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THE ROLE OF METALLURGICAL SILICON AND FERROALLOYS IN THE SEMICONDUCTOR VALUE CHAIN: THE CASE OF FERROGLOBE

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ABSTRACT

The semiconductor industry plays a crucial role in the modern economy, being a key player in all technological processes and products. The idea behind this bachelor's degree final thesis arises from a personal interest in the semiconductor industry and its actual situation. To understand it better I tried to analyze, deconstruct and separate its value chain and focus on a specific part of it, the initial stages of production and material processing. I dug deeper into processes that make possible the production and use of semiconductors in certain applications, focusing on how raw materials such as silica and ferroalloys, are transformed into essential components for advanced electronics.

This thesis is divided into two parts. The first one is focused on explaining semiconductors, their properties, historic evolution and critical role in the economy, becoming more important since last year's supply chain disruptions. Understanding their production, makes the exploration of silicon, the primary material used in the manufacturing process, imperative in this study. This led to the research of silica, the source of silicon, considering that it undergoes the necessary chemical processing to meet the high-purity standards required for semiconductors to be used in their different applications.

On the other hand, in the second part, the focus shifts to Ferroglobe, a leading company in the production of silicon metal and ferroalloys. This firm is a key player and is situated in the heart of the semiconductor value chain because of its role in the production and refinement of these materials. This part of the thesis explores the whole background of Ferroglobe, as well as their contribution to the global supply chain of semiconductors with their applications and collaborations. In this work I also carry out a simulation analyzing the impact of electricity price variations on Ferroglobe's production costs and profit margins. This simulation aims to evaluate the firm's sensitivity to changes in energy prices and to identify potential cost optimization strategies through production reallocation across the different countries where the company operates. The results provide insights and takeaways to understand how electricity affects the company's financial performance and to guide decision making.

The initial stages of material production (e.g. those managed by Ferroglobe) are crucial to the semiconductor industry. The aim of this work is to provide an analysis of the semiconductor value chain, focusing on the extraction and processing of materials such as silica into high-purity silicon and ferroalloys and their advanced properties and applications across industries. To achieve this goal, I connected both parts by researching and analyzing silica ("the roots of the tree"), silicon and ferroalloys (materials that Ferroglobe works with), which are the materials that form the basis of semiconductors.

Key words: semiconductors, ferroalloys, Ferroglobe, silica, silicon, electricity prices

RESUMEN

La industria de los semiconductores juega un papel crucial en la economía moderna, siendo clave en todos los procesos y productos tecnológicos. La idea detrás de este trabajo de fin de grado surge de un interés personal por la industria de los semiconductores y su situación actual. Para comprenderla mejor he analizado, desglosado y separado las distintas fases de su cadena de valor, enfocándome en una parte especifica: las etapas iniciales de producción y procesamiento de materiales; haciendo especial hincapié en los procesos que hacen posible la producción y el uso de semiconductores en diversas soluciones y productos.

Este trabajo está dividido en dos partes. La primera se centra en explicar los semiconductores, sus propiedades, evolución histórica y su papel crítico en la economía, cobrando mayor importancia a raíz de la escasez global de los últimos años. Comprender su proceso productivo hace necesario explorar sus orígenes, que se remontan al silicio, el material principal y "rey" de los semiconductores. Esto hace imprescindible la investigación del mineral de sílice, fuente del silicio, al que se le aplica una serie de procesos químicos para cumplir con los estándares de alta pureza requeridos para su uso en distintas aplicaciones.

En la segunda parte, el trabajo se centra en Ferroglobe, una empresa líder en la producción de silicio metal y ferroaleaciones. Es un actor principal en el desarrollo y funcionamiento de la cadena de valor de los semiconductores debido a su papel en la producción de estos materiales. Esta parte del trabajo explora todo el trasfondo de Ferroglobe, su contribución a la cadena de suministro, aplicaciones y demás colaboraciones. Además, en este trabajo de investigación se realiza una simulación, en la que se analiza el impacto de la variación en el precio de la electricidad en los costes de producción de Ferroglobe y en sus márgenes. Esta simulación trata de evaluar la sensibilidad de las principales magnitudes financieras de la empresa sobre las variaciones en los precios de la electricidad y de identificar posibles estrategias de optimización de costes a través de la relocalización de la producción en los diferentes países donde la empresa produce. Los resultados muestran conclusiones que ayudan a entender como la electricidad afecta la viabilidad financiera de una empresa electro intensiva y cómo orientar una hipotética toma de decisiones con el objetivo de reducir la exposición a la volatilidad de los precios.

Las etapas iniciales de la producción de materiales (las que gestiona Ferroglobe) son cruciales en la industria de los semiconductores. El objetivo de este trabajo es mostrar y explicar con más detalle una fase específica de la cadena de valor de los semiconductores, desde la extracción y procesamiento de materiales hasta su uso en diversas aplicaciones gracias a sus avanzadas propiedades. Para lograrlo, se ha establecido una unión contextual entre ambas partes del trabajo focalizada en la investigación y explicación del mineral de sílice (la cuna del silicio), el silicio y las ferroaleaciones (materiales con los que trabaja Ferroglobe), que forman la base de los semiconductores.

Palabras clave: semiconductores, ferroaleaciones, Ferroglobe, Sílice, Silicio, precio de la electricidad.

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Chapter 1. Introduction

The objective of this study is to analyze the initial stages of the semiconductor value chain, with a special focus on the extraction and transformation of silica into high-purity silicon and ferroalloys, as well as their use and integration into various technologies and applications. While previous studies have largely covered downstream applications and end-market dynamics, this research explores the upstream processes of enrichment and development that ensure the supply of critical raw materials. By providing more information on this topic, this work aims to define and reveal the details of the semiconductor supply and value chains, and the barriers they are currently facing in the global landscape.

This work offers a differential value by exploring a rarely addressed topic like the contribution of metallurgical silicon and ferroalloys in the semiconductor supply chain, with a detailed case study on Ferroglobe. Ferroglobe, a global leader in the production of silicon metal and ferroalloys, is particularly relevant for this research due to its key position in the value chain. It has a significant market share in North American and global silicon metal markets. It also exemplifies the complexities and barriers of the upstream processes in the semiconductor industry as it develops different activities of the value chain (mining, extraction, processing…). Analyzing a firm like Ferroglobe provides valuable insights into how raw materials suppliers contribute to the semiconductor ecosystem. Given the energy-intensive nature of silicon metal production and the worldwide-level operations of the company with different electricity costs, Ferroglobe is an ideal case study for exploring the impact of energy price volatility on production efficiency and financial performance. Specifically, in this research it is examined how electricity price fluctuations affect production costs and margins, a factor often underestimated in the semiconductor supply chain.

The methodology employed combines both quantitative and qualitative approaches. First, a literature review has been done to contextualize the importance of silica, silicon and ferroalloys in the semiconductor industry. After the first part, a detailed analysis of Ferroglobe's operations and historical data has been done to understand its role and positioning in the value chain, followed by a simulation development to model the impact of electricity price volatility on Ferroglobe's production costs and margins. The simulation incorporates regional electricity costs, production capacities and the company operations to identify cost-optimization opportunities and propose actionable insights.

The relevance of this research is justified by the uncovering of critical vulnerabilities and opportunities within the semiconductor supply chain, emphasizing the need for strategic resource allocation and risk management in initial stages. By focusing on a firm that directly supports the industry, the study aligns with industry objectives of enhancing global supply chain stability.

The findings of this research reveal several insights. The simulation demonstrates that electricity costs represent a significant portion of Ferroglobe's costs, with variations in costs concurring depending on the country where production is allocated. Shifting production to countries with lower electricity costs, such as Norway or the United States, can reduce expenses by up to 20%. In addition, this work introduces a framework for optimizing production in energy-intensive industries, enabling companies to protect themselves from excessive electricity price volatility. Also, the analysis develops an understanding of the initial production and transformation processes of silica, serving as a bridge between raw materials suppliers and early manufacturers. Finally, the work showcases the company's initiatives to reduce its carbon footprint and integrate renewable energy into its processes. Like the third insight, it provides a model where sustainable practices in energy-intensive industries form the core of their operations.

These results are important for several reasons. They provide Ferroglobe actionable strategies for improving cost efficiency and competitiveness. It highlights the importance of upstream procedures for the semiconductor industry, reinforcing the need for collaboration between raw materials suppliers and manufacturers. Finally, for policymakers, the insights help with the decision making on energy policies and support measures to promote sustainable and efficient industrial practices.

Chapter 2. Semiconductors

In this chapter, I am going to explain what semiconductors are, their development, their importance along with their relevance in today's world economic system (mainly because of their properties and applications) and the shortage situation affecting the semiconductors industry.

According to Mizutori & Yamada (2005), semiconductors are crystalline materials whose ability to conduct electricity is higher than insulators (like glass, rubber, or plastic, which hardly conduct electricity) and lower than conductors (like metals, which allow electricity to flow easily). Their electrical resistance is in the middle range, which makes them useful for controlling electric currents in devices like computers and smartphones (2005).

When considering electric resistivity, we can also identify three major characteristics of semiconductors. First, any impurities even at part-per-million level can affect the conductivity of a semiconductor (critical factor for commercial use of semiconductors). Secondly, the current-voltage relationship doesn't follow Ohm's law and such curve is not symmetrical around the origin which results in having a single direction current flow as semiconductors work as rectifiers. Finally, their resistivity decreases as the temperature increases (different from metals) (Mizutori et al., 2005).

2.1. Material composition and properties

Material composition

According to Bernardo, Lameirinhas, de Melo Cunha & Torres (2024), from a global point of view, semiconductors have two main types: elemental, if they are only made from a single atom, like silicon and germanium, and compound, which combine elements from groups III-V or II-VI or II-VI of the periodic table. Examples of last ones could be Cadmium Telluride (CaTe) and Zinc Oxide (ZnO) respectively.

When talking about materials that make up semiconductors, if we go into more detail, we can distinguish five different categories according to their structure, chemical composition and performance: elemental semiconductors, inorganic compound semiconductors, organic compound semiconductors, amorphous semiconductors and liquid semiconductors (Song, 2023). As a visual support, this project will apply the table used by the author to show the previous grouping. This table (Table 1) includes the main 12 elements that compose semiconductors, including Boron (B), Carbon (C), Silicon (Si), Phosphorus (P), Sulfur S), Germanium (Ge), Arsenic (As), Selenium (Se), Tin (Sn), Antimony (Sb), Tellurium (Te) and Iodine (I). Some of these elements are unstable or volatile, such as Sulfur, Phosphorus, Arsenic, Antimony and Iodine. Gray Tin can transform into white Tin at room temperature, becoming a metal. Boron and carbon have melting points too high to be processed into single crystals, and tellurium is rare. Therefore, only Selenium, Germanium and Silicon are commonly used in industrial applications as elemental semiconductors. Industrial semiconductors are primarily based on compounds from groups III-V and II-VI and their solid solutions (Song, 2023).

Table 1: Types of semiconductor materials

Classification	Semiconductor	
	Symbol	Name
Element semiconductor	Si	silicon
	Ge	germanium
	Se	Selenium
Binary compound semiconductor	SiC	silicon carbide
	AlP	Aluminium phosphide
	AlAs	Aluminium arsenide
	AlSb	Aluminium antimonide
	GaN	Gallium nitride
	GaP	Gallium phosphide
	GaAs	Gallium arsenide
	GaSb	Gallium antimonide
	InP	Indium phosphide
	InAs	Indium arsenide
	InSb	Indium antimonide
	ZnO	Zinc oxide
	ZnS	Zinc sulfide
	ZnSe	Zinc stannate
	ZnTe	Zinc telluride
	CdS	Cadmium sulfide
	CdSe	Cadmium stannate
	CdTe	Cadmium telluride
	HgS	Mercury sulfide
	PbS	Lead sulfide
	PbSe	Lead stannate
	PbTe	Lead telluride
Ternary compound semiconductor	$AlGa_{11}As$	Gallium aluminum arsenide
	$AlIn_{11}As$	Indium aluminum arsenide
	$GaAs_{1-x}P_x$	Arsenic gallium phosphide
	$Ga_xIn_{1-x}As$	Indium gallium arsenide
	$Ga_xIn_{1-x}P$	Indium gallium phosphide
Quaternary compound semiconductor	$Al_xGa_{1-x}As_ySb_{1-y}$	Arsenic gallium aluminum antimonide
	$Ga_xIn_{1-x}As_{1-y}P_y$	Arsenic indium gallium phosphide

Retrieved from The history and trends of semiconductor materials development, by J. Song, 2023, p.3, Journal of Physics: Conference Series.

Semiconductor properties

According to Mizutori et al. and based on their stated theories on the Ullmann's Encyclopedia of Industrial Chemistry in 2005, semiconductors have the following properties:

- Movement of Electrons and Holes: In semiconductor crystals, atoms are closely packed and form strong chemical bonds. This allows electrons to move freely through the crystal, enabling electrical conduction. The valence and conduction bands are formed due to the interaction of electrons through the crystal, facilitating the flow of charge when an electric field is applied.
- Temperature's Influence on Conductivity: As the temperature rises, more electrons get excited and can conduct electricity. This causes semiconductors to conduct better at higher temperatures, unlike metals, which have higher resistivity as temperatures go up (intrinsic conduction).
- "Doping" of Semiconductors: One of the most important features of semiconductors is that their ability to conduct electricity can be controlled by adding tiny amounts of impurities, called dopants. This is what allows the creation of devices like transistors and diodes in electronics (extrinsic conduction).

2.2. Historical evolution

The history of semiconductors began centuries ago, with Alessandro Volta introducing the term "semiconducting" in 1782. This basic insight established the platform for future discoveries that transformed the field of electronics. In 1833 a major finding was made when Michael Faraday documented a semiconductor effect by observing how resistance of silver sulfide decreased with high temperatures, contrary to the typical metallic behavior (Łukasiak & Jakubowski, 2010), being the first observation regarding an inherent property of semiconductors, distinguishing them from conductors and insulators.

In 1839, Alexander Edmund Becquerel discovered that a junction between a semiconductor and an electrolyte could generate a photovoltaic effect, establishing the basis for harnessing light energy through semiconductors. Decades later Karl Ferdinand Braun advanced in the field by identifying conduction and rectification properties in metal sulfides, followed by Charles Fritts who in 1833 built the first practical solar cell using selenium layer covered with gold (Łukasiak et al., 2010).

The 20th century saw rapid developments in semiconductor devices since its early beginnings, when American physicists developed crystal rectifiers and selenium based photovoltaic cells, followed by Germany's innovation in semiconductor infrared detectors, which played critical roles in military applications during World Warr II (Song, 2023). These innovations started to highlight the applications that these devices would have in the future. After these decades, a mayor leap occurred in 1947, when Bell Laboratories invented the transistor and contributed to the birth of modern electronics. Initially, its manufacturing started with germanium, but soon silicon became dominant due to its superior properties. With this change, compound semiconductors start being developed, creating a broader range of applications (Orton, 2004).

Semiconductors became the foundation of integrated circuits. However, Moore's law, which predicted doubling transistor density every two years, has begun to face physical challenges as chip sizes are approaching their limits. This shows the need to look for alternative materials and solutions to maintain technological process. Today, semiconductors are found in various fields and despite challenges in performance and cost, the industry continues to innovate (Song, 2023).

2.3. Functionalities and applications across industries

Thanks to their electronic properties, thermal stability and versatility, semiconductors have a wide range of applications across different industries that use both traditional and emerging technologies.

Electronics and Communication

Semiconductors are widely used in microprocessors, integrated circuits and memory devices manufacturing, being the roots of the electronics and communication industry. Silicon-based semiconductors are the ones that dominate these applications because of their excellent conductivity and stable crystal structure. Handling higher power loads and faster speeds have been achieved thanks to innovations in doping processes that allow semiconductors to develop their electric properties. With these advancements and according to Moore's law, there is a continual reduction in the size of components that would result in the doubling of transistors on a microchip every two years (Mukherjee, Pal, Bhattacharyya, & Roy, 2024). Compound semiconductors such as gallium arsenide (GaAs) and indium phosphide (InP) are used in communication industry because of their higher electron mobility compared to silicon. They are ideal for high-frequency applications such as radio frequency amplifiers and satellite communications, allowing faster data transmission and more reliable signal processing (Song, 2023).

Energy and Renewable Technologies

Semiconductor materials like silicon, gallium arsenide and cadmium telluride (CdTe) are critical in energy applications, being used to convert sunlight directly into electricity in photovoltaic cells. Semiconductors are also essential for fuel cells and energy storage devices (Mukherjee et al., 2024). During last years, amorphous silicon and CdTe have been used to develop thinner solar cells, resulting in lower costs and higher efficiency which lately, has given the advantage of offering an abundant and cost-free energy source, which has no hazardous or safety issues, as well it being non pollutant. Moreover, it operates at ambient temperatures while having the issue of the high installation costs and the low conversion efficiency (Patil & Bhargava, 2024). In photocatalytic water-splitting reactions, Titanium dioxide (TiO_2) is used to generate hydrogen fuel contributing to the development of sustainable energy solutions (Sahoo, Ray, Ghosh & Bhattacharya, 2024). The chemical reaction separates water into its basic components, hydrogen and oxygen, using sunlight (Becerra-Ruiz, Rangel-Vazquez, Jauregui-Correa, & Del Angel-Montes, 2021). When a semiconductor material absorbs light energy, its electrons get excited and the reaction occurs, creating electron-hole pairs. After certain chemical reactions between stimulated electrons and holes, the first ones can reduce protons (H^+) to form hydrogen gas, while the holes are responsible for oxidizing water molecules to release oxygen. This process is important as it provides a clean way to produce hydrogen to be used as a fuel without emitting any harmful pollutants (Sahoo et al., 2024).

