2.1 Sustainable practices at Talum

At the outset of the conversation, the focus was on discussing the implementation of the circular economy concept in Talum, which is connected to the first research question. This included an overview of the factors that led to the decision to transition from primary to secondary aluminium. Additionally, we explored which of Talum's products are most suitable for the use of recycled aluminium. Furthermore, we discussed Talum's recycling approaches. Finally, we addressed market expectations regarding the transition from primary to secondary aluminium.

In the beginning, respondent 5 explained that Talum has implemented recycling principles by increasing the use of secondary aluminium, establishing new production processes and modernizing existing technological units to reduce the carbon footprint as part of the transition from primary to secondary aluminium production.

Additionally, respondent 5 mentioned that Talum is following certain directives and initiatives as part of sustainable practices, including:

Corporate Sustainability Reporting Directive (CSRD), European Union directive that aims to enhance the transparency and consistency of sustainability reports by companies. Talum's adherence to the CSRD demonstrates their commitment to standardized sustainability reporting, providing transparent and comprehensive information on their environmental, social and governance (ESG) performance.

The Corporate Sustainability Due Diligence Directive (CSDDD), European Union initiative which aims to establish rules for companies to identify, prevent, mitigate and account for adverse environmental and human rights impacts in their operations and value chains. With integration of CSDDD principles Talum is monitoring and mitigating risks related to sourcing raw materials and ensuring accountability across the whole supply chain.

Aluminium Stewardship Initiative (ASI), which is a global, multi-stakeholder initiative aimed at defining and promoting responsible production, sourcing and stewardship of aluminium. By engaging in ASI, they align with the best international practices in aluminium production, meeting globally recognized sustainability standards, through recycling aluminium scrap, reducing carbon emission and optimizing resource use.

Respondent 3 noted that Talum operated as a primary aluminium producer until 2023, when the electrolysis shutdown occurred. He highlights that recycling in the aluminium industry began in the 1970s and 1980s, initially relying on stable rotary furnaces that caused ecological issues. To address this, technology for environmentally friendly waste management was developed, leading to the transition to recycled aluminium.

Additionally, respondent 3 explain that recycling gained momentum with the availability of cheap natural gas, mainly from Russia, leading to the development of technologies for melting scrap aluminium in gas furnaces. Talum entered this field at the end of the last century, recognizing the challenges in maintaining profitability with their primary aluminium-focused business model. Initial experiments with secondary aluminium began in 1998, particularly in ingots and foundry alloys. In subsequent years, Talum equipped itself with appropriate technology, establishing a processing area. A significant portion of the sales portfolio, especially in ingots and foundry alloys, relied on scrap aluminium. However, technological waste in this process can amount to up to 20%. Today, logistic costs pose a significant challenge, favouring local processors and confining processing activities to local circles.

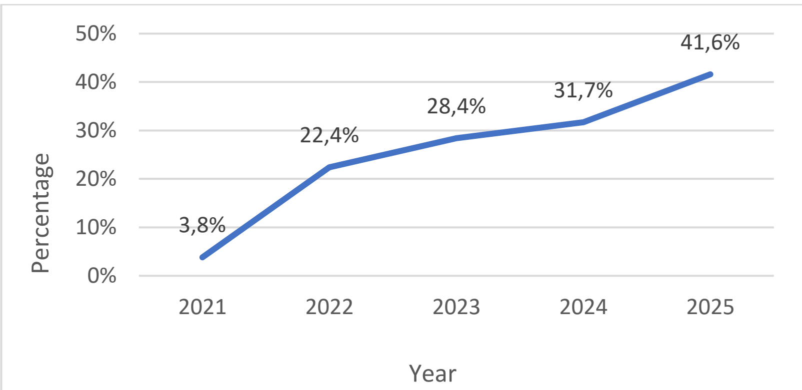
Respondent 1, focusing on BU Slugs and discs, explained that Talum began sourcing scrap aluminium from customers twenty years ago. Today, Talum's main strategies include sustainability, carbon footprint reduction and increasing the share of scrap aluminium in its products. Respondent 1 elaborated on two aspects of secondary aluminium usage.

The first aspect involves scrap aluminium purchased from the market, where the first experiments of including scrap aluminium to the production of slugs and discs started in 2005.

The second aspect involves scrap aluminium acquired from customers who transform slugs into tubes and containers. Between 2005 and 2023, the percentage of scrap aluminium purchased from customers was approximately 25%, but it has since decreased to around 15% due to discontinued products, with a goal to increase it back to 25%. Respondent 1 mentioned that the scrap generated during the production of tubes and containers from slugs accounts for approximately 15-20%.

Additionally respondent 1 explained that Talum started using scrap aluminium in 1998 and has accumulated significant expertise by 2021. Respondent 1 noted that the increased use of scrap aluminium for slugs and discs started in 2021, leading to an increased share of slugs and discs made from scrap aluminium (scrap aluminium in the product ranging from 50% to 100%). The plan for 2024 aims to increase this share to 31.7% and for 2025, to 41.6%. With investments in this area, the goal is to reach 50% of slugs and discs made from scrap aluminium by 2030. The increase and forecast of the increase in percentage of slugs and discs made mostly from scrap aluminium is presented in the figure 15 below.

Figure 15 Percentage of slugs and discs made mostly from scrap aluminium



Source: own work

Respondent 2 highlights that the key focus connected to slugs and discs today revolves around the percentage of recycled material and carbon footprint. According to respondent 2, there is significant pressure from customers, driven by multinational corporation's demands for sustainable packaging practices, which extend to products from Talum, such as tubes and containers. This pressure is felt across the entire supply chain, with increasing standards spreading from Europe to other continents. As a result, manufacturers of raw materials and products, including slugs and discs producers, are expected to adhere to sustainable packaging strategies. Respondent 2 concludes that the goal of achieving 50% of slugs and discs made from scrap aluminium by 2030 is both realistic and achievable.

To structure the responses from the first section of the focus group conversation, which focused on sustainability practices, and connect them to the theoretical findings, the answers were categorized accordingly. In figure 16 below, three categories connected to the answers from the respondents on the topic of sustainable practices were presented.

Figure 16 Sustainable practices at Talum

Research Question	Theme	Category
1	**1 Sustainable practices**	1.1 Timeline of shifting focus to secondary aluminium for Talum
		1.2 Secondary aluminium and aluminium scrap
		1.3 Sustainable packaging

Source: Own work

7.2.1.1 Timeline of shifting focus to secondary aluminium for Talum

Based on the responses related to this category, it can be summarized that Talum historically focused on primary aluminium production until 2023, when the electrolysis shutdown occurred. Recycling in the aluminium production industry started in the 1970s and 1980s, but Talum began engaging in recycling towards the end of the last century, when they established processing areas and increased the use of scrap aluminium. This goes in line with Wallace (2011), who states that from the start of commercial production, aluminium has been subjected to recycling, initially driven by both commercial and environmental motives.

At Talum, they were aware that their initial business model, mainly focused on primary aluminium production, would be challenging to keep profitable. This goes in line with Govidan and Hasanagic (2018), who states that for our economy to become more sustainable, transition to a circular economy is necessary, due to the current macro-economic, regulatory and ecological trends, which are enhancing the attractiveness of more resource efficient business practices to remain competitive.

By starting the implementation of recycling principles, Talum has increased the use of secondary aluminium, established new production processes and modernized existing technological units. Currently, Talum is adhered to sustainability directives such as the

Corporate Sustainability Reporting Directive (CSRD), Corporate Sustainability Due Diligence Directive (CSDDD) and Aluminium Stewardship Initiative (ASI).

7.2.1.2 Secondary aluminium and aluminium scrap

Analysing the responses associated with this category, we can outline Talum's history with secondary aluminium. They started integrating secondary aluminium in their production processes and sourcing it from their customers around twenty years ago. This aligns with the findings of De Angelis et al. (2018), who state that with consideration of environmental management and product lifecycle issues, companies and organizations started to adopt a closed-loop supply chain approach. This aspect of Talum's incorporation of secondary aluminium aligns with the closed-loop supply chain model, where the company collaborates with suppliers, including its customers, to utilize scrap aluminium and minimize environmental impacts. This strategy is consistent with the recommendation by Niero & Olsen (2016) to maintain the quality of recycled materials by establishing closed-loop material flows whenever feasible. Talum is actively working to enhance its utilization of secondary aluminium through the implementation of new production processes and the modernization of technological units, all while maintaining adherence to sustainability directives.

7.2.1.3 Sustainable packaging

The focus in the sustainable packaging category is centred on BU Slugs and discs, which are widely used in packaging applications like beverage cans, tubes and closures. These products are particularly suitable for utilizing scrap aluminium and directly tied to the concept of sustainable packaging. The pressure from customers, particularly multinational corporations worldwide, to use scrap aluminium in products like cans, tubes and closures was highlighted by the respondents. Next to buying scrap aluminium back from their customers, Talum is also buying scrap from the market, which is considered as open-loop recycling. This is typically more common for metals, including aluminium according to Paraskevas et al. (2015). This is because aluminium scrap comes from diverse sources with varying alloy compositions and contamination levels, which makes open-loop recycling more flexible and widespread. It was concluded that the goal of reaching 50% usage of scrap aluminium in slugs and discs by 2030 is realistic. This highlights the importance of Talum's efforts in sustainable packaging, aligning with global trends towards environmental responsibility and resource efficiency.

7.2.2 Financial metrics

Further focus group questions shifted the focus of the conversation to the performance assessments that Talum uses to evaluate its financial performance in transitioning from primary to secondary aluminium, which is connected to the first research question. This included discussing the effects of this transition on Talum's financial metrics in both short-term and long-term.

Respondent 1 highlighted Talum's dominance in the packaging industry, selling over half of Europe's green slugs and possessing significant expertise and equipment acquired over the last 25 years. Unlike some competitors, Talum skips the melting phase by using scrap aluminium from customers producing tubes and doses instead of ingots, giving it a production cost advantage. This advantage and expertise drive Talum's increasing production in the slugs and discs area.

An interesting fact was exposed by respondent 1, that certain products with aluminium packaging already indicate the percentage of recycled aluminium on the packaging of certain products, reflecting growing demand for this information and characteristics of the packaging from both corporations and B2C customers.

Respondent 3 explained that in these business models, using different materials than competitors is not feasible. Therefore, the company must reorganize its production to stay profitable. In the primary aluminium sector, the company prioritizes suppliers with the lowest carbon footprint, which is a crucial environmental metric.

Respondent 3 added that Talum could only maintain the previous level of business volume by establishing recycling and using recycled aluminium for their products. If they had not adapted and persisted with the initial business model, focused mainly on primary aluminium, maintaining the same volume of business would not have been possible. Talum needs to maintain this volume for continued operations, fully utilizing its infrastructure and production capacities.

Regarding the financial impact of the shift from primary to secondary aluminium usage, respondent 1 explained that the primary financial measure for slugs and discs is Talum's ability to achieve higher selling premiums for green slugs. Talum has an advantage over its competitors, as it sources aluminium scrap directly from its customers, such as scrap material generated during the production of tubes and doses in the case of slugs and discs. Consequently, PCR slugs and disc have a 15% higher selling premium per ton, compared to slugs discs produced from primary aluminium.

Respondent 1 explained that in the end slugs made from recycled aluminium can generate a 3-5% higher profit margin compared to those made from primary aluminium. However, this higher profit margin for PCR slugs and discs assumes that the price of recycled aluminium is not more expensive than primary aluminium.

Respondent 2 emphasized that the 3-5% profit margin on recycled slugs is crucial for enabling Talum to make further investments and highlights the importance of fully utilizing production capacity to maximize profitability. However, it was emphasized that the transition from primary to secondary aluminium usage affects cost structures, pricing strategies and margins, but quantifying the exact financial impact can be very complex.

Respondent 4 stated that, under current conditions at Talum, selling slugs made from recycled materials is yielding improved financial returns. The price of PCR waste products means that larger companies are compelled to purchase recycled aluminium at a higher price than primary aluminium due to their commitment to manufacturing products from recycled materials. In this scenario, it's not just about the financial impact, it's also about adhering to the company's strategy, contracts and expanding the sales program. Competitive advantages of PCR slugs and discs are presented in figure 17 below.

Figure 17 Competitive advantages of PCR slugs and discs

Aspect	Details
Competitive advantage	Direct sourcing of aluminium scrap from customers (scrap from tube and can production).
Selling Premium (PCR)	PCR slugs and discs have a **15% higher selling premium** compared to those made from primary aluminium.
Profit margin (PCR)	PCR slugs generate a **3-5% higher profit margin** compared to primary aluminium slugs.
Key assumption for PCR profit	Price of recycled aluminium must not exceed that of primary aluminium.

Source: own work

To organize the answers from the respondents connected to financial metrics, their answers were categorized into three categories, as visible in the figure 18 below.

Figure 18 Financial metrics

Research Question	Theme	Category
1	**2 Financial metrics**	2.1 Cost of investments
		2.2 Cost savings
		2.3 Revenue growth

Source: own work

7.2.2.1 Cost of investments

The transition to secondary aluminium production requires significant investments in technology, infrastructure and process optimization. In case of slugs and discs production, Talum has built expertise over the past 25 years. Using scrap aluminium from customers to produce tubes and doses instead of ingots, allows them to skip a melting phase that would be needed in case of acquiring recycled aluminium from the market. This results in reduced costs and provides a competitive advantage. However, recycling aluminium for the production of other products also demands adjustments, such as investments in melting technology, scrap sorting and process automation.

One of the main financial benefits of these investments is the ability to generate higher profit margins. In case of Talum, 3-5% profit margin from the PCR slugs and disc, enables them to make further investments. However, it can be challenging to measure performance results of one specific entity among multiple vendors, manufacturers, distributors and retailers that are spread globally over the whole supply chain, according to Hervani et al. (2005). This aligns with the focus group findings, that measuring the financial impact of the transition from primary to secondary aluminium usage can be challenging.

7.2.2.2 Cost savings

The transition to secondary aluminium production has provided Talum with certain cost saving opportunities, particularly through process optimization, energy efficiency and reduced raw material costs. One of Talum’s key advantages is its ability to skip a melting phase by using scrap aluminium directly from customers, eliminating the need to purchase ingots produced from recycled aluminium.

Energy savings play a crucial role in cost reduction. Producing aluminium from scrap requires up to 95% less energy compared to primary aluminium production, significantly lowering electricity costs, which was a key factor in Talum’s decision to shift away from electrolysis. With electricity prices fluctuating in recent years, reducing reliance on energy intensive processes was crucial for Talum.

Furthermore, optimizing logistics and supply chain management contributes to additional cost savings. As the overall stock of aluminium grows faster than secondary aluminium production (Blomberg & Söderholm, 2009), the availability of aluminium scrap increases, indicating that recovery and recycling expenses will decrease over time. As the stock grows, refiners will find it easier to acquire scrap of higher quality at a lower production cost. As mentioned by the respondents during the conversation, profitability of using recycled aluminium depends on maintaining a cost advantage over primary aluminium, ensuring that the cost of purchased scrap remains lower than that of primary aluminium.