Automotive Industry

Semiconductors are used in a wide range of automotive applications, from powertrain control to infotainment systems and advanced driver assistance systems, to enhance vehicle performance, safety and efficiency (Haramboure, Lalanne, Schwellnus & Guilhoto, 2023). Electric vehicles (EVs) are developed with silicon carbide (SiC) and gallium nitride (GaN) as they are the foundations of new generation power semiconductor devices (Song, 2023) because of their higher thermal conductivity and ability to handle higher volts amounts. These materials enhance efficiency in these vehicles extending the range and lifespan of EV batteries (Mukherjee et al., 2024).

Healthcare and Biomedical Applications

Regarding healthcare, semiconductors are used in diagnostic and imaging devices and in wearable health monitors. They are ideal for capturing detailed images of the human body thanks to their ability to convert light into electrical signals with higher precision (Mukherjee et al., 2024). One concrete example could be silicon-based photodetectors. Semiconductor sensors are set to revolutionize healthcare by enabling fast diagnostics and personalized treatments. Integrated with AI, these sensors will generate data for precision medicine to foster advancements in genomics and regenerative healthcare (Durmaz, Kahyaoğlu, Aytar, & Karakuş, 2024).

Environmental Applications

Water treatment and air purification are also important activities that are taking place with semiconductors. Metal oxide semiconductors like TiO_2 are used as photocatalysts since these materials can break down harmful chemicals when they are exposed to light and remove pollutants (Nasajpour-Esfahani, Koohbor, Garmestani & Liang, 2024). Additionally, semiconductors are used in sensors that detect environmental pollutants and monitor air quality, providing valuable data for environmental management (Kocyigit, 2024).

Quantum Computing and Optoelectrics

Semiconductors have unique properties at the nanoscale. Semiconductors quantum dots and other nanostructures are used to create qubits, the fundamental units of quantum information. Qubits are expected to be in different states simultaneously so quantum computers can make calculations way faster than classic ones (Farida & Mali, 2024). In optoelectronics semiconductors are used in devices that detect light, emit or modulate it. Within them we can find LEDs, photodetectors and laser diodes. Huge developments have been made among energy-efficient lighting and high-resolution displays during recent years thanks to the development of wide-bandgap semiconductors such as the ZnO, enabling the production of blue and ultraviolet LEDs (Lathe & Palve, 2024).

2.4. Market snapshot and major worldwide manufacturers

In 2024, the semiconductor industry is being marked by growth and increased market dynamics among its main players. The global semiconductor market reached almost $150 billion in Q2 2024. In this period, it is necessary to highlight the performance for memory chipmakers such as Kioxia and SK Hynix. During Q2 2024 memory segment companies’ revenues had a 22% increase compared to non-memory ones, which only grew by 3% (Semiconductor Intelligence, 2024).

Nowadays, NVIDIA has consolidated its dominance in the sector being the largest semiconductor company globally. According to Semiconductor Intelligence in 2024, its revenue for Q2 2024 reached de amount of $28 billion, significantly above its closest competitor Taiwan Semiconductor Manufacturing Company (TSMC), based mainly in the market-leader position on AI and high-performance GPUs (Omran, 2024). Samsung, another critical player, benefitted greatly from the booming demand for DDR5 memory and AI storage solutions. This memory chips boom is expected to extend throughout 2024, driven by high demand for AI servers and data center applications (Team Counterpoint, 2024). At this point, with the production of cutting-edge chips using advanced 5 to 3 nm processes for teach giants such as Apple and AMD, TSMC remains the top foundry (Westberg, 2024). Broadcom continues to be a critical supplier for AI and cloud computing infrastructure, remaining a major player in networking and storage solutions and a key contributor to the semiconductor ecosystem. The company remains a major force in wireless technology, making huge advancements in 5G connectivity. Their innovations in this field make them an essential partner for smartphone manufacturers. Regarding the automotive, industrial and consumer electronics industries, ASML keeps playing crucial roles with their embedded chips (Marjanovic, 2024). The leadership of x86 microprocessor technology is retained by Intel, which is now trying to diversify into new product lines to include AI and computing solutions to face the decline in their revenue (14% down in Q1 2024) due to the reduced demand for their Mobileye and foundry services (Team Counterpoint, 2024).

The semiconductor industry, with forecasted revenue increases between 14.4% and 20.7% for 2024, is expected to be maintaining its growth trend. A slower but steady growth rate between 11% and 15% is projected for 2025. These estimations are driven by the expansion in AI, data centers and development of automotive technologies (Semiconductor Intelligence, 2024).

2.5. Supply shortages and crisis

2.5.1. Origins and Contributing Factors

The global semiconductor shortage has become one of the most disrupting issues in recent years, affecting various industries and economies worldwide. Since 2020, the shortage has grown to such an extent that it is now frequently compared to the crisis of the 1970s due to its widespread implications across sectors, from consumer electronics and automotive to healthcare and defense. The crisis has highlighted the fragility and interdependence of global supply chains, and the urgent need for countries to re-evaluate their production strategies and reliance on a limited number of semiconductors producing nations.

The origins of the semiconductor shortage are complex and have various roots, the vulnerabilities of its supply chain and the COVID-19 pandemic being the most important ones. According to Mohammad, Elomri & Kerbache, the crisis can be attributed to the increased demand for electronics, supply chain disruptions, concentration of production in East Asia and geopolitical tensions. The pandemic led to a surge in demand for personal electronics such as laptops, smartphones and consoles driven by at-home entertainment, online education and remote work. As factories were forced to shut down or operate at reduced capacity, this demand couldn't match the available supply of semiconductors, tightening the market (2022).

The production of semiconductors is highly concentrated in East Asia, particularly in Taiwan, South Korea and Japan. For example, as Voas, Kshetri and DeFranco explained on page 79 of their article, these three countries alone account for 100% of the world's advanced semiconductor production, making the global supply chain vulnerable to natural disasters and geopolitical tensions. For example, Renesas Semiconductor Co Ltd, which supplies about one third of the microcontroller chips used in cars globally, experienced a severe fire at its Japan facility, causing significant disruptions in automotive chip supplies (2021).

When explaining geopolitical tensions, Voas et al. focused on the tightness between United States and China. Chinese firms, anticipating restrictions and potential sanctions have aggressively stockpiled semiconductors, creating additional shortages and driving up prices. China's imports of integrated circuits increased by over one third in the first quarter of 2021 compared to the previous year (2021).

Building new semiconductor facilities requires significant investment and time. According to A. Varas et al. in 2021 and quoted by Voas et al. on the same year, it is estimated that establishing a self-sufficient local supply chain in each region would require an upfront investment of $1 trillion, leading to a 35-65% increase in chip prices.

This high entry barrier has impeded the industry from quickly scaling up production to meet demand.

2.5.2. Industry impacts of the Shortage

The semiconductor shortage has disrupted various industries leading to delays in production, increased costs and significant revenue losses. The automotive sector has received the hardest hit, as modern vehicles rely heavily on microchips for everything, from the engine control units to infotainment systems. A single car can require from 50-150 microchips, reaching 3000 on the most sophisticated ones (Voas et al., 2021). Due to the shortage, car producers have been forced to reduce production volumes, resulting in increased car prices.

Another industry that has been affected by the shortage is healthcare. The fact that this industry relies on semiconductors for critical equipment such as medical ventilators, that can't be easily replaced, resulted in hardship (Mohammad et al., 2022). Delays in semiconductor supply timings have impacted the production of essential medical equipment, potentially affecting patient care. Also, the IoT industry has been hit by the shortage, since the advancements of this industry have been slowed down because of the unavailability of chips. AI architecture (software) grows and evolves faster than the hardware needed to implement the technology, which results in actual semiconductors being obsolete (Mohammad et al., 2022).

Lastly, Voas et al. mentioned that major electronic companies, including Apple, have reported significant revenue losses and delays in product launches due to the lack of chips. Prices for consumer electronics have risen sharply as manufacturers struggle to secure sufficient semiconductor supplies (2021).

2.5.3. Strategic responses, Policy Interventions and Long-Term Solutions

With the objective of strengthen the supply chain and reduce the reliance on East Asia, governments and industry leaders are responding with a range of strategic interventions.

The U.S Government has recognized the shortage as a critical issue with implications for national security and economic stability. In order to find a solution, it has developed the CHIPS Act (Creating Helpful Incentives to Produce Semiconductors for America Act), which allocates $50 billion to support domestic semiconductor manufacturing and research. In the European Union, the European Commission has set a target to produce

20% of the world's semiconductors by 2030, as part of its strategy to achieve digital independence from major producers. It has also planned to invest over $150 billion in advanced technologies, being semiconductors and artificial intelligence the main targets (Voas et al., 2021).

To go through the ongoing challenges that are being created by the semiconductor shortage and prevent similar situations in the future, establishing semiconductor manufacturing facilities in multiple regions to diversify supply chains could be a solution. Also investing in R&D could be a critical factor to reduce dependency on the few manufacturers. In these two solutions, government support is crucial (via tax incentives and grants) as well as collaboration between them and key industry players. Lastly, like many countries are doing with other critical commodities/materials (e.g. oil), building up reserves, called stockpiling, of critical components that make up semiconductors, would help mitigate the impact of future supply chain disruptions (Mohammad et al., 2022).

Chapter 3. Silica

Silica is a material with a deep historical and modern significance. This chapter explores its origins, tracing its geological formation during the Archean period and its role in Earths carbon cycle and biological evolution from sponge-made skeletons to diatoms. This chapter also examines the global silica market, led by the Asia-Pacific and North America regions, where silica is essential for construction, glass manufacturing and hydraulic fracturing. Through this combined focus, this chapter expose silica's crucial role in both nature and industry.

3.1. Origins

The origin of silica on Earth is tightly related to both geological and development processes of early life forms. Starting in the Archean period, intense hydrothermal activity released huge amounts of dissolved silica into the early oceans since the Earth was still "heated" from its formation. These continuous "flows" made that amorphous silica could precipitate naturally out of seawater and form deposits on the oceanic floor because of the high concentrations of dissolved silica that cannot be maintained dissolved in water. Over billions of years these processes deposited layers of silica-rich rock where small granules of nearly pure microcrystalline quartz became embedded within the rock structures. Examples of these formations can be seen in around 3-billion-year-old formations like the Barberton Greenstone Belt in South Africa and the Pilbara Craton in Australia. After all, Earth's geothermal activity would start to decrease gradually which would result in the decrease of the hydrothermal input of silica into the oceans (De La Rocha & Conley, 2017).

Silicate weathering will emerge after all the evolution of the geochemical environment, being a key process when contributing to Earth's habitability, as it works with solar energy to maintain a balanced climate. When silicate minerals (like wollastonite) weather, they release dissolved silica and calcium ions and contribute to the planet's alkalinity. In this process, carbon dioxide is absorbed and converted into carbonate ions which later will form shells and coral skeletons. These new calcium carbonate structures will play a vital role in Earths carbon cycle (De La Rocha et al., 2017).

Returning to the oceans, hydrothermal weathering of the oceanic crust kept seawater saturated with dissolved silica mainly because hot fluids released by underwater volcanic activity were turned back into the ocean. Over time, much of the silica present in these ancient oceans was removed through precipitation of particles, with silica-rich sediments being recycled back into Earth's mantle through tectonic plates movements (De La Rocha et al., 2017). After silica deposits dissolved, approximately 550 million years ago, the first known examples of silica biomineralization appeared with sponge-made silica skeletons. These early sponges had formed silica-based spicules which were similar to the modern sponge structures. A type of amoeba protist called Radiolarians followed the sponges, creating silica skeletons from dissolved oceanic silica and marking a further advancement of silica biomineralization in marine ecosystems (De La Rocha et al., 2017).

Another development came with diatoms, some of the most effective phytoplankton in using silica. Their cellular mechanisms take advantage of the natural gradient of sodium ions between the inside and outside of the cell, allowing them to transport dissolved silico into their cells and marking a critical point in the biological cycling of silica. At that time, the ocean's biogenic silica production remained relatively low as much of the silica produced by the organisms was buried in ocean sediments rather than redissolving, contrary to near total dissolution seen today. Additionally, ancient cyanobacteria on the seafloor facilitated the precipitation of iron oxides. These iron oxides collected silica and formed layered deposits like banded iron formations. This shallow marine environment process not only accumulated iron but also helped integrate silica into the Earths geological record (De La Rocha et al., 2017).

3.2. Key producers and deposits worldwide

The global silica sand market is driven largely by Asia-Pacific and North America and is primarily supported by the construction and glass manufacturing sectors. The Asia-Pacific area holds around 30% of the global market share and the North American market is expected to grow significantly over the next years, due to the increased production of oil and natural gas (Fortune Business Insights, 2024).

The Asia-Pacific region leads in production, highlighting the special role of India, Japan, China, Indonesia and Australia because of their high demands on sectors recently mentioned. This region's market value reached approximately USD 3.56 million in 2023 with key companies like Nippon Silica, Sibelco and PUM GROUP (Fortune Business Insights, 2024).

Industrial sand and gravel production in U.S. reached 114 million metric tons in 2019, with Texas, Wisconsin and Illinois the as the major contributors to this figure with a combined 86% of the whole production. High purity “Norther White” or “Ottawa” sands obtained from geological formations in the Midwest are essential for both glassmaking and hydraulic fracturing (Dolley, 2024). Silica is used in hydraulic fracturing, a process to get oil and natural gas from deep underground and consists of pumping a mix of water, sand and chemicals into rock formations at high pressure to create small cracks which allow trapped oil or gas to flow out to the surface. The sand keeps these cracks open for oil and gas to flow freely even though pressure is removed (U.S. Geological Survey, 2019). Examples of major companies regarding silica in the U.S. are U.S Silica Holdings Inc. and Covia Holdings (Dolley, 2024).

Regarding natural deposits, they are found around the world. The largest known diatomite reserves are in Lompoc, California, where its deposits have an economically viable thickness of about 300 meters. Also, marine and freshwater diatomite is extracted in Georgia, Mississippi and Nevada. Their economic value depends on various factors like mining conditions, processing and transportation costs (Flörke, Graetsch, Brunk, Benda, Paschen, Bergna, Roberts, Welsh, Chapman, Ettlinger, Kerner, Maier, Meon, Schmoll, Gies, & Schiffmann, 2007).

Chapter 4. Silicon

This chapter highlights the global production of silicon, with China leading at over 70%, and its growing market, valued at 14.5 billion in 2023. Key methods like the Siemens process ensure ultra-pure silicon for semiconductors, while innovations reduce environmental impacts. Silicon properties make it the core of semiconductors, powering integrated circuits and advanced electronics.

4.1. Key producers worldwide

Ferrosilicon became the 60% of global silicon production excluding the United Sates in 2023. The top producers in terms of silicon content were China, Russia and Norway. China was above Brazil and Norway, as it accounted for over 70% of the estimated global production of silicon materials. These resources are expected to sustain world demand for decades since most producing countries have an abundance of silica-based materials, serving as the base for silicon metal and alloys (U.S. Geological Survey, 2024).

When talking about worldwide reserves of high purity quartz, which are essential for silicon production, they remain geographically concentrated. The United States leads in its production, whilst Australia, Brazil, Canada, India and Russia have other key sources. This factor highlights both the strategic importance and limited availability of these resources (U.S. Geological Survey, 2024).

Meanwhile, the global silicon market reflects a dynamic and expanding sector. This market reached a value of $14.5 billion in 2023 and is projected to grow at a 5.1% CAGR until reaching $22.7 billion valuation by 2032. This growth is being produced due to the increased construction industry demand, expanding applications in cosmetics and personal care, and high R&D investments. Leading companies in the sector are not only focusing on developing new silicone-based products to meet new customer needs but they are also participating in strategic partnerships and acquisitions to enhance their portfolios, market presence and technological capabilities. These companies are supporting market growth through diversification efforts and entering emerging markets with key players including Wacker Chemie AG and Elkem ASA among others (Research and Markets, 2024).

4.2. Process of transforming metallurgical silicon into semiconductors

4.2.1. Extraction, production and purification of silicon

Silicon extraction, production and purification involve a wide range of methods whose focus is to reduce costs, environmental impact and energy consumption.

Industrial silicon is generally extracted through the carbothermic reduction process. Inside it, quartzite or sand is reduced with different types of coal or coke in an electric arc furnace (explained afterwards in Chapter 4.4) at approximately 1800ºC. Different alternative approaches have emerged during the last years as a response to the elevated carbon oxide emissions emitted by this traditional method because of its highly energy intensive characteristics (Juzeliunas, 2022). One of these many approaches is electrochemical extraction, which allows silicon production to use renewable energy sources as a green alternative. Another sustainable solution is molten oxide electrolysis (MOE), which extracts silicon from a liquid state feedstock, achieving high purity product and reducing energy consumption while avoiding additional purification (Juzeliunas, 2022).

Once extracted, silicon undergoes several production processes. One of the most relevant and commonly used is the Siemens method, the main method to create semiconductor-grade silicon (Chen, Liu, Wang, Li & Chen, 2014) which involves the chlorination of metallurgical-grade silicon (MG-Si) to produce trichlorosilane (SiHCl3). This combination decomposes and deposits silicon onto rods at approximately 1100ºC when exposed to hydrogen, resulting in high-purity silicon. This method continues to dominate thanks to its high purity and scalability standards (Juzeliunas, 2022) and can make silicon reach a purity above 99.99999% (Chen et al., 2014). An aqueous HCl solution is as effective as hydrogen chloride gas in removing impurities (used in this method). So, increasing the number of HCl washes in a controlled environment could further lower metal impurity levels while decreasing atmospheric dust contamination (Chen et al., 2014).

An alternative production method is the Stanford Research Institute (SRI) process, which transforms silicon tetrafluoride (SiF4) gas into silicon using metal sodium at temperatures above 500ºC. This process is efficient but is limited by its high energy consumption, treatment of hazardous waste and need of specialized reactors, which are major drawbacks to consider (Chen et al., 2014).