7.2.2.3 Revenue growth

The shift to secondary aluminium has positioned Talum to meet the growing market demand for sustainable products, particularly among multinational corporations with strict sustainability commitments. By offering PCR slugs and discs, Talum attracts large buyers in the packaging industry that require a certain percentage of recycled material in their products. This transition not only aligns with global environmental responsibility trends but also expands Talum’s product portfolio and strengthens their market presence, thereby unlocking new revenue streams.

The increasing demand for PCR slugs and discs presents an opportunity for revenue growth. Talum's ability to charge 15% higher selling premiums for PCR slugs and discs compared to primary aluminium-based products, coupled with the additional 3-5% higher profit margins associated with PCR materials further contribute to long-term benefits of transitioning to secondary aluminium.

However, the price of PCR slugs and discs comes with the added dynamic that large players on the market are often forced to purchase recycled aluminium at a higher price than primary aluminium. In this case, shift from primary to secondary aluminium usage is not solely based on the financial impact but also on expanding product portfolios and meeting customer commitments to include a certain percentage of recycled material in the products.

According to Sarfraz et al. (2023), the advantages of transitioning to a circular economy are only realized by companies in the long run. Therefore, it is crucial for Talum’s strategy to not only address social and environmental risks but also properly consider their financial impact to maximize the synergies of implementing a circular economy.

7.2.3 Environmental metrics

To organize the answers from the respondents connected to environmental metrics, their answers were categorized into two groups, as visible in figure 19 below.

Figure 19 Environmental metrics

Research Question	Theme	Category
1	**3 Environmental metrics**	3.1 Carbon footprint
		3.2 "Green" slugs

Source: Own work

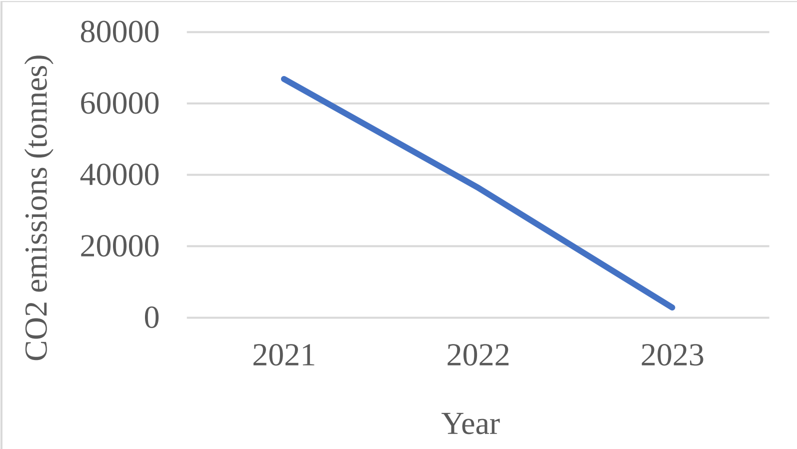
7.2.3.1 Carbon footprint

Respondent 5 explained that in 2023, Talum achieved a significant reduction in CO2 emissions due to the temporary suspension of primary aluminium production in April 2023. Direct greenhouse gas emissions from primary production decreased from 66,877 tonnes of CO2 emissions in 2021 to 36,455 tonnes of CO2 emissions in 2022 and further to 2,862 tonnes of CO2 emissions in 2023, representing a 92.1% decrease compared to the previous year. This reduction highlights Talum's shift towards secondary aluminium production, which is less energy-intensive and generates significantly lower emissions.

Since today environmental sustainability is a crucial factor in decision-making, especially in the aluminium industry, by prioritizing recycled aluminium over primary aluminium, Talum is aiming to significantly reduce its carbon footprint. This transition aligns with Talum’s efforts to mitigate climate change and reduce its environmental impact.

In figure 20 below, the decrease of CO2 emissions from primary aluminium production is presented.

Figure 20 CO2 emissions (tonnes) generated in primary aluminium production



Source: own work

7.2.3.2 "Green" slugs

Talum has positioned itself as a leading force in the packaging industry, particularly dealing with green slugs, which are mainly produced from the recycled aluminium. Talum sells over half of Europe's green slugs. This focus on green slugs not only drives revenue growth but also enhances Talum's reputation as an environmentally responsible company. According to Linton et al. (2007), several studies have found that prioritizing sustainability in the supply chain is related to lower costs and can have a neutral or positive effect on overall value. This is in line with findings by Larsen et al. (2018), who argues that reverse supply chain activities, which manufacturers have traditionally considered an expensive inconvenience, can strengthen financial performance in two ways, either by increasing revenue or reducing costs. Therefore, Talum's emphasis on green slugs not only aligns with its commitment to sustainability but also reflects a strategic approach that can lead to financial benefits in the long run.

In conclusion, Talum's investment in transitioning to recycled aluminium presents financial potential across various dimensions, but the implementation of sustainable practices in secondary aluminium production is not without its challenges and risks. To gain an understanding of this transition, it is essential to explore the obstacles the company faces, the opportunities that arise from these efforts and the risks involved.

7.2.4 Challenges of implementing sustainable practices in secondary aluminium production

In the second part of the focus group conversation, we discussed the challenges, opportunities and risks associated with implementing sustainable practices in secondary aluminium production, which is connected to the second research question.

Firstly, the focus of the conversation was on challenges. Respondent 2 explained that numerous challenges arise in the PCR sector, particularly in setting up expectations, standardization and legislation. These challenges significantly affect procurement of raw materials, especially considering the potential penalties that European importers may face for imported materials with a large carbon footprint.

Respondent 3 added that this additional cost will likely fall on the buyer. Favouring local manufacturers, if they have the capacity for recycled aluminium production, is more desirable and efficient. Furthermore, due to new standards and customer expectations in the packaging and automotive industries, there is a struggle for companies to obtain the desired amount of scrap aluminium. Not all current processing capacities for scrap aluminium can meet the market demand. While market expectations treat scrap aluminium as equivalent to primary aluminium, specifications and legislation do not allow for this, leading to regulatory challenges in this regard.

Respondent 1 noted that in the recycled aluminium industry, the primary challenge often arises not from the production processes, but from a persistent shortage of raw materials, a situation that has prevailed for the past two decades.

Respondent 3 noted that companies in the aluminium processing industry in Slovenia are facing a shortage of raw materials due to the absence of major players. The circular economy does not favour small companies like Talum, especially those not close to large processing centres. Respondent 4 highlighted several key challenges in the supply of scrap aluminium in Europe, as summarized in the following figure 21.

Figure 21 Challenges in the supply of scrap aluminium in Europe

Challenge	Description
Shortage of quality sorted materials	Quality sorted materials are increasingly scarce, especially after the COVID-19 outbreak.
Mixed waste purification	Purification methods include manual cleaning (hampered by high labour costs) and technological solutions.
Remaining undesired material	The separation process leaves behind material with no further use, posing disposal challenges.
Transition to recycling	Europe is moving towards recycling scrap aluminium due to the high cost of primary aluminium production.

Source: own work

Respondent 4 elaborated on the actions of major players in the industry. These companies are making significant investments in sorting centres across Europe with the aim of efficiently processing waste material into new products. By doing so, they are not only addressing environmental concerns but also capitalizing on the growing demand for recycled materials.

This expansion by larger companies poses significant challenges for smaller players like Talum. Due to financial constraints, smaller companies often find it difficult to afford the expensive sorting equipment necessary for efficient recycling processes. Consequently, they struggle to compete with larger competitors in terms of production efficiency and cost-effectiveness.

In this section, participants discussed the challenges, opportunities and risks in the regular production of primary aluminium compared to secondary aluminium production, which is linked to themes from 4 to 6. To organize the answers from the respondents connected to challenges in secondary aluminium production, their answers were categorized into three categories, as visible in figure 22 below.

Figure 22 Challenges in secondary aluminium production

Research Question	Theme	Category
2	**4 Challenges**	4.1 Procurement and supply chain challenges
		4.2 Logistics and distance from sorting centres
		4.3 Investment and restructuring

Source: own work

7.2.4.1 Procurement and supply chain challenges

This category discusses various challenges related to procurement and the supply chain at Talum, stemming from the establishment of expectations, standardization and legislation in the PCR sector. Importers in Europe face potential penalties for materials with a large carbon footprint, consequently favouring local manufacturers like Talum. However, not all companies have the capacity for recycled aluminium production, leading to struggles in meeting demand and potentially passing additional costs on to customers. This shortage of capacity is worsened by the onset of the coronavirus outbreak, which has further constrained the availability of quality sorted materials. These challenges are in line with research by Luthin et al. (2021), who note the absence of a standard process for aluminium recycling due to the variety of scrap compositions requiring different recycling methods and furnace technologies. Consequently, secondary aluminium production is much more challenging to track than primary production. Additionally, the challenges of purifying mixed waste, labour shortages and the high costs of sorting equipment further compound procurement difficulties.

7.2.4.2 Logistics and distance from sorting centres

This category discusses the logistical challenge posed by the distance from sorting centres, especially for companies like Talum, situated far from the main sorting centres in Europe. This distance affects the collection of end-of-life packaging for recycling, impacting traceability and recycling efforts. This goes in line with Jarrín et al. (2021), who highlight that while aluminium exhibits high rates of collection for recycling, material that is not segregated and enters subsequent waste treatment processes significantly decreases the probability of recovery, leading to a decline in material quality. This goes in line with one of the main challenges at Talum, since in the field of recycled aluminium, the problem often does not lie in the production processes, but in the shortage of quality sorted materials.

7.2.4.3 Investment and restructuring

Investments and restructuring are necessary for transitioning to sustainable practices. Talum is restructuring to use recycled aluminium and focusing on products with higher added value. However, significant investments are required, posing challenges in the short term. Smaller companies like Talum struggle to afford expensive sorting equipment, limiting their ability to compete with larger companies with extensive recycling collection centres. Market expectations consider scrap aluminium equivalent to primary aluminium, but regulations do not allow for this equivalence, creating regulatory challenges. Additionally, larger companies with significant resources are building sorting centres across Europe, making it challenging for smaller companies like Talum to compete.

7.2.5 Opportunities for implementing sustainable practices in secondary aluminium production

Secondly, the focus of the conversation was on finding opportunities in implementation of sustainable practices in secondary aluminium production. It was discussed by the respondents that smaller companies like Talum may need to adopt alternative strategies, in order to survive in the long-term. This could involve a combination of approaches, including leveraging internal recycled materials and procuring waste materials from external sources. This adaptive approach allows smaller companies to seize the opportunities and remain competitive while navigating the challenges posed by the evolving landscape of the aluminium industry.

Respondent 1 agreed that the challenges do not lie only in sourcing materials but also in traceability after the product's end-of-life. However, recycling requires adjustments and significant investments, leading to company restructuring. While short-term investments are high, they are necessary for the company's long-term sustainability.

Respondent 3 added that Talum is undergoing restructuring not only by transitioning from primary aluminium to recycled aluminium but also by focusing on higher-value-added products, such as slugs and discs. Recycling has facilitated an increase in the volume of slug production and market share. Talum had a competitive advantage over competitors due to established melting capacities for recycling, despite requiring significant investments. However, competing with larger companies on the market with extensive recycling collection centres remains a challenge. Respondent 4 added that establishing a local sorting centre in the region could bring significant advantages to Talum.

Respondent 5 added that establishing traceability of aluminium product waste can be challenging, but one option is to set up the business in a way that customers are contractually obligated to return products at the end of their lifecycle. However, this method is only suitable for certain types of products. Opportunities in the supply of scrap aluminium are presented in figure 23 below.

Figure 23 Opportunities in the supply of scrap aluminium

Opportunity	Description
Leveraging internal recycled materials	Allows for cost savings and reduces dependency on external suppliers.
Procuring scrap from external sources	Helps ensure a steady supply of raw materials for production, despite market fluctuations.
Establishing local sorting centres in the region	To improve the efficiency of scrap processing, reduce transportation costs and enhance material quality.
Enhancing traceability of recycled materials	To facilitate closed-loop recycling, ensuring that end-of-life products are returned for reuse.

Source: own work

Based on respondents answers, the opportunities in secondary aluminium production that Talum could leverage were categorized into two categories, as shown in figure 24 below.

Figure 24 Opportunities in the secondary aluminium production

Research Question	Theme	Category
2	**5 Opportunities**	5.1 Increasing demand for sustainable packaging
		5.2 Innovation and additional value creation

Source: own work

7.2.5.1 Increasing demand for sustainable packaging

The growing demand for sustainable packaging presents a significant opportunity for Talum to expand production and increase market share. Respondents emphasized that food, beverage and automotive industries are seeking low carbon packaging materials, aligning with Talum's shift towards recycled aluminium. By focusing on products like slugs and discs made from scrap aluminium, Talum can meet market expectations and achieve its goal of 50% scrap usage by 2030. In addition, partnerships with customers to improve traceability and end-of-life product returns could create closed-loop systems, further strengthening Talum's position in the market and contributing to long-term sustainability goals.

7.2.5.2 Innovation and additional value creation

There are opportunities for innovation and value addition in the production of sustainable aluminium. The circular economy does not favour small companies like Talum, which are not close to large processing centres. The economic efficiency of aluminium recycling heavily depends on the expenses incurred at various stages of the process, with transportation expenses being a significant factor. Logožar et al. (2006) note that approximately 25% of the energy required for secondary aluminium production is attributed to transportation and scrap preparation.

Hence, optimizing logistics and transport processes is crucial to ensure cost-effective recycling and lower environmental impact. Establishing local sorting centres could bring significant advantages to companies like Talum, enabling more efficient processing of recycled materials.

Finally, the risks that Talum has faced in the past and continues to face now in connection to increasing use of secondary aluminium were discussed.

7.2.6 Risks of implementing sustainable practices in secondary aluminium production

Respondent 4 discussed risk reduction when comparing the use of recycled aluminium versus primary aluminium. In primary aluminium production, risks include market prices, electricity prices, transportation costs and prices of other raw materials (alumina, coke, pitch). These risks remain when purchasing primary aluminium. This type of risk, determined by market prices and the current geopolitical situation, is largely beyond the company's control. However, with secondary aluminium, companies have more options and choices of procuring scrap material. It could be argued that the risk associated with using secondary aluminium is lower than that of using primary aluminium.

Respondent 5 highlighted that the risk associated with energy prices persists in the recycling of aluminium.

Respondent 3 added that the risk in recycling is more diversified, representing a overall risk compared to primary aluminium production or use. In primary aluminium production, there were more challenges over which the company had less control. Risks associated with recycled aluminium use are smaller, as the company now has more influence over the processes. Based on the answers from respondents, the risks were categorized into two categories, as shown in figure 25 below.