Union Carbide process is another alternative production method which converts MG-Si into monosilane (SiH_4) through hydrocholirantion, which allows further refinement through physical vapor deposition (Juzeliunas, 2022). Fluidized bed reactor (FBR) offers an additional production method that allows the production of granules to be withdrawn from the reactor continuously. The resulting polysilicon granules have higher packing density than the chunks developed in the Siemens technology. Contrary to the FBR process, the Siemens process must be interrupted every time to withdraw the produced silicon bars that are used to create the chunks (Juzeliunas, 2022).

Purification processes are critical for refining silicon from metallurgical-grade to electronic-grade since it requires a purity of 99.999999999% (Juzeliunas, 2022). While being effective, the Siemens process is highly energy-intensive and costly since it must go across different stages (distillation, reduction, deposition) until reaching high-purity silicon. Several alternative purification methods have been developed such as solvent refining and zone refining. Solvent refining is an effective method for purifying MG-Si when eliminating impurities like boron and phosphorus, causing impurities to migrate into the liquid phase during solidification. Specifically, the Sn-Si alloy system has proven highly effective for removing boron, utilizing solvent refining and gas pressure filtration decreasing segregation coefficient of boron in this alloy highly below than the one found in pure silicon. Additionally, the Sn-Si alloy ensures that no silicon is lost during the refining process since eutectic phase (mixture of two substances that when melting at a single temperature lower than the melting points of individual materials, solidifies forming a structure of separate parts of each material) and intermetallic compounds aren't formed. Furthermore, gas pressure filtration used enhances the efficiency of the process when increasing pressure differential as purity levels achieved are improved (Li, Guo, Wang & Guo, 2020).

Zone refining is another standard purification technique in which a short molten zone moves along a silicon rod, allowing impurities to segregate at one end, making this method particularly suitable for achieving high purity silicon. This method is effective in removing most impurities but faces a challenge regarding boron removal (Juzeliunas, 2022). Laser granulation and vacuum smelting have been employed for silicon recovery from silicon sawdust, increasing purity to over 94%, though further refinement may be required to meet solar-grade silicon standards (Wei, Yang, Wan, Ma, Wu & Lei, 2020).

Electrochemical methods also provide environmentally friendly purification options. The FFC Cambridge process reduces silicon dioxide to silicon in molten salts without carbon reductants (Juzeliunas, 2022).

4.2.2. Impact on the electronics industry

Silicon's role in technology can be compared to carbon's role in biology as it acts as the foundation of information systems and digital infrastructure. The versatility of silicon-based semiconductors supports complex circuit designs that facilitate switching and gate operations crucial for computing. The understanding of silicon semiconductor properties in the 1940s resulted in the rapid advancement of solid-state-electronics and the formation of today's internet technologies (Raymer, 2009).

The development of silicon micro-electromechanical systems (MEMS) technologies has enabled high-volume production of sensors and actuators at a low cost. This is possible thanks to controlled anisotropic etching (removing material from a surface at different speeds in different directions) that allows precise microscale mechanical structure fabrication. Over the past decade, mobile communications have driven MEMS advancements to an era where digital devices integrate with the physical world (Ryhänen & Pohjonen, 2015).

The reliability requirements of pressure and motion sensors in the automotive sector laid the foundation for the MEMS industry. These requirements demanded rigorous testing and verification to ensure correct performance, resulting in refinement of MEMS technology. The creation of silicon-on-insulators (SOI) wafers provided the production of thick and monocrystalline silicon layers for micromechanical structures (Ryhänen et al., 2015).

The fundamental role of silicon extends to semiconductor and transistor technologies, as it serves almost exclusively as the base material due to its excellent electrical and mechanical properties. Silicon's unique oxide can be produced in extremely high quality and can be used in durable and high-performance applications thanks to its high breakdown voltages. High-density integrated circuits are produced mainly from silicon due to their favorable properties and processing methods that allow silicon to be transformed into a durable insulator through thermal oxidation. The manufacture of these circuits goes through three stages: uniform doping of silicon wafers, integrating electrical functions and packaging (Hilleringmann, 2023).

Chapter 5. Ferroalloys

Ferroalloys improve steel properties and are essential to its production. Their origins, key producers, types, production methods and applications are all covered in this chapter. Ferroalloys first appeared in the 19th century and China, South Africa and Brazil now produce most of them. Bulk alloys like ferrosilicon and ferromanganese represent 85-95% of global output, while minor alloys like ferrotungsten serve specialized industries. Modern methods such as electric arc furnaces ensure efficient and high-purity production supporting applications in construction, automotive and medical fields.

5.1. Origins

The initial reason to develop ferroalloys was to improve the properties of steel and alloys. This was achieved by adding specific chemical elements to molten metal. These alloys are combinations of one or more elements with iron. Ferroalloys date from the late 19th century when ferromanganese and ferrosilicon were first produced in blast furnaces. Since the beginning, production methods have been evolving, and the archaic blast furnace led to the electric arc furnace. This change was made because blast furnaces couldn't handle elements with a higher affinity for oxygen or produce alloys with low carbon content (Holappa, 2013).

Initially, trial and error were the base of alloying steel with limited knowledge on how to manage carbon content to modify steel properties. Further knowledge regarding the role of elements such as manganese, silicon, chromium and molybdenum came with evolution of chemistry during the 18th and 19th centuries. Manufacturers began using these elements to improve steel properties like strength and resistance to corrosion (Holappa, 2013).

The Bessemer converter in the 19th century allowed steelmakers to remove impurities from iron while keeping control over the carbon, which resulted in advances regarding the production of ferroalloys. Later, higher temperatures and better control over chemical composition of alloys was achieved thanks to the use of electric furnaces. These developments set the foundation for the modern ferroalloy industry. The growth of the steel industry in the 20th century led to the use of bulk ferroalloys such as ferrochromium, ferrosilicon and silicomanganese in steelmaking. The high demand of these alloyed products in industries like construction, energy and transportation continues guiding the ferroalloys production (Holappa, 2013).

5.2. Key producers worldwide

When discussing ferroalloy production, it's important to emphasize that they represent approximately 3% of the world's total steel production. One-third of this 3% involves the production of manganese-based ferroalloys, another fifth includes silicon-based ferroalloys, and the remainder encompasses chromium-based and other types of ferroalloys (Shaojun & Kuangdi, 2024b).

The global ferroalloy industry has few dominant players that supply essential materials for their creation. Around half of the world's steel production is generated in China (Gasik, Dashevskii & Bizhanov, 2020). This country benefits also from having large reserves of manganese, tungsten, vanadium and titanium (Shaojun et al., 2024b) which results in producing alloys with these ores at a competitive scale.

South Africa is another key player in this situation, holding the biggest chromium reserve all over the world, amounting to the 70% of all reserves (Gasik, 2013b). Also, South Africa is the second country when referring to ferrovanadium production, reaching almost a 14% in worldwide figures (Gasik et al., 2020). Regarding chromium reserves, Zimbabwe also plays an important role as it holds the second largest reserve. The main difference regarding chromium from Zimbabwe and the one from South Africa is that Zimbabwe chromite's have a higher chromium oxide content and a chromium to iron ratio higher than 3/2, which results in it being more suitable for the smelting of commercial ferrochrome (Gasik, 2013b).

Brazil dominates the niobium alloy production being responsible for approximately 90% of global production (Gasik, 2013c). The global market of ferrotungsten is led by China, Vietnam and Sweden. Finally, it is important to highlight that one of the largest producers of ferronickel is Indonesia, where the total production capacity exceeds 140 thousand tons per year (Gasik et al., 2020).

5.3. Types

Ferroalloys are generally divided into two main categories: bulk (or major) ferroalloys or special (minor) ferroalloys.

On one hand, bulk ferroalloys are produced in large quantities (millions of tons per year) and account for approximately 85-90% of the worldwide ferroalloy production. Their main goal is to improve the mechanical properties of steel. In these properties we include strength, durability and corrosion resistance (Gasik, 2013a). Some of the most produced bulk ferroalloys are ferrosilicon, ferromanganese and ferrochromium. Ferrosilicon is mainly used for alloying purposes, as it is the most important deoxidizing steel, improving electrical properties and increasing strength (Holappa, 2013). It's particularly important in the production of silicon-rich steels which contain 45%-75% silicon and are used in electrical applications due to their superior electrical conductivity (Tangstad, 2013a). Ferromanganese consists of adding manganese to steel, which haves three levels of varieties: high, medium and low carbon ones. Manganese adds hardness and toughness and reduces sulfur and oxygen impurities to steel (Tangstad, 2013b). Silicomanganese (silicon, manganese and iron) also has similar deoxidation properties and is used in high-strength steel manufacturing (Holappa, 2013). Ferrochromium, as ferromanganese, has also the same three different varieties according to its carbon composition. Chromium content in this alloy is always between 50% and 70%, where its corrosion resistance and durability have a critical role, developing stainless steel iconic rust-resistant properties (Gasik et al., 2020).

On the other hand, we have minor ferroalloys. They are produced in smaller quantities (thousands to tens of thousands of tons per year). The most well-known minor ferroalloys are ferrotungsten, ferromolybdenum and ferrovanadium. Ferrotungsten is used in the production of high-speed and tool steels that will work at higher temperatures and must retain their hardness. It's also used in radio and X-ray technology. Ferromolybdenum uses molybdenum, which is a crucial material in the manufacturing of electric lighting lamps and vacuum devices. This alloy improves strength and corrosion resistance of steels with its heat-resistance and acid-resistance (Gasik et al., 2020). Ferrovanadium is widely used for its cold-resistance, strength, toughness and wear resistance properties in aerospace engineering and other fields of technology (Gasik et al., 2020).

An "extra" category of ferroalloys is the complex ferroalloys. These alloys are designed to introduce multiple elements into the steel simultaneously to simplify the steelmaking process by reducing costs and improving efficiency. The most popular ones are silicomanganese-aluminum, used as a deoxidizer and enhancer of mechanical properties and calcium-silicon, that acts as a desulfurizer and deoxidizer of steel to increase its purity (Shaojun et al., 2024b).

5.4. Production methods

Ferroalloy production has experienced a considerable evolution over the past decades. In the early stages of the industry, the dominant technology to create ferroalloys were blast furnaces, producing ferromanganese and low-concentrated ferrosilicon. These furnaces operate by a process called carbothermic reduction, in which metallic oxides are reduced with carbon. However, blast furnaces have limitations when producing low-carbon ferroalloys or dealing with adding elements that have a strong affinity for oxygen (Shaojun & Kuangdi, 2024a).

By the 20th century electric arc furnaces became the primary technology for ferroalloy production, since it was especially used for alloys like ferrochromium, ferrosilicon and silicon-manganese (Gasik et al., 2020). The use of this kind of furnace allowed for higher temperatures to be used in the process for an increase in efficiency as better control over the chemical composition and the final properties of the alloy was taking place. Submerged arc furnaces are widely used for smelting ferroalloys. This technology involves placing carbon electrodes into a furnace with the tips submerged beneath the ore mixture. In other words, a combination of raw materials, reductants and fluxes is loaded into the furnace. The electric arcs between the electrodes create extremely high temperatures enabling materials to be smelt, resulting in the separation of metal from the slag and the form of liquid ferroalloys. Precise control over heat distribution and reduction processes is the main advantage of this methodology, allowing furnaces to create high-purity ferroalloys (Shaojun et al., 2024a).

The Metallothermic Reduction Process is another way of producing ferroalloys which involves the use of aluminum or silicon as reductants to reduce metal oxides in ores. This process can be divided into two methods. In the first place, we have the process of smelting without external heating thanks to the heat of aluminum, called aluminothermic. And in the second place, we have the electrosilicothermic where silicon is used as reductant in electric arc furnaces. Aluminothermic is used for ferroalloys like ferrotitanium and ferromolybdenum, and electrosilicothermic combined with desiliconization produces low-carbon alloys such as ferrovanadium and ferrotungsten (Shaojun et al., 2024a).

Modern production methods of ferroalloys are trying to improve significantly thanks to ongoing fundamental and applied research in which we can include energy-saving smelting processes as well as sophisticated electric furnace equipment. In both improvements automated control systems and enhanced process management techniques can be implemented to improve efficiency and competitiveness, optimizing operational performance (Gasik, 2013a).

5.5. Applications and industrial uses

Ferroalloys play a critical role in steel production as "not a single steel grade is produced without ferroalloys" (Owen & Wood, 2005, quoted by Gasik, 2013a). The extensive use of ferroalloys when deoxidizing and alloying metal products acting as enriching additives results in it being one of the bases of steelmaking processes, ensuring that the physical and mechanical characteristics meet industry standards and requirements. Ferroalloys that are sprayed with water are used in the manufacture of welding electrodes, within the powder metallurgy (Gasik et al., 2020).

Regarding casting and foundries, ferroalloys like ferrosilicon increase elasticity and reduce the oxidation in certain stainless-steel production. Also, they serve as inoculants promoting graphite nucleation, a process that becomes essential for the strengthening of cast iron (Tangstad, 2013a) used in automotive and construction sectors.

Certain high-silicon ferroalloys like ferrosilicon are used in the chemical industry specifically for producing silicones. These product properties, where we can find high temperature thermal stability, inertness and low content of impurity elements make them important regarding medical uses, insulators, lubricants and hydraulic fluids (Tangstad, 2013a). Ferroalloys are also used to increase resistance to corrosion and enhance durability during the enrichment of minerals, in order to create protective coatings for metal structures. (Gasik et al., 2020).

Chapter 6. Ferroglobe

Ferroglobe is a global leader in silicon metal, silicon-based alloys and manganese-based alloys that operates 25 facilities worldwide, dominating North American and global markets with a production capacity of 382.000 metric tons. Its diverse portfolio supports industries like construction, healthcare and electronics. In addition, the firm is committed to sustainability, with a focus on innovation and environmental responsibility, aiming to reduce Scope 1 and Scope 2 emissions by 2030 and continue leading the silicon and ferroalloy industries.

6.1. History and Global Presence

Ferroglobe PLC was formed on December 23, 2015. It was the result of a merger between Grupo FerroAtlántica in Spain and Globe Specialty Metals in the United States. This operation created a leading global producer of silicon metal, silicon-based alloys and manganese-based alloys (Ferroglobe PLC, 2024a).

The company began as VeloNewco Limited, a wholly owned subsidiary of Grupo VM incorporated under the U.K. Companies Act in February 2015. As a result of the operation previously mentioned, at the end of the same year it was registered as a public limited company, transforming into a new industry leader known as Ferroglobe PLC. Nowadays, Ferroglobe has a global range with 25 operational facilities spread throughout North America, Europe, South America, South Africa and Asia. The global presence provides the advantage of efficiently addressing fluctuations in global demand and modifying its production to meet specific customer requirements (Ferroglobe PLC 2024a). More than 18 electrometallurgy centers and 50 furnaces are part of their production facilities, collectively contributing to annual sales that exceed $2.6 billion (Ferroglobe PLC 2024b). This worldwide network establishes Ferroglobe as the leader with the capacity of silicon metal production reaching a global output of approximately 328,000 metric tons, holding a 66% share of the North American market and a 25% share of the global market without considering China (Ferroglobe PLC, 2024a).

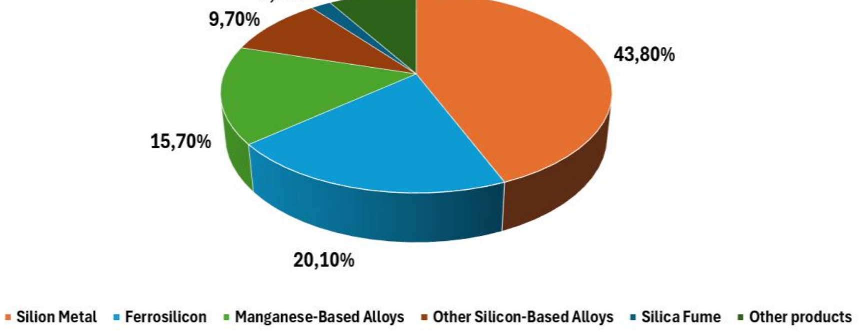
Ferroglobe's capabilities and activities extend beyond manufacturing and alloy production, including vertically integrated operations such as quartz mining activities in Spain, the United States, Canada and South Africa, as well as low-ash coal mining activities in the U.S. Additionally, the firm has stakes within the hydroelectric power sector in France, which in turn supports its manufacturing requirements and highlights the company commitment to sustainability (Ferroglobe PLC, 2024a).

In recent years, the firm has devoted significant efforts to strengthen its competitive position starting in 2020, as it launched a transformation process to enhance global efficiency, long term profitability and competitiveness. This initiative is driven by innovation, digitalization and sustainability, seeking to unify the company's brand and operations across all its activity regions. Throughout the company's history, several transactions have shaped its current structure and market position. These include the acquisition of Hidro Nitro Española SA in 1996, Pechiney Électrométallurgie in 2005 and the divestiture of FerroAtlántica S.A.U. in 2019 (Ferroglobe PLC, 2024b).

6.2. Products, Applications and Industrial Collaborations

Ferroglobe stands as a global leader in the production of silicon metal, silicon-based alloys and manganese-based alloys supporting multiple industries. Silicon metal is a key player in the product portfolio of Ferroglobe due to its versatile applications. Ferroglobe also produces a variety of specialized foundry products tailored to customer needs, with over 20 different solutions that try to meet different industrial requirements. Another critical product for Ferroglobe is ferrosilicon, used extensively in steel production. Calcium silicon is also developed by the firm, a solution which supports steel deoxidation and desulfurization in the process of quality enhancement of liquid steel. Additionally, as a result of their manufacturing process Ferroglobe collects a product called silica fume, which is used in construction applications. The fact that almost every output throughout the different processes is being used, including its waste, demonstrates the company's commitment to sustainable practices by reusing materials (Ferroglobe PLC, 2024a).

Chart 1: Ferroglobe's product portfolio according to 2023 revenues



Author elaboration with data retrieved from *Form 20-F: Annual report for the fiscal year ended December 31, 2023*, by Ferroglobe PLC, 2024.

The applications for Ferroglobe’s products can be found in a wide range of sectors. Starting with silicon metal, its presence is crucial in aluminum production as it reduces shrinkage and enhances the castability, hardness and corrosion resistance of the material. Construction, healthcare and electronics also benefit from silicon metal as they are used in silicone chemicals. In addition, silicon acts as the foundation of polysilicon, which is the starting point of solar cells and semiconductor manufacturing. Ferrosilicon supports the production of high-quality alloys. Finally, with silica flume, Ferroglobe offers a solution that increases water resistance and durability used in big scale infrastructures (Ferroglobe PLC, 2024a).

Regarding industrial collaborations, Ferroglobe has created strong links with different firms to support its R&D and market outreach. The company has stablished partnerships with universities and research institutes across Spain, France and other regions, to develop its technologies and applications. In addition, an important partnership with Dow Corning is taking place as Ferroglobe holds a majority stake in the Canada based silicon metal producer Bécanour Silicon Inc. (Ferroglobe PLC, 2024a).

6.3. Research and Development

Ferroglobe is a constantly growing firm that is immersed in several research and development initiatives to offer advanced and next generation products. Through its efforts, Ferroglobe is positioning itself as one of the leaders in advanced silicon-based solutions. One of Ferroglobe's main innovations is the ELSA electrode, which enhances energy efficiency during the silicon production process and prevents iron contamination. This solution is specifically tailor-made for silicon metal furnaces, making it a valuable asset for the industry. The commercialization of this solution has been done by licensing to worldwide silicon producers, paying royalties for its use. Constant developments and evolutions refine the ELSA electrode in order for it to keep being at the forefront of the industry (Ferroglobe PLC, 2024a).

Ferroglobe has also focused on producing high purity silicon highly demanded in certain specialized markets. Firstly, it started with creating solar-grade silicon whose purity exceeded 99.9999% through an innovative electrometallurgical process, while facing various market challenges. Because of that, Ferroglobe temporarily suspended its investments in solar-grade production in 2018. However, even with divestitures in this area, the company used their technological advances to redefine the strategy in producing high-purity silicon demanded in advanced materials applications such as lithium-ion batteries, reaching purity levels between 99.9-99.99%. When silicon is integrated into li-ion battery anodes battery capacity is improved, production costs and carbon emissions are reduced, and performance is enhanced in various conditions such as extreme cold (Ferroglobe PLC, 2024a).

All the efforts done by the firm to reach into specialized applications led to the creation of the Silicon for Advanced Technologies project, where purification techniques acknowledged from the solar-grade project and the expertise in milling were developed at the same time. The project also includes a program regarding li-ion batteries. To support this project, Ferroglobe has established a demonstration milling unit at its Innovation Centre in Sabón, Spain, and industrial purification units in Montricher, France, and Puertollano, Spain (Ferroglobe PLC, 2024a).

Ferroglobe's commitment to innovation is evident through its resource allocation to R&D. As of December 31, 2023, Ferroglobe reported $53.59 million in total accumulated development expenditures, focused as previously said on the development of the ELSA electrode and the high-purity silicon for lithium-ion batteries. While specific values like returns generated thanks to these investments or other data to calculate the ROI are not disclosed, the financial impact of these innovations is reflected in the company's operating performance, representing an average of 1% of annual sales (Ferroglobe PLC, 2024a).

6.4. Environmental Impact, Carbon Footprint Reduction initiatives and Compliance with Environmental Standards

All the operations and processes in which Ferroglobe is involved are strictly reviewed and controlled with a clear environmental, health and safety regulatory framework at local, national and global levels. These laws (those in European Union, U.S. and South Africa) affect Ferroglobe on the generation, discharge, and disposal of hazardous substances, as well as requirements for pollution prevention, waste management, greenhouse gas emissions and employee safety. To maintain the achievement of their objectives and the compliance of these regulations, Ferroglobe closely monitors their situation as non-compliance of the framework can result in administrative or civil fines or criminal charges. Also, another penalty for the companies that don't follow the rules includes mandates to remediate affected areas or the installation of additional pollution control equipment. Non-compliance could lead Ferroglobe to have restrictions on its operations or expose itself to be claimed for damages and have a considerable percentage of liabilities (Ferroglobe PLC, 2024a).

Ferroglobe is being increasingly impacted by carbon emission regulations as they impose or are expected to impose further limits or additional costs associated with carbon dioxide and greenhouse gas emissions. Ferroglobe's EU facilities operate under a cap-and-trade system which lands within the European Union broader strategy to mitigate carbon emissions. In this methodology, emissions exceeding allocated levels must be offset by purchasing additional emission rights from the market. Climate regulations will become stricter over time because of stakeholders' expectations. These pressures may require Ferroglobe to go beyond simple mandates and contribute to minimize climate change effects. As a response, the company established as an objective to reduce Scope 1 and Scope 2 emissions by 2030, to reflect Ferroglobe's commitment to transparency and environmental responsibility (Ferroglobe PLC, 2024a).

To manage financial risks linked to environmental compliance, Ferroglobe has an insurance coverage for potential liabilities. Although this hedging technique is effective, regulatory framework and compliance costs may vary in the future and surpass the insured resources. Those scenarios where increased compliance costs are not fully covered by the insurance would affect negatively the company's financial stability and operational results (Ferroglobe PLC, 2024a).

Chapter 7. Simulation of Electricity Price Fluctuations

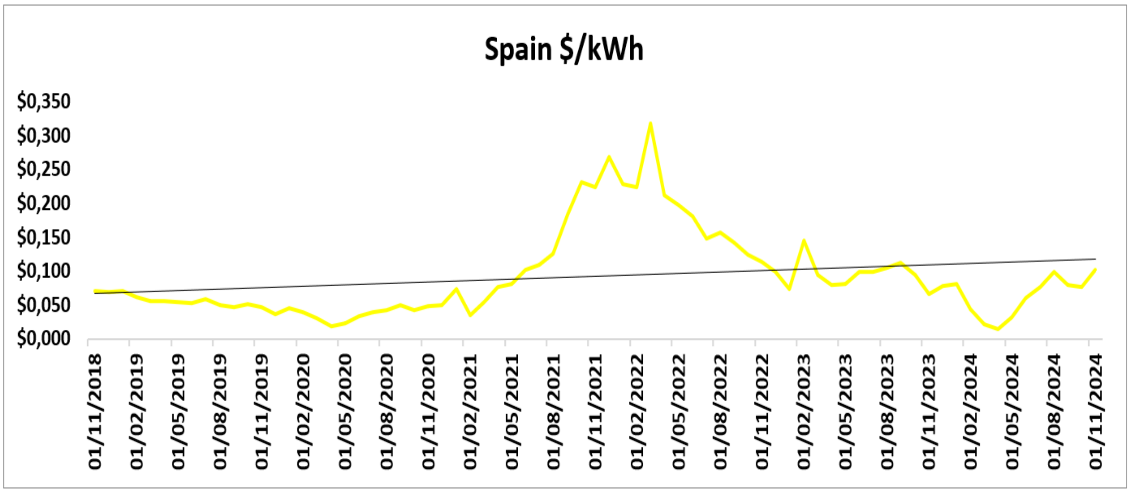
7.1. Simulation Methodology

After a description of the firm, the objective of this chapter is to evaluate how electricity price volatility affects Ferroglobe's production costs and profit margins. The simulation developed in this chapter will forecast cost scenarios and their respective mitigation sub-scenarios over the next five years, helping to determine the sensitivity of Ferroglobe's financial strength regarding electricity price changes. I have chosen electricity prices because they represent one of the most significant cost drivers for Ferroglobe's operations. As an energy-intensive company, the firm's production of silicon metal and ferroalloys relies significantly on electricity, which fluctuations have a substantial impact on the firm's production costs and margins.

Ferroglobe operates production facilities in several locations with tailored strategies when approaching electricity costs. In its factories in Spain, it buys electricity in the wholesale market, which has been incredibly volatile throughout the past five years. It benefits from long-term contracts and credits for electro-intensive consumption. In France, Ferroglobe benefits from three-year agreement that allows it French entities to leverage reduced transmission tariffs and interpretability compensation. Also, under the EU Emission Trading System, they receive compensation for indirect carbon dioxide costs, enhancing operational competitiveness through the year. In the United States, long-term supply contracts offer flexibility to interrupt load as needed. An example could be the West Virginia factory, where half of the power needs are met by a Brookfield Renewable Partners hydroelectric facility under a fixed-rate contract until 2025. South Africa operates under an "evergreen" agreement with the state-owned Eskom. These rates are regulated by the National Energy Regulator (NERSA) and are adjusted annually every April. Finally, in Norway, a long-term contract with Statkraft supplies 75% of Ferroglobe's energy at a fixed price (Ferroglobe PLC, 2024a).

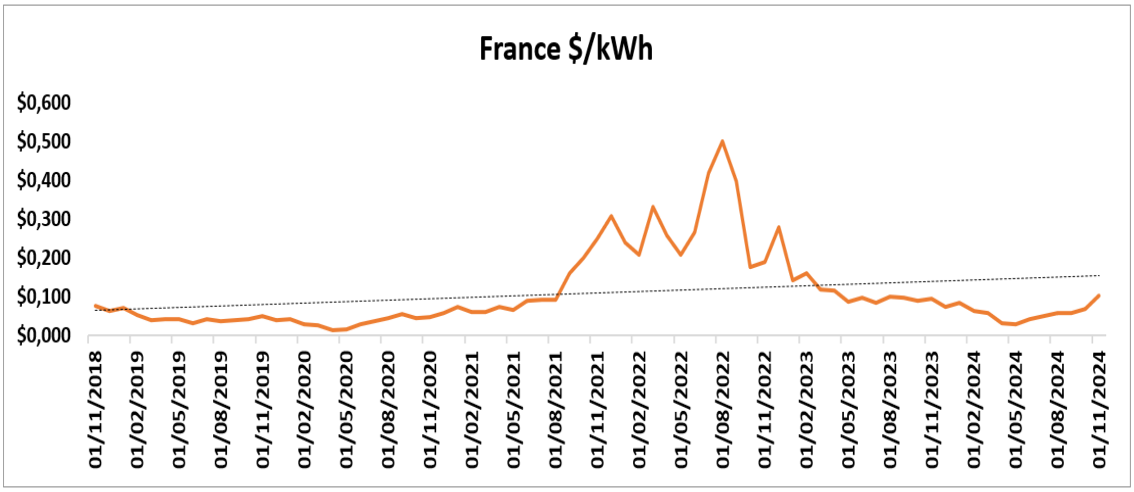
For the purpose of this study, historical electricity price data will be collected for these regions for the past 6 years, starting in November 2018. This data series will capture price volatility and trends over time. For the Spanish and French wholesale markets, the data was gathered from Red Eléctrica de España online database. The data from the North American wholesale market is obtained from the U.S Energy Information Administration online database. The same type of source was used for the Norwegian data but generated by Statistik sentralbyrå of Norway corresponding to the Nord Pool. Lastly, the fixed rates that correspond to the wholesale market prices in South Africa were gathered from Eskom online database. Furthermore, thorough research is done as each country has its own price measures (€/MWh, øre/kWh…) and has to be converted into a common measurement methodology and a common currency, being the $/kWh the selected one. For all the conversion work average monthly exchange rates from domestic currencies to dollars are downloaded from FactSet. After standardizing the unit of measurement prices across all countries where the Company operates, I illustrate through a graphical representation of the time series for each country. This consists in creating a visual of the evolution of electricity prices in each geographical location.

Chart 2: Spanish Historic Electricity Price in wholesale market



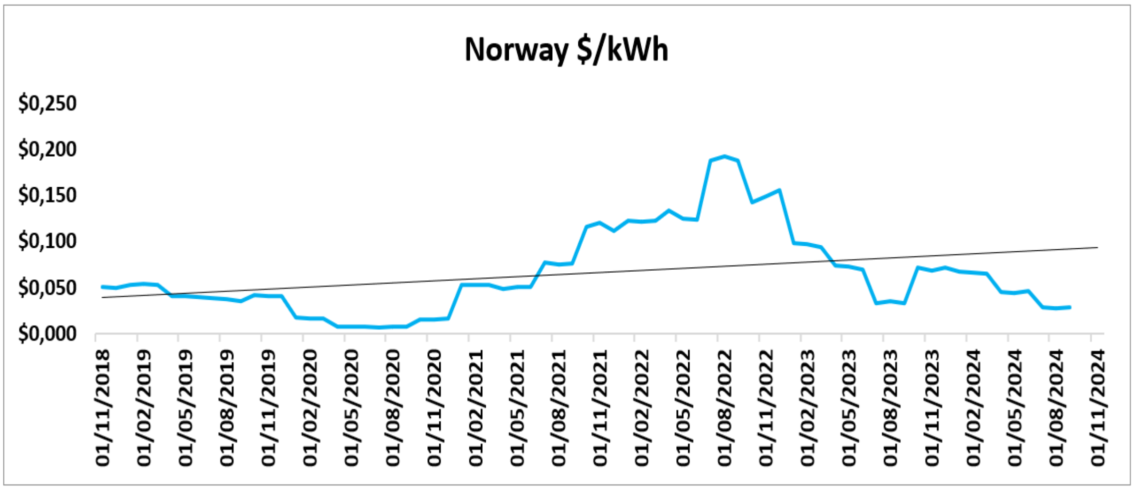
Author elaboration with data retrieved from *Appendix 1. Spot Prices for Spanish Wholesale Electricity Market*.

Chart 3: French Historic Electricity Price in wholesale market



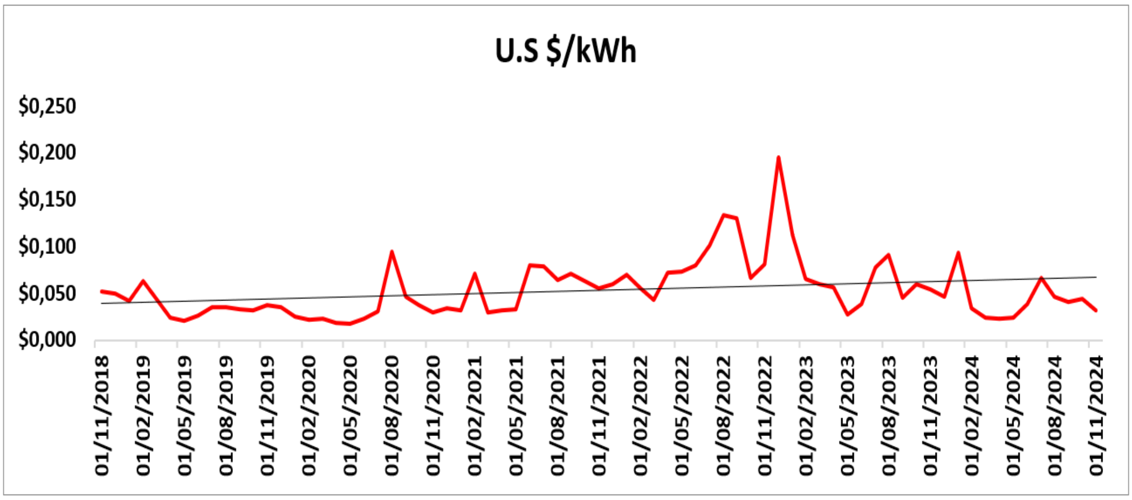
Author elaboration with data retrieved from *Appendix 2. Spot Prices for French Wholesale Electricity Market*.

Chart 4: Norwegian Historic Electricity Price in wholesale market



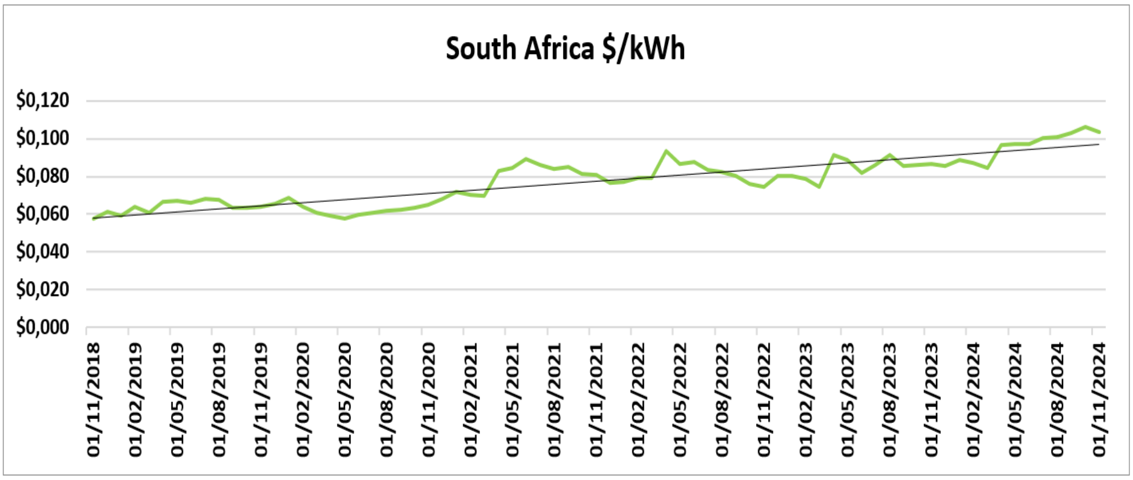
Author elaboration with data retrieved from *Appendix 3. Spot Prices for Norwegian Wholesale Electricity Market*.

Chart 5: North American Historic Electricity Price in wholesale market



Author elaboration with data retrieved from *Appendix 4. Spot Prices for North American Wholesale Electricity Market*.

Chart 6: South African Historic Electricity Price in wholesale market



Author elaboration with data retrieved from *Appendix 5. Spot Prices for South African Wholesale Electricity Market*.