Figure 25 Risks of primary versus secondary aluminium production

Research Question	Theme	Category
2	**6 Risks**	6.1. Risks of primary aluminium production
		6.2. Risks of secondary aluminium production

Source: own work

7.2.6.1 Risks of primary aluminium production

In primary aluminium production the main risks arise from fluctuating market prices, electricity costs, transportation expenses and the prices of essential raw materials such as alumina, coke and pitch. These risks persist throughout the purchasing process of primary aluminium and are heavily influenced by market volatility and geopolitical factors that are largely beyond the control of the company. Such risks make it challenging for Talum to predict costs and manage long-term financial planning, as the price fluctuations and supply chain uncertainties are difficult to mitigate. Additionally, primary aluminium production is more exposed to global commodity markets, making it highly sensitive to external shocks.

7.2.6.2 Risks of secondary aluminium production

In secondary aluminium production, companies experience lower risk levels due to the increased flexibility and choice in sourcing scrap material at varying prices. Unlike primary production, secondary aluminium offers more control over procurement processes, allowing companies like Talum to adjust their raw material inputs according to availability and cost. This flexibility in sourcing helps mitigate some of the risks associated with price volatility and supply shortages. However, risks related to energy costs remain a concern in recycling processes. Despite this, the overall risk profile in secondary aluminium production is smaller and more manageable compared to primary aluminium, making it a more stable and sustainable option in the long term.

In conclusion of the focus group analysis, Talum faces challenges in procurement and supply chain mostly due to post-consumer recycling standards and logistical constraints. However, there are opportunities in the increasing demand for sustainable packaging and innovation. Transitioning to sustainability requires significant investment but offers market differentiation. While risks persist in primary aluminium production, secondary aluminium presents a more stable alternative. Talum's journey involves navigating weaknesses and threats while seizing strengths and opportunities in the transition to secondary aluminium production. This will be further detailed in the SWOT analysis below.

7.3 SWOT analysis

Based on the company’s annual reports and the focus group conversation at Talum, I was able to conduct a thorough SWOT analysis of the secondary aluminium production and use at Talum as presented in figure 26 below.

Below the figure 26 the identified strengths, weaknesses, opportunities and threats of secondary aluminium production and use at Talum are furtherly discussed.

Figure 26 SWOT analysis of the secondary aluminium production

Strengths	Weaknesses
1. **Established melting capacities**: Advantage in recycling and increasing production volume.	1. **Procurement challenges**: Difficulties in sourcing raw materials.
2. **Competitive edge in sustainable practices**: Meets growing demand, improves market position.	2. **High investment requirements**: Significant financial challenges for sorting equipment.
3. **Experience in transitioning**: Adaptability and focus on higher-value-added products.	3. **Regulatory and standardization issues**: Scrap aluminium not fully recognized.
Opportunities	**Threats**
1. **Increasing demand for sustainable packaging**: growth in producing recycled products.	1. **Competition from larger companies**: Advanced sorting equipment and efficiency.
2**. Innovation and value creation**: Potential in sustainable production and local sorting centres.	2. **Logistical constraints:** Distance from main sorting centres.
3. **Flexible supply chain**: More options and reduced risks in sourcing materials.	3. **Energy price volatility:** Impact on production costs.

Source: own work

One of key strength of Talum is its established melting capacities, which allow for efficient recycling and increased production volumes of secondary aluminium. This provides the company with a competitive advantage, as it can meet rising demand while minimizing reliance on primary aluminium. Additionally, Talum's competitive edge in sustainable practices further strengthens its market position, aligning with the growing trend of sustainability-driven consumer preferences. The company's experience in transitioning from primary to secondary aluminium has also been a crucial asset, as it demonstrates adaptability and an ability to focus on higher-value-added products like slugs and discs, which cater to the increasing demand for sustainable packaging solutions.

Talum also faces several significant weaknesses. Procurement challenges have been an issue, particularly difficulties in sourcing high-quality raw materials for recycling. This is compounded by the high investment requirements needed to implement advanced sorting technologies and modernization of processes, which poses financial pressure on the company. Additionally, regulatory and standardization issues remain a barrier, as scrap aluminium is not yet fully recognized under existing regulations, complicating efforts to integrate it into the circular economy framework.

Despite these challenges, there are also numerous opportunities available for Talum. The increasing demand for sustainable packaging provides a growth opportunity for the company to expand its recycled aluminium production, particularly in slugs and discs. Talum also has potential for innovation and value creation, especially through investments in local sorting centres and advancements in recycling technologies. Additionally, the flexibility of the supply chain in sourcing materials can reduce procurement risks and position Talum as a more agile player in the competitive aluminium market.

Talum faces significant competition from larger companies, which have more advanced sorting equipment and greater production efficiency. This presents a potential threat to Talum’s market share and ability to compete on cost. Logistical constraints, particularly the distance from main sorting centres in Europe, further worsen this issue, increasing both costs and inefficiency in the supply chain. Finally, energy price volatility remains a critical threat to production costs, especially as energy-intensive processes like aluminium production are vulnerable to price fluctuations in the energy market.

In conclusion, while Talum has demonstrated considerable strengths in its transition to a sustainable aluminium production model, it must address its weaknesses, while seizing the opportunities presented by growing demand for sustainable packaging and innovation. At the same time, Talum must mitigate the external threats posed by competition, logistics and energy volatility to ensure its continued success and long-term growth.

7.4 Discussion of the results in relation to the research questions

By employing a combination of a quantitative approach, which involved analysing company annual reports and through a focus group conversation at Talum, I was able to provide the answers to the research questions below.

Research Question 1: What is the financial impact of sustainable practices in secondary aluminium production measured using metrics such as investment costs, cost savings, revenue growth and risk reduction?

The financial impact of Talum's implementation of sustainable practices in secondary aluminium production is demonstrated by key metrics, including investment costs, cost savings, revenue growth and risk reduction.

Investment costs: Transitioning from primary to secondary aluminium production required substantial investments, particularly in new technologies and the adaptation of existing infrastructure. Despite challenges in the primary aluminium sector due to unfavourable energy market conditions, Talum's shift towards secondary aluminium, particularly in the slugs and discs segment, has been financially advantageous. Investments in recycling expertise and modernized equipment have allowed Talum to reach a 15% higher selling premium per tonne for PCR slugs and discs.

Cost savings: The transition to secondary aluminium production has provided significant cost-saving opportunities, particularly in process optimization, energy efficiency and raw material procurement. The use of recycled aluminium enables Talum to bypass the energy-intensive melting phase in the production of slugs and discs. Producing aluminium from scrap requires up to 95% less energy compared to primary aluminium production, significantly reducing electricity costs, which is a crucial factor given the volatility in energy markets. Talum's decision to stop the production of electrolytic aluminium was largely driven by these cost considerations.

Revenue growth: Despite challenges in primary aluminium production, Talum experienced strong demand for slugs and discs in 2022, with PCR slugs and discs accounting for more than 20% of sales in that area. PCR slugs and discs achieved a 3-5% higher profit margin, contributing to long-term financial benefits.

Risk reduction: The shift to secondary aluminium production has mitigated many of the financial risks associated with primary aluminium production, such as exposure to fluctuating market prices, electricity costs and raw material prices. By diversifying its material supply and adopting a more flexible production approach, Talum has significantly lowered its vulnerability to external market conditions. Secondary aluminium offers a more stable and less volatile production environment, providing Talum with greater control over costs and a buffer against market instability.

Talum's adoption of sustainable practices in secondary aluminium production has yielded certain financial benefits. By investing in the right technologies, reducing costs, driving revenue growth and mitigating risks, Talum could position itself for long-term success in the competitive market, while also maintaining a strong focus on environmental sustainability.

Research Question 2: What are the challenges and opportunities associated with implementing sustainable practices in secondary aluminium production?

The implementation of sustainable practices in secondary aluminium production presents both challenges and opportunities for Talum.

One of the main challenges is procurement and supply chain difficulties, since ecuring high-quality scrap aluminium remains a persistent challenge for Talum. Regulatory complexities in the PCR sector, compounded by the impact of the COVID-19 pandemic, have led to a shortage of quality sorted materials. Moreover, new environmental regulations, which impose penalties on materials with large carbon footprints, could create additional cost pressure for importers in Europe, potentially placing Talum at a disadvantage if local suppliers cannot meet their demand.

Logistical constraints are also challenging, sincethe distance from the main sorting centres poses significant logistical challenges for Talum, increasing transportation costs and impacting the quality of sorted materials. This logistical inefficiency not only complicates supply chain management but also affects the traceability and consistency of recycled materials, both of which are crucial to Talum's production processes.

Investment and restructuring is another challenge for Talum sincetransition to secondary aluminium production requires substantial capital investment, particularly for the acquisition of advanced sorting equipment. Given the company’s financial constraints, these investments are difficult to manage. Moreover, regulatory barriers and competition from larger, better capitalized companies further hinder Talum's ability to scale production and remain cost effective.On the other hand, there are opportunities in growing demand for sustainable packaging. There is a clear opportunity for Talum to capitalize on the rising demand for sustainable packaging, particularly in the slugs and discs segment. As global environmental awareness continues to grow, Talum is positioned well to expand its market share by offering high-quality recycled aluminium products that meet the needs of environmentally conscious consumers and businesses.

Establishing local sorting centres presents a significant opportunity for Talum to reduce both transportation costs and reliance on external suppliers for scrap aluminium. By investing in local infrastructure, Talum can enhance the quality of recycled materials, optimize logistics and secure a more reliable supply chain.

In conclusion, the challenges and opportunities associated with implementing sustainable practices in secondary aluminium production present a complex financial landscape for Talum to navigate. While challenges such as procurement and supply chain issues, logistics and investment constraints exist, there are also opportunities for growth and innovation. Talum's ability to conquer these challenges and seize opportunities will be crucial for its long-term financial success in the transition to sustainable practices.

7.5 Managerial implications for Talum

According to the findings from the theoretical research and the case study of the company the following managerial implications are proposed to support Talum's sustainability goals and enhance its competitive position on the market:

Investments in local sorting centers to enhance supply chain efficiency and material quantity: The distance from the main sorting centers in Europe poses logistical challenges and impacts the quality of sorted materials. Talum should consider investing in local sorting centers to improve the efficiency of its recycling operations. By establishing sorting centers closer to its production facilities, Talum can reduce both transportation costs and reliance on external providers for scrap aluminum of higher quality. This will also allow Talum to enhance the quality of the recycled aluminum used in its products, further supporting its sustainability goals and increasing production volumes in areas with high demand like slugs and discs.

Enhancement of procurement strategies through formation of stronger partnerships: Securing quality sorted materials has been a significant issue, so Talum should focus on strengthening its procurement strategies by building long-term partnerships with key suppliers and customers who can consistently provide high-quality scrap aluminum. This approach would not only improve the reliability of supply but also enable Talum to better manage the volatility in material availability. In addition, Talum should explore diverse sources for raw materials, including collaborations with other companies in the circular economy system, to mitigate the risk of shortages.

Increase of focus on high-value-added products: Transition to higher-value-added products like slugs and discs has shown financial benefits, so Talum should continue expanding its production of high-value-added products. This aligns with both market demand for sustainable packaging and Talum's commitment to reducing its carbon footprint. By investing in technology and process improvements to increase production capacity for these products, Talum can secure a competitive edge in the market while contributing to a circular economy.

Fostering innovation and continuous improvement to enhance competitive edge: Innovation in sustainable aluminium production can lead to value creation and operational efficiency, so Talum should invest in R&D to develop new technologies and processes that enhance the efficiency and quality of recycled aluminium production. This includes advancing techniques to reduce technological waste and addressing challenges like logistical constraints in the supply chain. Furthermore, fostering a culture of continuous improvement within the company will help identify cost-saving innovations and reduce environmental impacts.

Focus on strengthening financial planning and risk management to mitigate energy price volatility and ensure cost stability: Transitioning to secondary aluminium offers a more stable and less volatile production environment, but energy price volatility remains a risk, so Talum should enhance its financial planning and risk management strategies by implementing hedging mechanisms against energy price fluctuations. This could involve diversifying energy sources, such as exploring renewable energy options to reduce dependency on traditional energy markets. By leveraging renewable energy, Talum can further align with sustainability initiatives such as the Aluminium Stewardship Initiative (ASI), enhancing its market position as a leader in sustainable aluminum production.

Enhance sustainability reporting and transparency: Transparency in sustainability practices can improve brand reputation and meet customer expectations. Talum should continue to improve its sustainability reporting by clearly documenting its initiatives, progress and achievements in areas such as carbon footprint reduction and increased use of scrap aluminum. By doing so, Talum can build stakeholder trust, improve brand reputation and meet rising customer expectations for environmentally friendly products. This will also strengthen Talum’s market positioning as a key player in the circular economy, particularly in sectors like sustainable packaging.

7.6 Limitations of the study

The primary limitation of this master’s thesis is that it focuses on a single company, Talum, which may limit the applicability of the findings to the broader aluminum industry or other sectors. Furthermore, the data analysis is restricted to a relatively short timeframe, covering the period between 2018 and 2022, which may not fully capture the long-term impact of implementing sustainable practices or accurately predict future outcomes. Additionally, the study does not include a comparative analysis with other companies in the aluminum industry, which could have provided further insights and broader context. These limitations should be considered when interpreting the findings, as they may affect the generalizability of the conclusions.

Another limitation comes from the methodology used in the focus group discussions. Note-taking as the primary data collection method might have led to missing some details during discussions. Additionally, since the focus group conversation was conducted in Slovene and later translated into English for analysis, there is a risk of contextual misinterpretation or loss of meaning during translation. This language barrier could potentially affect the validity and reliability of the data. However, the efficiency and flexibility of taking notes allowed for immediate adaptation of insights during the session, making it advantageous in terms of time and accessibility. Future research could consider incorporating multiple case studies, longer observation periods and alternative data collection methods, such as recordings and transcriptions, to enhance the depth and accuracy of the findings.

To build on this master’s thesis, future research could include multiple companies across different regions to provide a broader industry perspective on sustainability and circular economy practices. Extending the analysis beyond 2022 would help capture long-term trends and assess the evolving financial impact of these initiatives. Additionally, qualitative methods, such as interviews with experts could offer deeper insights into managerial perspectives and decision-making processes. Incorporating advanced data analytics could further enhance predictive modelling, allowing for a more accurate evaluation of sustainability’s long-term financial effects.

8 CONCLUSION

The shift towards sustainable practices and circular economy principles has become a key priority in industries with high environmental footprints, such as aluminium production. Talum has undergone significant changes in its production strategies and market dynamics, particularly in response to challenges faced in the primary aluminium market. The company's transition from primary to secondary aluminium production, with a focus on products like slugs and discs, has proven to be beneficial in a rapidly evolving industry landscape.

From 2018 to 2022, Talum witnessed a large decline in primary aluminium production mostly due to unfavourable energy market conditions. Rising electricity prices during this period compelled the company to reduce its reliance on primary aluminium and transition toward the use of recycled aluminium. This led to a decrease in the production of primary aluminium and a shift towards purchasing primary and scrap aluminium instead. Despite these difficulties, Talum's strategic focus on secondary aluminium, particularly in slugs and discs, enabled the company to retain its market share and capitalize on growing demand for sustainable products.

Next to the rising electricity prices, the price of aluminium experienced significant fluctuations between 2018 and 2022 due to various factors, including trade tariffs, geopolitical tensions, economic conditions, environmental regulations and supply chain disruptions. Nonetheless, the company successfully navigated these challenges by embracing secondary aluminium production into its business model.