At first sight, it becomes evident that all countries where Ferroglobe operates have experienced a gradual upward trend in electricity prices. All regions except South Africa saw a significant price spike in early to mid-2022, coinciding with the outbreak of the Russian-Ukrainian conflict. After the start of it, electricity prices tended to stabilize toward the end of the year, although they continued to maintain their overall upward line.

The projection of electricity prices in each region will involve simulating three different scenarios: (1) a pessimistic scenario in which a monthly increase of 1.5% in electricity prices will be assumed, (2) a neutral scenario which will consider normal fluctuations around the historical average of electricity prices in each region but incorporating a trend component to reflect the behavior previously explained in the graphs, and (3) an optimistic scenario which will assume a monthly decrease of 1% in electricity prices compared to the previous month.

The use of historical data as the core of the simulation is based on the premise that past trends provide the most reliable and unbiased basis to understand electricity price behavior in countries where the firm operates, ensuring that estimations are firmly grounded in observable realities rather than speculative forecasts. The decision to design these scenarios with their respective assumptions is entirely my own and is not derived from the projections of market analysts or external institutions. This approach allows greater adaptability as it avoids potential biases or inaccuracies associated with relying on third-party forecasts.

In this simulation, it is necessary to understand a new concept: Maximum Productive Capacity. As the name suggests, it represents the sum of maximum production capacities of all Ferroglobe furnaces and plants across geographies where it operates. This figure is crucial as it will help establish the maximum productive capacity for each country in which Ferroglobe operates.

Returning to the scenarios proposed for the simulation, each of the three general scenarios will include two sub-scenarios (a, b) that share the same conditions. In the first sub-scenario (a), the weighted price representing the average electricity costs for Ferroglobe will be calculated by summing the product of the projected price under the conditions set for each country and its percentage contribution to Ferroglobe's Maximum Productive Capacity. When estimating the company's total electricity costs for each month, the starting point was the Raw Materials and Energy Consumption costs reported in

Ferroglobe's 2023 annual report, obtained from FactSet. Once this figure was determined, it was divided and assigned to each country based on its contribution to the company's total production. From there, an estimation of kWh consumption was made for each country by dividing the total estimated cost for that country by the average of all the twelve electricity prices recorded in that country throughout the year. It is important to note that this 2023 kWh consumption estimate will remain constant in the analysis to simplify the process and ensure that the focus is exclusively on the influence of electricity prices on Ferroglobe's financial situation. Finally, to determine total monthly electricity costs across all geographies, the previously calculated weighted price will be multiplicated by the total kWh consumption figure and then divided by the 12 months of the year to distribute the consumption across the months.

In the second sub-scenario (b), the weighted average price representing the average electricity cost for the company will be calculated using a new figure: the tons of products manufactured by Ferroglobe in 2023. This data is obtained from the 20-F document reviewed for the completion of this thesis. The total production for 2023 will be set as a constant for the simulations to simplify calculations. This annual production figure will be divided by twelve to obtain monthly production volumes. Following, an Excel macro has been created to replicate Ferroglobe's real-world operational behavior. This behavior involves leveraging its high producing capacity and high demand to adjust production across different countries based on electricity prices. Specifically, the macro will distribute the monthly production of material among the countries where Ferroglobe operates, prioritizing those with the lowest simulated electricity prices. In practice, the allocation of material to countries will be done considering their maximum productive capacity while favoring regions with lower electricity costs. After all the electricity price for each country will be multiplied by the share of the production assigned to that country for the given month relative to the total production.

After completing the simulation of future electricity prices and total costs incurred by the company under each scenario and sub-scenario, the next step is to analyze the results in relation to the company's income statement. For this purpose, the historical quarterly income statements from the past six years will serve as a baseline, with them sourced from FactSet. For maximum precision on the analysis, income statements are downloaded and worked the same way as the firm reports them, avoiding mistakes in standardization. To provide a simpler understanding of the general distribution of Ferroglobe's P&L, a table has been created to highlight its main components. Since the Q4 2024 results had not been published at the time of completing this research, the 2023 data will be used as a reference for illustrative purposes.

Table 2: Main components of Ferroglobe's 2023 Full year P&L

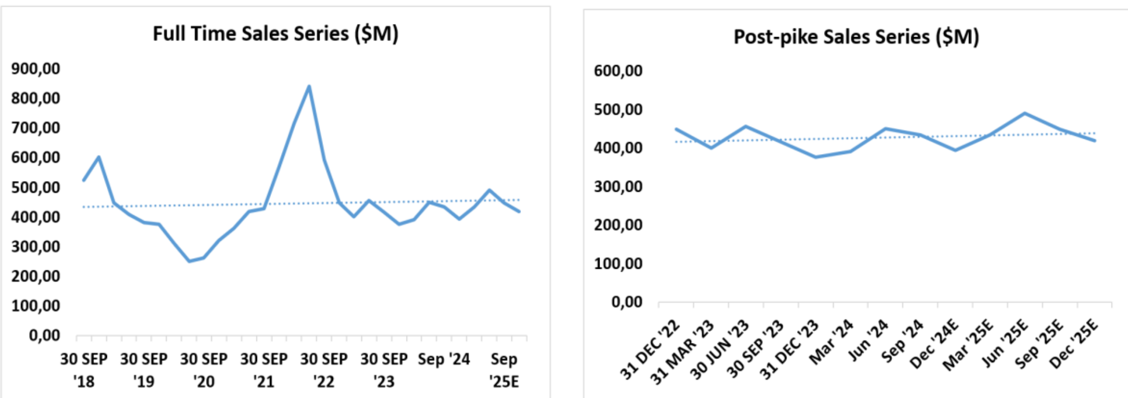
	Value (USD thousands)	% Net Sales
Net Sales	$1.650.034	
Operating Income	$100.992	6,12%
Raw materials and energy consumption	-$879.286	-53,29%
Staff Costs	-$305.859	-18,54%
Other operating Expense	-$27.009	-1,64%
Depreciation and amortization	-$73.532	-4,46%
Impairement of Long-lived assets	-$2.529	-0,15%
Finance Income	$5.422	0,33%
Finance Costs	-$38.793	-2,35%
Exchange differences	-$7.551	-0,46%

Author elaboration with data retrieved from *Appendix 14. Ferroglobe Historic Income Statement*.

After identifying the main components, general and standardized items will be hand-made. Subsequently, the estimated projections for the company's sales over the next five quarters, provided by analysts and quants from FactSet, will be obtained. These figures will serve as the foundation for building the income statement projection items for the future 60 months.

First, as it was done with the time series for electricity prices, the time series for all key income statement items will be plotted. These include sales, COGS (in our case study Raw materials and Energy Consumption), staff costs, depreciation and amortization, impairment of long-lived assets, other operating income, other operating expenses and other gains and losses. This visualization will allow the analysis of their structure.

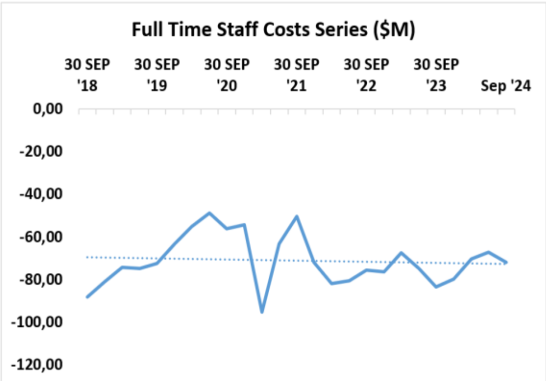
Charts 7 and 8: Ferroglobe's Sales evolution

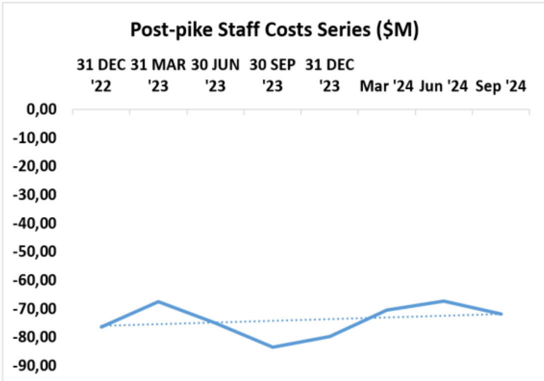


Author elaboration with data retrieved from *Appendix 14. Ferroglobe Historic Income Statement*

We will start by focusing on sales. Upon examining the graphs, it becomes apparent that like electricity prices, the company's sales have a value that could be considered an outlier in mid-2022. After it, sales stabilized in the following quarters while maintaining an upward trend. After reaching the apex point, sales display a positive trend with noticeable seasonality: Q2 sales are consistently the highest of the year while Q4 are the lowest. This pattern has been repeated over the past two years. Therefore, it becomes necessary to apply sales projections influenced by both a trend-based approach and a seasonal adjustment. Using analysts estimates from FactSet as a reference, the sales simulation will incorporate a positive trend calculated based on the sales data from the last 12 quarters (starting from the first quarter after the mid-2022 peak). Additionally, a seasonal component will be added, reflecting the observed seasonality: Q2 sales will peak as the highest of the year, Q3 sales are higher than Q1 and Q4 sales will be the lowest.

Charts 9 and 10: Ferroglobe's Staff Costs evolution

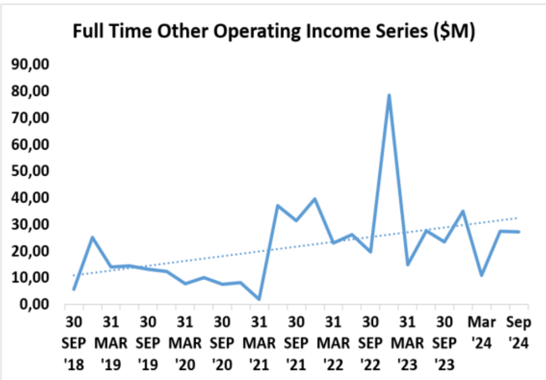


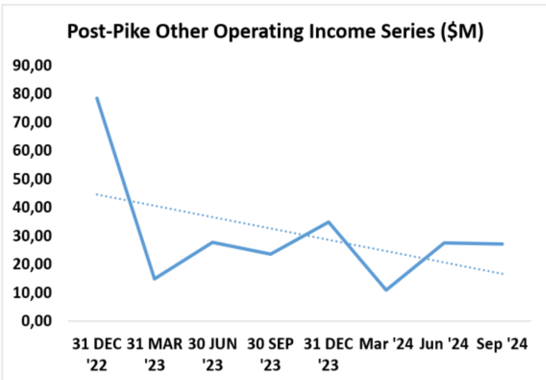


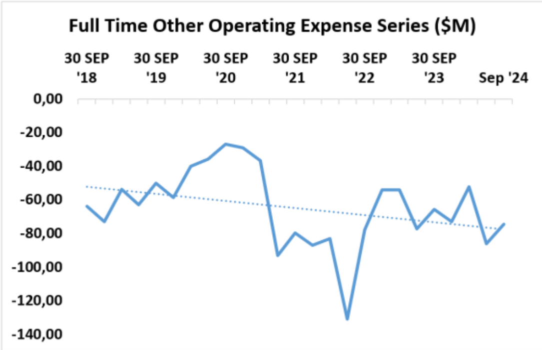
Author elaboration with data retrieved from *Appendix 14. Ferroglobe Historic Income Statement*

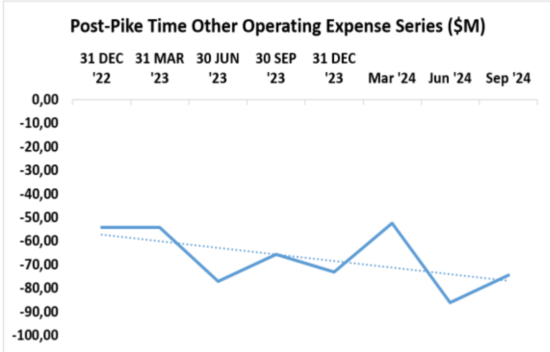
When analyzing the charts for staff costs, it becomes evident that their value over the quarters has been directly proportional to the volume of sales in the same period. Consequently, their future estimation will be based on calculating the historical average proportion of staff costs relative to the gross income over the past 25 quarters. This proportion will then be applied to the gross income of the specific quarter.

Charts 11, 12, 13 and 14: Ferroglobe's Other Operating Income and Expense evolution









Author elaboration with data retrieved from *Appendix 14. Ferroglobe Historic Income Statement*

Analyzing Other Operating Income and Other Operating Expenses, it becomes clear that both exhibit highly variable values. However, a closer examination of annual ranges reveals distinct seasonal patterns. For Other Operating Income, Q2 values are consistently higher than those in Q1, while Q4 values are the highest of the year. Next, Q3 values are lower than those in Q2. A similar seasonality is observed in Other Operating Expenses, where Q1 shows the lowest expense of the year, followed by Q2 which has the highest expenses, then Q3 where expenses decrease, and finally Q4 where expenses rise again but remain lower than in Q2. Like the sales projections, the forecasts for these two-line items will be calculated by multiplying the average values from the last 8 quarters (post sales pike) by the seasonal component applied to the same seasonal component applied to the sales projections. However, this seasonal adjustment will be tailored to the specific seasonal variations observed for each line item, to ensure that the projections accurately reflect their own cyclical behavior.

Finally, since values for Depreciation and Amortization, Impairment of long-lived assets and Other Gains and Losses are influenced by external factors such as investments and other activities, which are challenging to predict accurately, a historical average will be used for projections.

7.2. Comparative analysis

After completing all the projections, several insights have been detected from the different scenarios. First, a comparative analysis of the scenarios reveals critical differences.

Neutral Scenario

On one hand, in the neutral scenario under the sub-scenario preferences on maximum productive capacity allocation, electricity costs account for an average of 52% like COGS throughout the simulated period. This tends to reduce the EBITDA and EBIT margins to averages of 22% and 5% respectively. By the last simulated period (Q4 2029), the EBITDA margin drops to 20%, which highlights the company's dependence on electricity prices but having a strong position against fluctuations. If the historic medium term upward trend combined with the 2022 price hike effects persist in the future, the company would experience financial distress as EBIT margins keep shrinking considerably from quarter to quarter. On the other hand, if the optimal allocation method is applied, the average electricity costs proportion to sales decrease by approximately 20%, leading to a 5% improvement in the EBITDA margin compared to the company's historical average. Moreover, the estimated EBIT margin under this sub-scenario improves significantly, reaching an average of 14%, completely in contrast to the small EBIT margin observed in the first one.

Optimal distribution saved $55-$65M per quarter on average compared to the Maximum Capacity approach. These savings were driven by prioritizing production in Norway and the United States, where electricity costs are consistently lower. For example, electricity costs in Q1 2027 optimal scenario were $131M, compared to $153M in the standard scenario.

Pessimistic Scenario

Looking at the pessimistic scenario, where electricity prices gradually increase, the standard allocation sub-scenario shows that electricity costs rise to represent the 66% of total sales. This causes EBITDA margin to shrink to 16% during the simulated period. Consequently, the average EBIT margin moves around 0%, with negative margins starting to appear in the two final projected years with significant values. However, if optimal production is implemented the production costs would drop to 55% of sales under the same pessimistic scenario. This approach would limit the EBITDA margin reduction to 21% and to 5% the EBIT one. Despite this mitigation, in the final simulated year the company will still incur operating losses.

In this scenario, despite higher electricity prices overall, Optimal Distribution still saved around $45-$50M per quarter. The impact of price increases was mitigated by avoiding high-cost regions like France and at some point, Spain, and focusing on Norway, U.S and South Africa.

Optimistic Scenario

Finally, in the optimistic scenario the projections for the inefficient distribution sub-scenario indicate that the energy expenses account for 33% of total sales, representing a 15% reduction from the neutral scenario, leading to the EBITDA margin to increase to 32% and the EBIT margin to 16%. Although this is the scenario where electricity prices gradually decline, efficiency can still be improved by localizing production in regions with the cheapest prices. With it, the electricity expenses of the firm drop further to 29% of sales, increasing the EBITDA margin by an additional 2% and the EBIT margin by 1% compared to the inefficient distribution sub-scenario.

Savings were smaller, but thanks to the Optimal Distribution, Ferroglobe would still save $17-$22M per quarter on electricity costs.

Table 3: Scenarios Summary

Metric	Pessimistic Scenario		Neutral Scenario		Optimistic Scenario	
Sub-scenario	Max. Productive Capacity allocation	Optimal allocation	Max. Productive Capacity allocation	Optimal allocation	Max. Productive Capacity allocation	Optimal allocation
Electricity Costs (% of Sales)	66%	55%	52%	32%	33%	29%
EBITDA Margin (%)	16%	21%	22%	27%	32%	34%
EBIT Margin (%)	0%	5%	5%	14%	16%	17%
Quarterly Savings ($M)	$45-$50M		$55-$65M		$17-$22M	
Key Insights	Mitigates EBIT losses but negative margins appear in the later years. Prioritize Norway, U.S. and South Africa		Stronger resilience under Optimal Allocation by prioritizing Norway and U.S.		Savings diminish but efficiency gains still notable.	

Author elaboration with data retrieved from simulations

Regarding country issues, the United Sates offers the lowest electricity costs followed by Norway, contributing the highest proportion of production in Optimal allocation sub-scenarios. This consistent advantage should be prioritized for future capacity expansions or adding long-term electricity supply contracts. Also, Spain and France have the highest prices, as France is not used at all in the optimistic and pessimistic scenarios and the same for Spain in the neutral one. Finally, South Africa is in the middle and plays a key role in balancing the production costs. Although the terms of the long-term contract with the South African state-owned supplier Eskom are not accessible, it is likely that the terms and prices are more favorable than those simulated in this thesis. Therefore, further relationships and investments should be considered in this country given its “stable” pricing trend.

Making a simple sensitivity analysis consisting of proving and analyzing the effects of increasing or decreasing electricity prices by 10%. It has been previously revealed that an increase of that amount in the prices would reduce EBITDA margins by 3%-6% in all sub-scenarios. On the other hand, a 10% decrease would result in boosted EBITDA margins of around 3%-6,5% on average in all sub-scenarios. These considerable changes confirm the importance of hedging correctly the electricity prices fluctuations with flexible production strategies.

The simulation exposes the significant influence of electricity price fluctuations on Ferroglobe's financial performance, highlighting the critical role of cost management and strategic production allocation when reallocating production to regions with lower electricity costs to generate savings. The pessimistic scenario demonstrates the financial vulnerabilities arising from the increase in electricity prices, having margins contract to critical levels without proper mitigation strategies. Contrarily, the optimistic scenario showcases the benefits of lower electricity prices, although efficiency gains from optimal allocation remain relevant even in favorable conditions.

In addition, the United States, Norway and South Africa emerge as advantageous regions due to their stable electricity prices (some driven by market conditions and others by long-term supply contracts). This stability offers Ferroglobe a unique opportunity to increase production in these countries while developing a more predictable and conservative cost structure.

As a summary, this simulation not only identifies cost-saving opportunities and solutions but also provides actionable insights for the company's decision-making in future scenarios.

Conclusions

The semiconductor industry is serving as the steppingstone for the advancements in electronics, renewable energy, healthcare, transportation and many other industries. Recent supply chain disruptions have highlighted its critical role in the economy and the need to reinforce it. By examining the industry's initial production stages, this study underlines the importance of raw material production in ensuring industry's sustainability and growth.

Silica, as the source of silicon, undergoes chemical transformations to meet the purity standards required in different applications. The evolution of purification techniques such as the Siemens method and other electrochemical methods reflects the commitment to efficiency and environmental standards, in order not only to improve cost efficiency but also to reduce the environmental footprint created during all the process.

Ferroglobe, as a global leader in silicon metal and ferroalloy production, exemplifies the ability to combine resource management with innovation while it aligns its operations with sustainable practices, such as recycling byproducts and investing in renewable energy. The firm doesn't only meet industry demands but also contributes to broader goals related to environmental responsibility and carbon footprint reduction.

One of the most relevant insights of this thesis is based on the impact of electricity price fluctuations on energy-intensive companies like Ferroglobe. The simulation of future electricity pricing scenarios revealed the importance of efficient allocation of production to regions with lower or more stable energy costs. Optimal production allocation in locations like United States, Norway and South Africa can substantially mitigate operational risks.

Additionally, the analysis demonstrates that advanced silicon applications like lithium-ion batteries and solar energy systems represent growth areas where Ferroglobe is well positioned thanks to its investment in research and development. This thesis opens the door for further research into external factors such as regulatory or demand changes, development of sustainable technologies or new silicon applications. These elements could redefine the global outlook for this industry in the future.

Appendix

Appendix 1. Spot Prices for Spanish Wholesale Electricity Market Retrieved November 15, 2024, from https://www.esios.ree.es/es/analisis/600?compare_indicators=1001%2C705&start_date=01-11-2018T00%3A00&geoids=&vis=1&end_date=30-11-2024T23%3A55&compare_start_date=01-10-2018T00%3A00&groupby=month

id	name	geoid	geoname	value	datetime
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600	Precio mercado SPOT Diario España	3	España	30,399	2024-05-01T00:00:00+02:00
600	Precio mercado SPOT Diario España	3	España	56,08	2024-06-01T00:00:00+02:00
600	Precio mercado SPOT Diario España	3	España	72,313	2024-07-01T00:00:00+02:00
600	Precio mercado SPOT Diario España	3	España	91,054	2024-08-01T00:00:00+02:00
600	Precio mercado SPOT Diario España	3	España	72,623	2024-09-01T00:00:00+02:00
600	Precio mercado SPOT Diario España	3	España	68,554	2024-10-01T00:00:00+02:00
600	Precio mercado SPOT Diario España	3	España	94,41	2024-11-01T00:00:00+01:00

Appendix 2. Spot Prices for French Wholesale Electricity Market Retrieved November 15, 2024, from https://www.esios.ree.es/es/analisis/600?compare_indicators=1001%2C705&start_date=01-11-2018T00%3A00&geoids=&vis=1&end_date=30-11-2024T23%3A55&compare_start_date=01-10-2018T00%3A00&groupby=month

id	name	geoid	geoname	value	datetime
600	Precio mercado SPOT Diario Francia	2	Francia	67,805	2018-11-01T00:00:00+01:00
600	Precio mercado SPOT Diario Francia	2	Francia	54,896	2018-12-01T00:00:00+01:00
600	Precio mercado SPOT Diario Francia	2	Francia	61,155	2019-01-01T00:00:00+01:00
600	Precio mercado SPOT Diario Francia	2	Francia	46,621	2019-02-01T00:00:00+01:00
600	Precio mercado SPOT Diario Francia	2	Francia	33,864	2019-03-01T00:00:00+01:00
600	Precio mercado SPOT Diario Francia	2	Francia	38,081	2019-04-01T00:00:00+02:00
600	Precio mercado SPOT Diario Francia	2	Francia	37,213	2019-05-01T00:00:00+02:00
600	Precio mercado SPOT Diario Francia	2	Francia	29,257	2019-06-01T00:00:00+02:00
600	Precio mercado SPOT Diario Francia	2	Francia	37,663	2019-07-01T00:00:00+02:00
600	Precio mercado SPOT Diario Francia	2	Francia	33,393	2019-08-01T00:00:00+02:00
600	Precio mercado SPOT Diario Francia	2	Francia	35,542	2019-09-01T00:00:00+02:00
600	Precio mercado SPOT Diario Francia	2	Francia	38,598	2019-10-01T00:00:00+02:00
600	Precio mercado SPOT Diario Francia	2	Francia	45,942	2019-11-01T00:00:00+01:00
600	Precio mercado SPOT Diario Francia	2	Francia	36,462	2019-12-01T00:00:00+01:00
600	Precio mercado SPOT Diario Francia	2	Francia	38,006	2020-01-01T00:00:00+01:00
600	Precio mercado SPOT Diario Francia	2	Francia	26,246	2020-02-01T00:00:00+01:00
600	Precio mercado SPOT Diario Francia	2	Francia	23,832	2020-03-01T00:00:00+01:00
600	Precio mercado SPOT Diario Francia	2	Francia	13,45	2020-04-01T00:00:00+02:00
600	Precio mercado SPOT Diario Francia	2	Francia	14,862	2020-05-01T00:00:00+02:00
600	Precio mercado SPOT Diario Francia	2	Francia	25,786	2020-06-01T00:00:00+02:00
600	Precio mercado SPOT Diario Francia	2	Francia	33,412	2020-07-01T00:00:00+02:00
600	Precio mercado SPOT Diario Francia	2	Francia	36,754	2020-08-01T00:00:00+02:00
600	Precio mercado SPOT Diario Francia	2	Francia	47,196	2020-09-01T00:00:00+02:00
600	Precio mercado SPOT Diario Francia	2	Francia	37,887	2020-10-01T00:00:00+02:00
600	Precio mercado SPOT Diario Francia	2	Francia	40,112	2020-11-01T00:00:00+01:00
600	Precio mercado SPOT Diario Francia	2	Francia	48,416	2020-12-01T00:00:00+01:00
600	Precio mercado SPOT Diario Francia	2	Francia	59,48	2021-01-01T00:00:00+01:00
600	Precio mercado SPOT Diario Francia	2	Francia	49,012	2021-02-01T00:00:00+01:00
600	Precio mercado SPOT Diario Francia	2	Francia	50,215	2021-03-01T00:00:00+01:00
600	Precio mercado SPOT Diario Francia	2	Francia	63,104	2021-04-01T00:00:00+02:00
600	Precio mercado SPOT Diario Francia	2	Francia	55,277	2021-05-01T00:00:00+02:00
600	Precio mercado SPOT Diario Francia	2	Francia	73,51	2021-06-01T00:00:00+02:00
600	Precio mercado SPOT Diario Francia	2	Francia	78,37	2021-07-01T00:00:00+02:00
600	Precio mercado SPOT Diario Francia	2	Francia	77,303	2021-08-01T00:00:00+02:00
600	Precio mercado SPOT Diario Francia	2	Francia	135,309	2021-09-01T00:00:00+02:00
600	Precio mercado SPOT Diario Francia	2	Francia	172,446	2021-10-01T00:00:00+02:00
600	Precio mercado SPOT Diario Francia	2	Francia	217,059	2021-11-01T00:00:00+01:00
600	Precio mercado SPOT Diario Francia	2	Francia	274,672	2021-12-01T00:00:00+01:00
600	Precio mercado SPOT Diario Francia	2	Francia	211,423	2022-01-01T00:00:00+01:00
600	Precio mercado SPOT Diario Francia	2	Francia	185,549	2022-02-01T00:00:00+01:00
600	Precio mercado SPOT Diario Francia	2	Francia	295,205	2022-03-01T00:00:00+01:00
600	Precio mercado SPOT Diario Francia	2	Francia	233,096	2022-04-01T00:00:00+02:00
600	Precio mercado SPOT Diario Francia	2	Francia	197,431	2022-05-01T00:00:00+02:00
600	Precio mercado SPOT Diario Francia	2	Francia	248,4	2022-06-01T00:00:00+02:00
600	Precio mercado SPOT Diario Francia	2	Francia	400,866	2022-07-01T00:00:00+02:00
600	Precio mercado SPOT Diario Francia	2	Francia	492,489	2022-08-01T00:00:00+02:00
600	Precio mercado SPOT Diario Francia	2	Francia	394,703	2022-09-01T00:00:00+02:00
600	Precio mercado SPOT Diario Francia	2	Francia	178,881	2022-10-01T00:00:00+02:00
600	Precio mercado SPOT Diario Francia	2	Francia	191,883	2022-11-01T00:00:00+01:00
600	Precio mercado SPOT Diario Francia	2	Francia	270,887	2022-12-01T00:00:00+01:00
600	Precio mercado SPOT Diario Francia	2	Francia	132,097	2023-01-01T00:00:00+01:00
600	Precio mercado SPOT Diario Francia	2	Francia	148,765	2023-02-01T00:00:00+01:00
600	Precio mercado SPOT Diario Francia	2	Francia	111,958	2023-03-01T00:00:00+01:00
600	Precio mercado SPOT Diario Francia	2	Francia	106,363	2023-04-01T00:00:00+02:00
600	Precio mercado SPOT Diario Francia	2	Francia	77,547	2023-05-01T00:00:00+02:00
600	Precio mercado SPOT Diario Francia	2	Francia	91,292	2023-06-01T00:00:00+02:00
600	Precio mercado SPOT Diario Francia	2	Francia	77,647	2023-07-01T00:00:00+02:00
600	Precio mercado SPOT Diario Francia	2	Francia	90,874	2023-08-01T00:00:00+02:00
600	Precio mercado SPOT Diario Francia	2	Francia	88,705	2023-09-01T00:00:00+02:00
600	Precio mercado SPOT Diario Francia	2	Francia	84,262	2023-10-01T00:00:00+02:00
600	Precio mercado SPOT Diario Francia	2	Francia	88,958	2023-11-01T00:00:00+01:00
600	Precio mercado SPOT Diario Francia	2	Francia	68,474	2023-12-01T00:00:00+01:00
600	Precio mercado SPOT Diario Francia	2	Francia	76,594	2024-01-01T00:00:00+01:00
600	Precio mercado SPOT Diario Francia	2	Francia	58,371	2024-02-01T00:00:00+01:00
600	Precio mercado SPOT Diario Francia	2	Francia	53,593	2024-03-01T00:00:00+01:00
600	Precio mercado SPOT Diario Francia	2	Francia	28,234	2024-04-01T00:00:00+02:00
600	Precio mercado SPOT Diario Francia	2	Francia	27,172	2024-05-01T00:00:00+02:00
600	Precio mercado SPOT Diario Francia	2	Francia	37,6	2024-06-01T00:00:00+02:00
600	Precio mercado SPOT Diario Francia	2	Francia	47,034	2024-07-01T00:00:00+02:00
600	Precio mercado SPOT Diario Francia	2	Francia	54,561	2024-08-01T00:00:00+02:00
600	Precio mercado SPOT Diario Francia	2	Francia	51,857	2024-09-01T00:00:00+02:00
600	Precio mercado SPOT Diario Francia	2	Francia	62,056	2024-10-01T00:00:00+02:00
600	Precio mercado SPOT Diario Francia	2	Francia	95,03	2024-11-01T00:00:00+01:00

Appendix 3. Spot Prices for Norwegian Wholesale Electricity Market Retrieved November 15, 2024, from https://www.ssb.no/en/statbank/table/09363/tableViewLayout1/

09363: Electricity prices in the wholesale market (øre/kWh), by type of contract, quarter and contents

		Electricity price, excl. taxes
WHOLESALES	2018K1	35,7
	2018K2	36,6
	2018K3	46,5
	2018K4	42,8
	2019K1	45,8
	2019K2	35,5
	2019K3	32,8
	2019K4	38,0
	2020K1	15,5
	2020K2	8,3
	2020K3	6,8
	2020K4	14,7
	2021K1	46,0
	2021K2	42,1
	2021K3	66,6
	2021K4	102,0
	2022K1	108,2
	2022K2	116,8
	2022K3	186,2
	2022K4	155,6
	2023K1	97,1
	2023K2	78,0
	2023K3	35,7
	2023K4	77,3
	2024K1	69,1
	2024K2	49,5
	2024K3	30,4

VAT and tax on consumption are not included. The fixed prices are based on market conditions.

Updated:
Electricity price, excl. taxes:
20241115 08:00

Appendix 4. Spot Prices for North American Wholesale Electricity Market Retrieved November 15, 2024, from https://www.bls.gov/regions/midwest/data/averageenergyprices_selectedareas_table.htm

Monthly Average	$/MWh	$/kWh
nov-18	52,00	0,052
dic-18	50,15	0,050
ene-19	42,28	0,042
feb-19	63,09	0,063
mar-19	43,19	0,043
abr-19	24,20	0,024
may-19	20,91	0,021
jun-19	25,98	0,026
jul-19	35,93	0,036
ago-19	35,16	0,035
sep-19	33,47	0,033
oct-19	31,90	0,032
nov-19	37,95	0,038
dic-19	35,56	0,036
ene-20	25,73	0,026
feb-20	22,20	0,022
mar-20	22,85	0,023
abr-20	18,67	0,019
may-20	17,48	0,017
jun-20	22,96	0,023
jul-20	31,11	0,031
ago-20	94,93	0,095
sep-20	46,35	0,046
oct-20	37,80	0,038
nov-20	29,38	0,029
dic-20	33,85	0,034
ene-21	31,97	0,032
feb-21	70,91	0,071
mar-21	29,40	0,029
abr-21	31,80	0,032
may-21	32,90	0,033
jun-21	79,85	0,080
jul-21	79,03	0,079
ago-21	65,01	0,065
sep-21	70,79	0,071
oct-21	63,03	0,063
nov-21	55,81	0,056
dic-21	60,20	0,060
ene-22	70,37	0,070
feb-22	55,56	0,056
mar-22	43,63	0,044
abr-22	72,12	0,072
may-22	73,78	0,074
jun-22	79,83	0,080
jul-22	100,88	0,101
ago-22	134,08	0,134
sep-22	130,65	0,131
oct-22	66,81	0,067
nov-22	80,91	0,081
dic-22	195,57	0,196
ene-23	112,85	0,113
feb-23	65,94	0,066
mar-23	59,60	0,060
abr-23	57,11	0,057
may-23	27,52	0,028
jun-23	38,34	0,038
jul-23	77,36	0,077
ago-23	91,35	0,091
sep-23	45,72	0,046
oct-23	60,44	0,060
nov-23	54,24	0,054
dic-23	46,09	0,046
ene-24	93,33	0,093
feb-24	34,83	0,035
mar-24	23,94	0,024
abr-24	23,14	0,023
may-24	24,00	0,024
jun-24	38,37	0,038
jul-24	66,98	0,067
ago-24	46,94	0,047
sep-24	41,26	0,041
oct-24	44,49	0,044
nov-24	32,40	0,032

Appendix 5. Spot Prices for South African Wholesale Electricity Market Retrieved November 15, 2024, from https://www.eskom.co.za/distribution/tariffs-and-charges/tariff-history/

Average prices c/kWh sold	Average prices c/kWh sold								
	2016/17	2017/18	2018/19	2019/20	2020/21	2021/22	2022/23	2023/24	2024/25
Local-authorities	81,38c	83,71c	88,53c	99,62c	109,44c	125,54c	140,18c		
Residential	118,60c	118,56c	125,73c	142,29c	154,57c	177,57c	196,71c		
Commercial	109,09c	111,25c	117,30c	134,15c	147,52c	169,40c	187,95c		
Industrial	67,71c	70,02c	73,99c	82,79c	90,03c	106,26c	119,34c		
Mining	84,80c	86,91c	91,64c	104,41c	113,77c	130,68c	143,51c		
Agriculture	141,70c	142,78c	149,79c	170,52c	187,91c	215,53c	243,68c		
Traction	104,95c	100,10c	110,17c	127,81c	154,17c	163,39c	202,28c		
International	70,77c	62,42c	66,13c	80,51c	76,93c	86,10c	93,55c		
Internal									
Average prices c/kWh	81,77c	82,49c	85,12c	95,95c	105,62c	122,75c	136,86c	162,38c	183,07c