The financial impact of Talum’s adoption of sustainable practices in secondary aluminium production is clearly visible. Metrics such as investment costs, cost savings, revenue growth and risk reduction highlight the positive outcomes of this shift. Talum’s investments in recycling expertise and the modernization of its production processes have contributed to higher profit margins, particularly in the slugs and discs segment, where 3-5% higher profit margin is achieved for PCR products, due to growing demand for sustainable products. Furthermore, Talum’s ability to bypass the energy-intensive melting phase has resulted in cost savings, positioning the company competitively on the market.

The focus group analysis provided valuable insights into the challenges and opportunities associated with implementing sustainable practices in secondary aluminium production. Challenges such as procurement and supply chain issues, logistical constraints and investment requirements were identified. However, opportunities in the increasing demand for sustainable packaging and innovation were also highlighted.

Revenue growth has been driven by strong demand for slugs and discs, particularly in sectors requiring sustainable packaging solutions. Additionally, Talum’s shift to secondary aluminium has reduced its exposure to volatile market prices, electricity costs and raw material fluctuations, which has lowered the financial risk of the company and is providing a more stable production environment.

The transition to secondary aluminium usage has presented Talum with both challenges and opportunities. On the one hand, the company faces difficulties in procuring high-quality scrap aluminium, complicated by regulatory constraints in the PCR and logistical challenges, particularly the distance from main sorting centres. These factors increase transportation costs and limit the traceability of materials, which are critical to ensuring production efficiency. Additionally, high investment costs for advanced sorting technologies and competition from larger companies pose significant challenges for Talum’s continued expansion in secondary aluminium production.

On the other hand, Talum is well-positioned to capitalize on the growing demand for sustainable packaging, particularly through its slugs and discs segment. By investing in local sorting centres, Talum could improve the efficiency of its recycling processes, reduce transportation costs and secure a more reliable supply of high-quality recycled materials.

In conclusion, Talum's strategic shift towards sustainable practices and secondary aluminium production, particularly in slugs and discs, has been crucial in maintaining its competitiveness and ensuring long-term success.

REFERENCES

1. Aboulamer, A., Soufani, K., & Esposito, M. (2020). Financing the circular economic model. *Thunderbird International Business Review, 62(6),* 641–646.
2. Bartolacci, F., Paolini, A., Quaranta, A.G., & Soverchia, M. (2018). The relationship between good environmental practices and financial performance: Evidence from Italian waste management companies. *Sustainable production and consumption, 14,* 129–135.
3. Blomberg, J., & Söderholm, P. (2009). The economics of secondary aluminium supply: An econometric analysis based on European data. *Resources, Conservation and Recycling, 53(8),* 455–463.
4. Bressanelli, G., Perona, M., & Saccani, N. (2018). Challenges in supply chain redesign for the Circular Economy: a literature review and a multiple case study. *International Journal of Production Research,* 1–28.
5. Budler, M., & Lunder, E. (2024). S skrbnim pregledom do trajnostnosti: Usmeritve in praktični primeri. *Focus, društvo za sonaraven razvoj,* 1-62
6. Caiado, R. G. G., Dias, R. de F., Mattos, L. V., Quelhas, O. L. G., & Leal Filho, W. (2017). Towards sustainable development through the perspective of eco-efficiency: A systematic literature review. *Journal of Cleaner Production, 165,* 890-904.
7. Carter, C. R., & Rogers, D. S. (2008). A framework of sustainable supply chain management: moving toward new theory. *International Journal of Physical Distribution & Logistics Management, 38(5),* 360–387.
8. Charlo, M. J., Moya, I., & Muñoz, A. M. (2013). Sustainable Development and Corporate Financial Performance: A Study Based on the FTSE4Good IBEX Index. Bus. *Strategy Environ. 2013,* 24, 277–288.
9. De Angelis, R., Howard, M., & Miemczyk, J. (2018). Supply chain management and the circular economy: towards the circular supply chain. *Production Planning & Control, 29(6),* 425–437.
10. Ellen MacArthur Foundation. (2013). *Towards the circular economy Vol. 1: An economic and business rationale for an accelerated transition*. https://www.ellenmacarthurfoundation.org/towards-the-circular-economy-vol-1-an-economic-and-business-rationale-for-an
11. Ethirajan, M., Arasu M, T., Kandasamy, J., K.E.K, V., Nadeem, S. P., & Kumar, A. (2020). Analysing the risks of adopting circular economy initiatives in manufacturing supply chains. *Business Strategy and the Environment, 30(1),* 204–236.
12. Ferretti, I., Zanoni, S., Zavanella, L., & Diana, A. (2007). Greening the aluminium supply chain. *International Journal of Production Economics, 108(1-2),* 236–245.
13. Frischknecht, R. (2010). LCI modelling approaches applied on recycling of materials in view of environmental sustainability, risk perception and eco-efficiency. *The International Journal of Life Cycle Assessment, 15(7),* 666–671.

14. Genovese, A., Acquaye, A. A., Figueroa, A., & Koh, S. C. L. (2017). Sustainable supply chain management and the transition towards a circular economy: Evidence and some applications. *Omega, 66,* 344–357
15. Ghisellini, P., Ripa, M., & Ulgiati, S. (2018). Exploring environmental and economic costs and benefits of a circular economy approach to the construction and demolition sector. A literature review. *Journal of Cleaner Production, 178,* 618–643.
16. Gonçalves, B.d.S.M.; Carvalho, F.L.d.; Fiorini, P.d. C. (2022). Circular Economy and Financial Aspects: A Systematic Review of the Literature. *Sustainability, 14(5), 3023.*
17. Govindan, K., & Hasanagic, M. (2018). A systematic review on drivers, barriers and practices towards circular economy: a supply chain perspective. *International Journal of Production Research, 56(1-2),* 278–311.
18. Hervani, A. A., Helms, M. M., & Sarkis, J. (2005). Performance measurement for green supply chain management. Benchmarking: *An International Journal, 12(4),* 330–353.
19. International Aluminium Institute. (2023). *Primary Aluminium Production Statistics.* https://international-aluminium.org/statistics/primary-aluminium-production/
20. Jarrín J. G, Godoy, M.F.; Alvarenga, R.A.F., Dewulf, J. (2021). Tracking the Fate of Aluminium in the EU Using the MaTrace Model. *Resources 2021,* 10, 72.
21. Larsen, S. B., Masi, D., Feibert, D. C., & Jacobsen, P. (2018). How the reverse supply chain impacts the firm's financial performance. *International Journal of Physical Distribution & Logistics Management, 48(3),* 284–307.
22. Linton, j., Klassen, r., & Jayaraman, V. (2007). Sustainable supply chains: An introduction. *Journal of Operations Management, 25(6),* 1075–1082.
23. Luthin, A., Backes, J. G., & Traverso, M. (2021). A framework to identify environmental-economic trade-offs by combining life cycle assessment and life cycle costing – A case study of aluminium production. *Journal of Cleaner Production, 321,* 128902.
24. Logožar, K., Radonjič, G., & Bastič, M. (2006). Incorporation of reverse logistics model into in-plant recycling process: A case of aluminium industry. *Resources, Conservation and Recycling, 49(1),* 49–67.
25. Niero, M., & Olsen, S. I. (2016). Circular economy: To be or not to be in a closed product loop? A Life Cycle Assessment of aluminium cans with inclusion of alloying elements. *Resources, Conservation and Recycling, 114,* 18–31.
26. Paraskevas, D., Kellens, K., Dewulf, W., & Duflou, J. R. (2015). Environmental modelling of aluminium recycling: a Life Cycle Assessment tool for sustainable metal management. *Journal of Cleaner Production, 105,* 357–370.
27. Paraskevas, D., Ingarao, G., Deng, Y., Duflou, J. R., Pontikes, Y., & Blanpain, B. (2019). Evaluating the material resource efficiency of secondary aluminium production: A Monte Carlo-based decision-support tool. *Journal of Cleaner Production. 215,* 488–496