Appendix 6. EUR/USD Historic rates

Price History: EURUSD

Date	Bid	Ask	Mid	Change	% Change	Cumulative Change %	High	Low
10/31/18	1,132900	1,133200	1,133050				1,158650	1,133050
11/30/18	1,132100	1,132400	1,132250	0,00	-0,07	-0,07	1,147100	1,125100
12/31/18	1,143000	1,143300	1,143150	0,01	0,96	0,89	1,143450	1,129750
01/31/19	1,147300	1,147600	1,147450	0,00	0,38	1,27	1,152150	1,135350
02/28/19	1,138600	1,138800	1,138700	-0,01	-0,76	0,50	1,146800	1,126350
03/29/19	1,122700	1,123000	1,122850	-0,02	-1,39	-0,90	1,138750	1,122400
04/30/19	1,120600	1,120800	1,120700	0,00	-0,19	-1,09	1,131400	1,114400
05/31/19	1,114200	1,114500	1,114350	-0,01	-0,57	-1,65	1,124400	1,112650
06/28/19	1,138700	1,138900	1,138800	0,02	2,19	0,51	1,138950	1,118550
07/31/19	1,113300	1,113500	1,113400	-0,03	-2,23	-1,73	1,132450	1,112650
08/30/19	1,101100	1,101400	1,101250	-0,01	-1,09	-2,81	1,121900	1,101250
09/30/19	1,090100	1,090300	1,090200	-0,01	-1,00	-3,78	1,108400	1,090200
10/31/19	1,115500	1,115800	1,115650	0,03	2,33	-1,54	1,115650	1,091750
11/29/19	1,102500	1,102700	1,102600	-0,01	-1,17	-2,69	1,116950	1,099950
12/31/19	1,122400	1,122600	1,122500	0,02	1,80	-0,93	1,122500	1,104900
01/31/20	1,108100	1,108300	1,108200	-0,01	-1,27	-2,19	1,122479	1,099850
02/28/20	1,098300	1,098600	1,098450	-0,01	-0,88	-3,05	1,105750	1,079250
03/31/20	1,097100	1,097400	1,097250	0,00	-0,11	-3,16	1,141850	1,068900
04/30/20	1,095200	1,095400	1,095300	0,00	-0,18	-3,33	1,096900	1,078350
05/29/20	1,112200	1,112500	1,112350	0,02	1,56	-1,83	1,112350	1,077750
06/30/20	1,123000	1,123300	1,123150	0,01	0,97	-0,87	1,138100	1,113750
07/31/20	1,182400	1,182600	1,182500	0,06	5,28	4,36	1,182500	1,122850
08/31/20	1,195800	1,196100	1,195950	0,01	1,14	5,55	1,195950	1,173800
09/30/20	1,172500	1,172800	1,172650	-0,02	-1,95	3,49	1,196350	1,161900
10/30/20	1,164700	1,165000	1,164850	-0,01	-0,67	2,81	1,187450	1,164850
11/30/20	1,196100	1,196300	1,196200	0,03	2,69	5,57	1,196200	1,163650
12/31/20	1,223400	1,223700	1,223550	0,03	2,29	7,99	1,230050	1,203250
01/29/21	1,214800	1,215000	1,214900	-0,01	-0,71	7,22	1,228100	1,207500
02/26/21	1,213700	1,213900	1,213800	0,00	-0,09	7,13	1,222400	1,197850
03/31/21	1,175200	1,175400	1,175300	-0,04	-3,17	3,73	1,207450	1,172750
04/30/21	1,203700	1,203900	1,203800	0,03	2,42	6,24	1,211200	1,176050
05/31/21	1,222500	1,222800	1,222650	0,02	1,57	7,91	1,224450	1,200500
06/30/21	1,185800	1,186000	1,185900	-0,04	-3,01	4,66	1,224500	1,185600
07/30/21	1,185700	1,185900	1,185800	0,00	-0,01	4,66	1,188450	1,176150
08/31/21	1,180300	1,180600	1,180450	-0,01	-0,45	4,18	1,188150	1,167950
09/30/21	1,158800	1,159100	1,158950	-0,02	-1,82	2,29	1,188100	1,158950
10/29/21	1,157100	1,157400	1,157250	0,00	-0,15	2,14	1,167650	1,154250
11/30/21	1,125500	1,125700	1,125600	-0,03	-2,73	-0,66	1,159050	1,119650
12/31/21	1,137100	1,137300	1,137200	0,01	1,03	0,37	1,137200	1,124700
01/31/22	1,120900	1,121100	1,121000	-0,02	-1,42	-1,06	1,146050	1,114900

Date	Bid	Ask	Mid	Change	% Change	Cumulative Change %	High	Low
02/28/22	1,123100	1,123300	1,123200	0,00	0,20	-0,87	1,146750	1,111400
03/31/22	1,112500	1,112800	1,112650	-0,01	-0,94	-1,80	1,116450	1,087550
04/29/22	1,054800	1,055100	1,054950	-0,06	-5,19	-6,89	1,103650	1,051650
05/31/22	1,071100	1,071400	1,071250	0,02	1,55	-5,45	1,077950	1,039450
06/30/22	1,045300	1,045600	1,045450	-0,03	-2,41	-7,73	1,073150	1,041050
07/29/22	1,019500	1,019800	1,019650	-0,03	-2,47	-10,01	1,042400	0,999650
08/31/22	1,005400	1,005700	1,005550	-0,01	-1,38	-11,25	1,035550	0,996650
09/30/22	0,979500	0,979800	0,979650	-0,03	-2,58	-13,54	1,013100	0,962100
10/31/22	0,988200	0,988500	0,988350	0,01	0,89	-12,77	1,004850	0,970050
11/30/22	1,029500	1,029800	1,029650	0,04	4,18	-9,13	1,040950	0,975850
12/30/22	1,067100	1,067400	1,067250	0,04	3,65	-5,81	1,067250	1,047350
01/31/23	1,085900	1,086200	1,086050	0,02	1,76	-4,15	1,090250	1,051950
02/28/23	1,060400	1,060600	1,060500	-0,03	-2,35	-6,40	1,094050	1,054150
03/31/23	1,086300	1,086600	1,086450	0,03	2,45	-4,11	1,091300	1,053450
04/28/23	1,103900	1,104100	1,104000	0,02	1,62	-2,56	1,104750	1,083950
05/31/23	1,066000	1,066200	1,066100	-0,04	-3,43	-5,91	1,105300	1,066100
06/30/23	1,090900	1,091100	1,091000	0,02	2,34	-3,71	1,095950	1,069050
07/31/23	1,102400	1,102700	1,102550	0,01	1,06	-2,69	1,124250	1,086750
08/31/23	1,085200	1,085500	1,085350	-0,02	-1,56	-4,21	1,102300	1,077050
09/29/23	1,058600	1,058900	1,058750	-0,03	-2,45	-6,56	1,080750	1,051150
10/31/23	1,056900	1,057100	1,057000	0,00	-0,17	-6,71	1,062950	1,047550
11/30/23	1,091000	1,091200	1,091100	0,03	3,23	-3,70	1,098100	1,053750
12/29/23	1,104500	1,104800	1,104650	0,01	1,24	-2,51	1,110550	1,074450
01/31/24	1,086100	1,086400	1,086250	-0,02	-1,67	-4,13	1,104632	1,079850
02/29/24	1,082000	1,082300	1,082150	0,00	-0,38	-4,49	1,085150	1,071750
03/29/24	1,079900	1,080100	1,080024	0,00	-0,20	-4,68	1,096000	1,080000
04/30/24	1,069100	1,069400	1,069250	-0,01	-1,00	-5,63	1,086800	1,062700
05/31/24	1,085500	1,085700	1,085600	0,02	1,53	-4,19	1,087600	1,068350
06/28/24	1,071600	1,071900	1,071750	-0,01	-1,28	-5,41	1,088000	1,068150
07/31/24	1,082000	1,082200	1,082100	0,01	0,97	-4,50	1,093150	1,072950
08/30/24	1,106800	1,107000	1,106900	0,02	2,29	-2,31	1,117850	1,079250
09/30/24	1,115900	1,116200	1,116050	0,01	0,83	-1,50	1,117900	1,101000
10/31/24	1,085500	1,085800	1,085650	-0,03	-2,72	-4,18	1,107650	1,077500
11/01/24	1.084800	1.085000	1.084900	0.00	-0.07	-4.25	1.084900	1.084900

Appendix 7. NOK/USD Historic rates

Price History: NOKUSD

Date	Bid	Ask	Mid	Change	% Change	Cumulative Change %	High	Low
10/31/18	0,118943	0,119012	0,118978				0,122723	0,118978
11/30/18	0,116202	0,116268	0,116235	0,00	-2,30	-2,30	0,120171	0,116015
12/31/18	0,115448	0,115521	0,115485	0,00	-0,65	-2,94	0,117873	0,113603
01/31/19	0,118682	0,118749	0,118715	0,00	2,80	-0,22	0,118715	0,114590
02/28/19	0,116980	0,117037	0,117008	0,00	-1,44	-1,66	0,118578	0,114671
03/29/19	0,116089	0,116156	0,116122	0,00	-0,76	-2,40	0,118028	0,113952
04/30/19	0,115611	0,115670	0,115640	0,00	-0,42	-2,80	0,117902	0,115258
05/31/19	0,114203	0,114270	0,114237	0,00	-1,21	-3,98	0,115652	0,113923
06/28/19	0,117259	0,117316	0,117288	0,00	2,67	-1,42	0,117779	0,114365
07/31/19	0,113837	0,113893	0,113865	0,00	-2,92	-4,30	0,117188	0,113865
08/30/19	0,109783	0,109847	0,109815	0,00	-3,56	-7,70	0,112658	0,109815
09/30/19	0,110033	0,110087	0,110060	0,00	0,22	-7,50	0,112029	0,109682
10/31/19	0,108887	0,108949	0,108918	0,00	-1,04	-8,45	0,110217	0,108330
11/29/19	0,108556	0,108608	0,108582	0,00	-0,31	-8,74	0,110187	0,108582
12/31/19	0,113772	0,113829	0,113801	0,01	4,81	-4,35	0,113904	0,108873
01/31/20	0,108460	0,108512	0,108486	-0,01	-4,67	-8,82	0,113853	0,108455
02/28/20	0,105546	0,105607	0,105577	0,00	-2,68	-11,26	0,108564	0,105577
03/31/20	0,095160	0,095298	0,095229	-0,01	-9,80	-19,96	0,108494	0,085620
04/30/20	0,097813	0,097890	0,097852	0,00	2,75	-17,76	0,098147	0,092779
05/29/20	0,102845	0,102913	0,102879	0,01	5,14	-13,53	0,102879	0,096440
06/30/20	0,103631	0,103687	0,103659	0,00	0,76	-12,87	0,107923	0,102566
07/31/20	0,110113	0,110179	0,110146	0,01	6,26	-7,42	0,110284	0,104799
08/31/20	0,115199	0,115268	0,115234	0,01	4,62	-3,15	0,115234	0,109378
09/30/20	0,106848	0,106905	0,106876	-0,01	-7,25	-10,17	0,114494	0,104338
10/30/20	0,104582	0,104648	0,104615	0,00	-2,12	-12,07	0,109494	0,104311
11/30/20	0,112883	0,112937	0,112910	0,01	7,93	-5,10	0,113315	0,104403
12/31/20	0,116745	0,116847	0,116796	0,00	3,44	-1,83	0,117131	0,113127
01/29/21	0,116885	0,116952	0,116919	0,00	0,11	-1,73	0,118965	0,115846
02/26/21	0,116090	0,116144	0,116117	0,00	-0,69	-2,40	0,119274	0,115687
03/31/21	0,117118	0,117174	0,117146	0,00	0,89	-1,54	0,118576	0,115421
04/30/21	0,120335	0,120391	0,120363	0,00	2,75	1,16	0,121726	0,117218
05/31/21	0,120158	0,120249	0,120203	0,00	-0,13	1,03	0,121846	0,119238
06/30/21	0,116182	0,116236	0,116209	0,00	-3,32	-2,33	0,121134	0,114948
07/30/21	0,113157	0,113220	0,113188	0,00	-2,60	-4,87	0,116635	0,110566
08/31/21	0,114840	0,114904	0,114872	0,00	1,49	-3,45	0,115666	0,110537
09/30/21	0,114520	0,114595	0,114557	0,00	-0,27	-3,72	0,116823	0,114427
10/29/21	0,118180	0,118247	0,118213	0,00	3,19	-0,64	0,120179	0,115846
11/30/21	0,109720	0,109786	0,109753	-0,01	-7,16	-7,75	0,119131	0,109753
12/31/21	0,113370	0,113431	0,113401	0,00	3,32	-4,69	0,113912	0,108943
01/31/22	0,112129	0,112186	0,112157	0,00	-1,10	-5,73	0,115286	0,110862
02/28/22	0,113685	0,113751	0,113718	0,00	1,39	-4,42	0,114241	0,110094
03/31/22	0,114331	0,114397	0,114364	0,00	0,57	-3,88	0,116661	0,110574
04/29/22	0,107301	0,107371	0,107336	-0,01	-6,15	-9,78	0,115014	0,106324
05/31/22	0,106340	0,106410	0,106375	0,00	-0,90	-10,59	0,106455	0,101581
06/30/22	0,101180	0,101255	0,101217	-0,01	-4,85	-14,93	0,106573	0,099479
07/29/22	0,103403	0,103476	0,103439	0,00	2,20	-13,06	0,103439	0,097072
08/31/22	0,100733	0,100795	0,100764	0,00	-2,59	-15,31	0,105324	0,100764
09/30/22	0,091734	0,091799	0,091766	-0,01	-8,93	-22,87	0,101684	0,091766
10/31/22	0,096145	0,096221	0,096183	0,00	4,81	-19,16	0,097608	0,092919
11/30/22	0,100252	0,100327	0,100289	0,00	4,27	-15,71	0,101276	0,094621
12/30/22	0,101482	0,101543	0,101513	0,00	1,22	-14,68	0,102575	0,099881
01/31/23	0,100080	0,100155	0,100118	0,00	-1,37	-15,85	0,102033	0,097498
02/28/23	0,096622	0,096679	0,096651	0,00	-3,46	-18,77	0,100168	0,096019
03/31/23	0,095457	0,095508	0,095483	0,00	-1,21	-19,75	0,097189	0,092454
04/28/23	0,093505	0,093566	0,093536	0,00	-2,04	-21,38	0,097278	0,093536
05/31/23	0,089723	0,089763	0,089743	0,00	-4,06	-24,57	0,095268	0,089420
06/30/23	0,093318	0,093361	0,093340	0,00	4,01	-21,55	0,095011	0,089988
07/31/23	0,098818	0,098879	0,098848	0,01	5,90	-16,92	0,100134	0,092588
08/31/23	0,093982	0,094038	0,094010	0,00	-4,89	-20,98	0,098879	0,093162
09/29/23	0,093929	0,094026	0,093977	0,00	-0,03	-21,01	0,093983	0,092432
10/31/23	0,089492	0,089532	0,089512	0,00	-4,75	-24,77	0,092415	0,089087
11/30/23	0,092736	0,092813	0,092775	0,00	3,65	-22,02	0,093903	0,089052
12/29/23	0,098441	0,098493	0,098467	0,01	6,14	-17,24	0,099276	0,091060
01/31/24	0,095607	0,095660	0,095633	0,00	-2,88	-19,62	0,098467	0,094818
02/29/24	0,094321	0,094372	0,094346	0,00	-1,35	-20,70	0,095551	0,093481
03/29/24	0,092157	0,092198	0,092178	0,00	-2,30	-22,53	0,096381	0,092178
04/30/24	0,090276	0,090324	0,090300	0,00	-2,04	-24,10	0,093668	0,090300
05/31/24	0,095202	0,095246	0,095224	0,00	5,45	-19,96	0,095328	0,090255
06/28/24	0,093893	0,093944	0,093919	0,00	-1,37	-21,06	0,095443	0,093158
07/31/24	0,091429	0,091478	0,091454	0,00	-2,62	-23,13	0,094851	0,090572
08/30/24	0,094388	0,094430	0,094409	0,00	3,23	-20,65	0,095413	0,090643
09/30/24	0,094916	0,094969	0,094943	0,00	0,57	-20,20	0,095890	0,091869
10/31/24	0,090634	0,090683	0,090659	0,00	-4,51	-23,80	0,094488	0,090659
11/01/24	0,090498	0,090537	0,090517	0,00	-0,16	-23,92	0,090517	0,090517