28. Pagell, M., & Wu, Z. (2009). Building a more complete theory of sustainable supply chain management using case studies of 10 exemplars. *Journal of Supply Chain Management, 45(2),* 37–56.
29. Sarfraz, M., Ivascu, L., Artene, A.E., Bobitan, N., Dumitrescu, D., Bogdan, O., & Burca, V. (2023). The relationship between firms' financial performance and performance measures of circular economy sustainability: an investigation of the G7 countries. *Economic Research-Ekonomska Istraživanja, 36(1),* 2545-2572.
30. Smith, J. (2021). Sustainable Practices in Metal Production. *Journal of Environmental Economics and Management, 90*, 123-145.
31. Soo, V. K., Peeters, J., Paraskevas, D., Compston, P., Doolan, M., & Duflou, J. R. (2018). Sustainable aluminium recycling of end-of-life products: *A joining techniques perspective. Journal of Cleaner Production, 178,* 119–132.
32. Talum (2022a). *Annual report for the year 2022.* https://www.talum.si/en/porocila.html
33. Talum (2022b). *Talum Group Sustainability Report.* https://www.talum.si/en/trajnost.html
34. Talum (2022c). *Talum Group Sustainability Policy.* https://www.talum.si/en/trajnost.html
35. Tseng, M.-L., Islam, M. S., Karia, N., Fauzi, F. A., & Afrin, S. (2019). A literature review on green supply chain management: Trends and future challenges. *Resources, Conservation and Recycling, 141,* 145-162.
36. Wallace, G. (2011). Production of secondary aluminium. *Fundamentals of Aluminium Metallurgy,* 70–82.
37. Wu, Z., & Pagell, M. (2011). Balancing priorities: Decision-making in sustainable supply chain management. *Journal of Operations Management, 29(6),* 577–590.
38. Yin, R. K. (2003). Case study research: Design and methods (3rd ed.). Sage Publications.
39. Zhu, Q., Sarkis, J., & Lai, K. (2007). Green supply chain management: pressures, practices and performance within the Chinese automobile industry. *Journal of Cleaner Production,* 15(11-12), 1041–1052.

APPENDICES

Appendix 1: Summary in Slovene

V zadnjih letih se zaradi pomanjkanja virov, skrbi za okolje in zahtev kupcev, trajnostne prakse v globalnih industrijah hitro razvijajo. Ta prehod je še posebej opazen v sektorjih z visokimi okoljskimi odtisi, kot je proizvodnja kovin, kjer aluminij izstopa na čelu prizadevanj za trajnostnost. Talum, vodilno proizvodno podjetje, specializirano za proizvodnjo in obdelavo aluminija, predstavlja zanimiv primer za raziskovanje finančnih posledic trajnostnih praks pri proizvodnji sekundarnega aluminija

Cilji raziskave te magistrske naloge naslavljajo predvsem vprašanja o finančnem vplivu trajnostnih praks pri proizvodnji sekundarnega aluminija in vprašanja o izzivih ter priložnosti, povezanih z implementacijo teh trajnostnih praks.

V magistrski nalogi sem izvedla raziskavo na primeru podjetja Talum, ki v zadnjih letih vedno bolj osredotoča na proizvodnjo in uporabo sekundarnega aluminija. Prehod na model krožnega gospodarstva je ključen za obravnavo teh vprašanj. Krožno gospodarstvo poudarja učinkovitost virov, zmanjševanje odpadkov in ohranjanje vrednosti, kar se ujema s strateško vizijo Taluma o povečanju proizvodnje sekundarnega aluminija. S preoblikovanjem dobavnih verig in povečevanjem uporabe sekundarnega aluminija, lahko podjetja zmanjšajo svoj okoljski vpliv in povečajo učinkovitost uporabe virov.

Pri prehodu na uporabo sekundarnega aluminija se podjetja srečujejo z različnimi izzivi. Talum se sooča z izzivi v nabavi sekundarnega aluminija, logističnimi izzivi, zahtevami po investicijah in dinamiko trga. Za premagovanje teh izzivov so potrebne strateške naložbe, inovacije in usklajenost s spreminjajočimi se regulativnimi okvirji.

Vendar pa prehod prinaša številne priložnosti za Talum, vključno z diferenciacijo na trgu, konkurenčno prednostjo, zmanjševanjem tveganj, inovacijami in usklajenostjo s cilji ogljične nevtralnosti. S pravilno izkoriščenimi priložnostmi Talum izboljša svoje finančne rezultate in hkrati prispeva k okoljski trajnosti.

Magistrska naloga poudarja pomembnost integracije trajnosti v procese finančnega odločanja ter izpostavlja pomemben potencial za ekonomske koristi, povezane s trajnostnimi praksami pri proizvodnji sekundarnega aluminija. S kombinacijo kvantitativne analize in pridobivanje informacij skozi pogov s fokusno skupino z izbranimi sogovorniki iz Taluma, magistrska naloga ponuja vpogled za Talum in druga podjetja, ki se spopadajo s prehodom k trajnostnim proizvodnim praksam v kovinsko predelovalni industriji.

Appendix 2: Questions for the focus group conversation

The purpose of data collection from the focus group conversation is to provide a framework to data already collected from Talum's reports that are publicly disclosed (Talum Group's Sustainable Development Report, Talum Sustainability Policy, Annual Report of Group Talum) and to identify the strategy of transition from primary to secondary aluminium at Talum. Section 1 focused on obtaining answers that would help address the first research question, while section 2 served as a basis for providing insights to answer the second research question.

Section 1: Sustainable practice at Talum and measuring performance

1. How did Talum implement the circular economy concept in its business model? Is the process already completed? If not, what are the company's long-term sustainability and circularity goals?

2. Which factors impact the decision for transition from primary to secondary aluminium?

3. Within Talum, for which specific area or business unit would the adoption of the circular economy principles have the greatest impact and furthermore, which of Talum's business units is the most suitable for the implementation of secondary aluminium use and why?

4. For production of which products is secondary aluminium the most suitable? Explain more about the product and the process of switching from primary to secondary aluminium usage.

5. Can you describe the process of transitioning from primary to secondary aluminium usage for certain products? Explain the product and the process.

6. Which approach do you follow, open-loop aluminium recycling or closed-loop aluminium recycling and what challenges do you face?

7. Compare the differences that you have observed in transition from primary to secondary aluminium in terms of cost, quality and customer relationships.

8. What are the key performance indicators or other performance measures that Talum uses to measure its financial and environmental performance?

9. To what extent do you expect that using secondary aluminium production instead of primary aluminium production affects Talum's financial metrics? Please, try to compare effects on short-term and long-term.

10. To what extent do you expect that using secondary aluminium production instead of primary aluminium production could lead to cost reduction or increase?

Section 2: Challenges, opportunities and risks in regular production of aluminium

11. What are the key challenges Talum is facing in the transition to secondary aluminium production? What are the regulatory, procurement, logistics, financial and operational challenges?

12. What could be the opportunities associated with implementing sustainable practices in secondary aluminium production in financial terms?

13. How does the risk profile of secondary aluminium production compare to that of primary aluminium production in terms of market prices, energy costs and supply chain stability?