Appendix 8. ZAR/USD Historic rates

Price History: ZARUSD

Date	Bid	Ask	Mid	Change	% Change	Cumulative Change %	High	Low
10/31/18	0,067706	0,067738	0,067722				0,070472	0,067244
11/30/18	0,072099	0,072136	0,072118	0,00	6,49	6,49	0,073294	0,068942
12/31/18	0,069496	0,069538	0,069517	0,00	-3,61	2,65	0,073013	0,068611
01/31/19	0,075338	0,075378	0,075358	0,01	8,40	11,28	0,075358	0,069360
02/28/19	0,071106	0,071141	0,071124	0,00	-5,62	5,02	0,075050	0,070169
03/29/19	0,069325	0,069359	0,069342	0,00	-2,50	2,39	0,070559	0,068382
04/30/19	0,069736	0,069771	0,069753	0,00	0,59	3,00	0,071826	0,069294
05/31/19	0,068677	0,068710	0,068693	0,00	-1,52	1,43	0,070385	0,067739
06/28/19	0,070898	0,070934	0,070916	0,00	3,24	4,72	0,070916	0,066689
07/31/19	0,070535	0,070571	0,070553	0,00	-0,51	4,18	0,072215	0,070139
08/30/19	0,065844	0,065875	0,065860	0,00	-6,65	-2,75	0,068794	0,064877
09/30/19	0,065937	0,065967	0,065952	0,00	0,14	-2,61	0,068906	0,065849
10/31/19	0,066370	0,066401	0,066386	0,00	0,66	-1,97	0,068707	0,065189
11/29/19	0,068229	0,068262	0,068245	0,00	2,80	0,77	0,068245	0,066537
12/31/19	0,071495	0,071531	0,071513	0,00	4,79	5,60	0,071513	0,067283
01/31/20	0,066653	0,066684	0,066669	0,00	-6,77	-1,56	0,071513	0,066669
02/28/20	0,063553	0,063581	0,063567	0,00	-4,65	-6,14	0,067875	0,063567
03/31/20	0,055971	0,056011	0,055991	-0,01	-11,92	-17,32	0,065428	0,055645
04/30/20	0,054439	0,054464	0,054451	0,00	-2,75	-19,60	0,055914	0,052650
05/29/20	0,056711	0,056736	0,056723	0,00	4,17	-16,24	0,057587	0,053012
06/30/20	0,057534	0,057574	0,057554	0,00	1,46	-15,01	0,060194	0,057290
07/31/20	0,058710	0,058739	0,058724	0,00	2,03	-13,29	0,060976	0,058450
08/31/20	0,059014	0,059041	0,059028	0,00	0,52	-12,84	0,060105	0,056433
09/30/20	0,059934	0,059970	0,059952	0,00	1,57	-11,47	0,061605	0,058298
10/30/20	0,061527	0,061560	0,061543	0,00	2,65	-9,12	0,062093	0,059957
11/30/20	0,064600	0,064630	0,064615	0,00	4,99	-4,59	0,065743	0,061501
12/31/20	0,068063	0,068096	0,068079	0,00	5,36	0,53	0,068729	0,065237
01/29/21	0,066419	0,066450	0,066434	0,00	-2,42	-1,90	0,068236	0,064423
02/26/21	0,066003	0,066043	0,066023	0,00	-0,62	-2,51	0,069270	0,066023
03/31/21	0,067705	0,067739	0,067722	0,00	2,57		0,067998	0,064610
04/30/21	0,068909	0,068951	0,068930	0,00	1,78	1,78	0,070550	0,068294
05/31/21	0,072868	0,072905	0,072886	0,00	5,74	7,63	0,072886	0,069091
06/30/21	0,070008	0,070060	0,070034	0,00	-3,91	3,41	0,074102	0,069610
07/30/21	0,068342	0,068375	0,068359	0,00	-2,39	0,94	0,070194	0,067365
08/31/21	0,069104	0,069161	0,069132	0,00	1,13	2,08	0,069692	0,065306
09/30/21	0,066449	0,066486	0,066467	0,00	-3,86	-1,85	0,070790	0,065887
10/29/21	0,065766	0,065813	0,065789	0,00	-1,02	-2,85	0,069207	0,065789
11/30/21	0,062373	0,062441	0,062407	0,00	-5,14	-7,85	0,066892	0,061614
12/31/21	0,062632	0,062681	0,062657	0,00	0,40	-7,48	0,064376	0,061809
01/31/22	0,064624	0,064659	0,064641	0,00	3,17	-4,55	0,066173	0,062617

Date	Bid	Ask	Mid	Change	% Change	Cumulative Change %	High	Low
02/28/22	0,064695	0,064734	0,064714	0,00	0,11	-4,44	0,066895	0,064482
03/31/22	0,068418	0,068451	0,068435	0,00	5,75	1,05	0,069192	0,064584
04/29/22	0,063212	0,063240	0,063226	-0,01	-7,61	-6,64	0,069031	0,062184
05/31/22	0,064152	0,064187	0,064169	0,00	1,49	-5,25	0,064521	0,061588
06/30/22	0,061024	0,061057	0,061041	0,00	-4,88	-9,87	0,065301	0,061041
07/29/22	0,060014	0,060039	0,060026	0,00	-1,66	-11,36	0,061237	0,058017
08/31/22	0,058650	0,058690	0,058670	0,00	-2,26	-13,37	0,061977	0,058670
09/30/22	0,055629	0,055652	0,055641	0,00	-5,16	-17,84	0,058475	0,055352
10/31/22	0,054404	0,054425	0,054414	0,00	-2,20	-19,65	0,056671	0,054256
11/30/22	0,058819	0,058846	0,058832	0,00	8,12	-13,13	0,058906	0,054315
12/30/22	0,058745	0,058798	0,058772	0,00	-0,10	-13,22	0,059220	0,056521
01/31/23	0,057368	0,057393	0,057381	0,00	-2,37	-15,27	0,059542	0,057381
02/28/23	0,054460	0,054495	0,054477	0,00	-5,06	-19,56	0,058707	0,054226
03/31/23	0,056351	0,056373	0,056362	0,00	3,46	-16,77	0,056362	0,053821
04/28/23	0,054680	0,054706	0,054693	0,00	-2,96	-19,24	0,056144	0,053996
05/31/23	0,050451	0,050476	0,050464	0,00	-7,73	-25,48	0,054746	0,050464
06/30/23	0,052919	0,052950	0,052935	0,00	4,90	-21,84	0,055021	0,050957
07/31/23	0,056216	0,056246	0,056231	0,00	6,23	-16,97	0,056855	0,052383
08/31/23	0,052802	0,052822	0,052812	0,00	-6,08	-22,02	0,054953	0,052240
09/29/23	0,053070	0,053091	0,053080	0,00	0,51	-21,62	0,053340	0,051898
10/31/23	0,053332	0,053352	0,053342	0,00	0,49	-21,23	0,053342	0,051154
11/30/23	0,052761	0,052780	0,052770	0,00	-1,07	-22,08	0,054953	0,052770
12/29/23	0,054670	0,054695	0,054682	0,00	3,62	-19,25	0,054768	0,052298
01/31/24	0,053757	0,053777	0,053767	0,00	-1,67	-20,61	0,054682	0,052121
02/29/24	0,052116	0,052139	0,052127	0,00	-3,05	-23,03	0,053756	0,051765
03/29/24	0,052799	0,052819	0,052809	0,00	1,31	-22,02	0,053872	0,052342
04/30/24	0,053079	0,053103	0,053091	0,00	0,53	-21,60	0,054120	0,051989
05/31/24	0,053099	0,053129	0,053114	0,00	0,04	-21,57	0,055390	0,053114
06/28/24	0,054754	0,054775	0,054765	0,00	3,11	-19,13	0,055714	0,052729
07/31/24	0,054960	0,054983	0,054971	0,00	0,38	-18,83	0,055594	0,053747
08/30/24	0,056311	0,056333	0,056322	0,00	2,46	-16,83	0,056461	0,053881
09/30/24	0,058017	0,058042	0,058030	0,00	3,03	-14,31	0,058462	0,055581
10/31/24	0,056547	0,056575	0,056561	0,00	-2,53	-16,48	0,057612	0,056046
11/01/24	0,056874	0,056900	0,056887	0,00	0,58	-16,00	0,056887	0,056887

Appendix 9. Historic evolution of prices

Fecha	€/MWh	EUR/USD	$/kWh	Monthly Fluctuations	Quarterly Fluctuations
	Spain				
01/11/2018	61,97 €	$1,13	$0,070		
01/12/2018	61,81 €	$1,13	$0,070	-0,26%	
01/01/2019	61,99 €	$1,14	$0,071	0,29%	
01/02/2019	54,01 €	$1,15	$0,062	-13,78%	
01/03/2019	48,82 €	$1,14	$0,056	-10,10%	
01/04/2019	50,41 €	$1,12	$0,057	3,20%	-21%
01/05/2019	48,39 €	$1,12	$0,054	-4,09%	
01/06/2019	47,19 €	$1,11	$0,053	-2,50%	
01/07/2019	51,46 €	$1,14	$0,059	8,66%	2%
01/08/2019	44,96 €	$1,11	$0,050	-13,51%	
01/09/2019	42,11 €	$1,10	$0,046	-6,54%	
01/10/2019	47,17 €	$1,09	$0,051	11,33%	-9%
01/11/2019	42,19 €	$1,12	$0,047	-11,15%	
01/12/2019	33,81 €	$1,10	$0,037	-22,16%	
01/01/2020	41,10 €	$1,12	$0,046	19,54%	-14%
01/02/2020	35,87 €	$1,11	$0,040	-13,62%	
01/03/2020	27,74 €	$1,10	$0,030	-25,70%	
01/04/2020	17,65 €	$1,10	$0,019	-45,20%	-85%
01/05/2020	21,26 €	$1,10	$0,023	18,57%	
01/06/2020	30,62 €	$1,11	$0,034	36,50%	
01/07/2020	34,64 €	$1,12	$0,039	12,33%	67%
01/08/2020	36,20 €	$1,18	$0,043	4,41%	
01/09/2020	41,96 €	$1,20	$0,050	14,76%	
01/10/2020	36,56 €	$1,17	$0,043	-13,77%	5%
01/11/2020	41,94 €	$1,16	$0,049	13,72%	
01/12/2020	41,97 €	$1,20	$0,050	0,07%	
01/01/2021	60,17 €	$1,22	$0,074	36,03%	50%
01/02/2021	28,49 €	$1,21	$0,035	-74,74%	
01/03/2021	45,45 €	$1,21	$0,055	46,70%	
01/04/2021	65,02 €	$1,18	$0,076	35,80%	8%
01/05/2021	67,13 €	$1,20	$0,081	3,19%	
01/06/2021	83,30 €	$1,22	$0,102	21,59%	
01/07/2021	92,42 €	$1,19	$0,110	10,38%	35%
01/08/2021	105,94 €	$1,19	$0,126	13,66%	
01/09/2021	156,14 €	$1,18	$0,184	38,79%	
01/10/2021	199,90 €	$1,16	$0,232	24,70%	77%
01/11/2021	193,43 €	$1,16	$0,224	-3,29%	
01/12/2021	239,17 €	$1,13	$0,269	21,22%	
01/01/2022	201,72 €	$1,14	$0,229	-17,03%	1%
01/02/2022	200,22 €	$1,12	$0,224	-0,75%	
01/03/2022	283,39 €	$1,12	$0,318	34,74%	
01/04/2022	191,52 €	$1,11	$0,213	-39,18%	-5%
01/05/2022	187,13 €	$1,05	$0,197	-2,32%	
01/06/2022	169,63 €	$1,07	$0,182	-9,82%	
01/07/2022	142,66 €	$1,05	$0,149	-17,31%	-29%
01/08/2022	154,90 €	$1,02	$0,158	8,23%	
01/09/2022	141,07 €	$1,01	$0,142	-9,35%	
01/10/2022	127,22 €	$0,98	$0,125	-10,33%	-11%
01/11/2022	115,56 €	$0,99	$0,114	-9,62%	
01/12/2022	96,95 €	$1,03	$0,100	-17,55%	
01/01/2023	69,55 €	$1,07	$0,074	-33,22%	-60%
01/02/2023	133,47 €	$1,09	$0,145	65,18%	
01/03/2023	89,70 €	$1,06	$0,095	-39,75%	
01/04/2023	73,73 €	$1,09	$0,080	-19,60%	6%
01/05/2023	74,21 €	$1,10	$0,082	0,64%	
01/06/2023	93,02 €	$1,07	$0,099	22,60%	
01/07/2023	90,47 €	$1,09	$0,099	-2,78%	20%
01/08/2023	96,05 €	$1,10	$0,106	5,98%	
01/09/2023	103,34 €	$1,09	$0,112	7,32%	
01/10/2023	90,03 €	$1,06	$0,095	-13,79%	0%
01/11/2023	63,45 €	$1,06	$0,067	-35,00%	
01/12/2023	72,17 €	$1,09	$0,079	12,89%	
01/01/2024	74,10 €	$1,10	$0,082	2,63%	-19%
01/02/2024	40,00 €	$1,09	$0,043	-61,66%	
01/03/2024	20,31 €	$1,08	$0,022	-67,80%	
01/04/2024	13,67 €	$1,08	$0,015	-39,57%	-169%
01/05/2024	30,40 €	$1,07	$0,033	79,92%	
01/06/2024	56,08 €	$1,09	$0,061	61,24%	
01/07/2024	72,31 €	$1,07	$0,078	25,42%	167%
01/08/2024	91,05 €	$1,08	$0,099	23,04%	
01/09/2024	72,62 €	$1,11	$0,080	-22,62%	
01/10/2024	68,55 €	$1,12	$0,077	-5,77%	-5%
01/11/2024	94,41 €	$1,09	$0,102	32,00%	
AVERAGE	84,041 €	POST UKR PIKE	$0,090	0,58%	0,44%

Fecha	€/MWh	EUR/USD	$/kWh	Monthly Fluctuations	Quarterly Fluctuations
	France				
01/11/2018	67,81 €	$1,13	$0,077		
01/12/2018	54,90 €	$1,13	$0,062	-21,12%	
01/01/2019	61,16 €	$1,14	$0,070	10,80%	
01/02/2019	46,62 €	$1,15	$0,053	-27,14%	
01/03/2019	33,86 €	$1,14	$0,039	-31,97%	
01/04/2019	38,08 €	$1,12	$0,043	11,74%	-47%
01/05/2019	37,21 €	$1,12	$0,042	-2,31%	
01/06/2019	29,26 €	$1,11	$0,033	-24,05%	
01/07/2019	37,66 €	$1,14	$0,043	25,26%	-1%
01/08/2019	33,39 €	$1,11	$0,037	-12,03%	
01/09/2019	35,54 €	$1,10	$0,039	6,24%	
01/10/2019	38,60 €	$1,09	$0,042	8,25%	2%
01/11/2019	45,94 €	$1,12	$0,051	17,42%	
01/12/2019	36,46 €	$1,10	$0,040	-23,11%	
01/01/2020	38,01 €	$1,12	$0,043	4,15%	-2%
01/02/2020	26,25 €	$1,11	$0,029	-37,02%	
01/03/2020	23,83 €	$1,10	$0,026	-9,65%	
01/04/2020	13,45 €	$1,10	$0,015	-57,21%	-104%
01/05/2020	14,86 €	$1,10	$0,016	9,98%	
01/06/2020	25,79 €	$1,11	$0,029	55,10%	
01/07/2020	33,41 €	$1,12	$0,038	25,91%	91%
01/08/2020	36,75 €	$1,18	$0,043	9,53%	
01/09/2020	47,20 €	$1,20	$0,056	25,01%	
01/10/2020	37,89 €	$1,17	$0,044	-21,97%	13%
01/11/2020	40,11 €	$1,16	$0,047	5,71%	
01/12/2020	48,42 €	$1,20	$0,058	18,82%	
01/01/2021	59,48 €	$1,22	$0,073	20,58%	45%
01/02/2021	49,01 €	$1,21	$0,060	-19,36%	
01/03/2021	50,22 €	$1,21	$0,061	2,42%	
01/04/2021	63,10 €	$1,18	$0,074	22,85%	6%
01/05/2021	55,28 €	$1,20	$0,067	-13,24%	
01/06/2021	73,51 €	$1,22	$0,090	28,51%	
01/07/2021	78,37 €	$1,19	$0,093	6,40%	22%
01/08/2021	77,30 €	$1,19	$0,092	-1,37%	
01/09/2021	135,31 €	$1,18	$0,160	55,98%	
01/10/2021	172,45 €	$1,16	$0,200	24,25%	79%
01/11/2021	217,06 €	$1,16	$0,251	23,01%	
01/12/2021	274,67 €	$1,13	$0,309	23,54%	
01/01/2022	211,42 €	$1,14	$0,240	-26,17%	20%
01/02/2022	185,55 €	$1,12	$0,208	-13,05%	
01/03/2022	295,21 €	$1,12	$0,332	46,44%	
01/04/2022	233.10 €	$1.11	$0.259	-23.62%	10%
01/05/2022	197,43 €	$1,05	$0,208	-16,61%	
01/06/2022	248,40 €	$1,07	$0,266	22,97%	
01/07/2022	400,87 €	$1,05	$0,419	47,86%	54%
01/08/2022	492,49 €	$1,02	$0,502	20,58%	
01/09/2022	394,70 €	$1,01	$0,397	-22,13%	
01/10/2022	178,88 €	$0,98	$0,175	-79,14%	-81%
01/11/2022	191,88 €	$0,99	$0,190	7,02%	
01/12/2022	270,89 €	$1,03	$0,279	34,48%	
01/01/2023	132,10 €	$1,07	$0,141	-71,82%	-30%
01/02/2023	148,77 €	$1,09	$0,162	11,88%	
01/03/2023	111,96 €	$1,06	$0,119	-28,42%	
01/04/2023	106,36 €	$1,09	$0,116	-5,13%	-22%
01/05/2023	77,55 €	$1,10	$0,086	-31,60%	
01/06/2023	91,29 €	$1,07	$0,097	16,32%	
01/07/2023	77,65 €	$1,09	$0,085	-16,19%	-31%
01/08/2023	90,87 €	$1,10	$0,100	15,73%	
01/09/2023	88,71 €	$1,09	$0,096	-2,42%	
01/10/2023	84,26 €	$1,06	$0,089	-5,14%	8%
01/11/2023	88,96 €	$1,06	$0,094	5,42%	
01/12/2023	68,47 €	$1,09	$0,075	-26,17%	
01/01/2024	76,59 €	$1,10	$0,085	11,21%	-10%
01/02/2024	58,37 €	$1,09	$0,063	-27,17%	
01/03/2024	53,59 €	$1,08	$0,058	-8,54%	
01/04/2024	28,23 €	$1,08	$0,030	-64,09%	-100%
01/05/2024	27,17 €	$1,07	$0,029	-3,83%	
01/06/2024	37,60 €	$1,09	$0,041	32,48%	
01/07/2024	47,03 €	$1,07	$0,050	22,39%	51%
01/08/2024	54,56 €	$1,08	$0,059	14,84%	
01/09/2024	51,86 €	$1,11	$0,057	-5,08%	
01/10/2024	62,06 €	$1,12	$0,069	17,95%	28%
01/11/2024	95,03 €	$1,09	$0,103	42,62%	
AVERAGE	100,658 €	POST UKR PIKE	$0,083	0,47%	0,06%

Fecha	(øre/kWh)	NOK/USD	$/kWh	Monthly Fluctuations	Quarterly Fluctuations	$/kWh	Monthly Fluctuations	Quarterly Fluctuations
	Norway					United States		
01/11/2018	42,8	$0,12	$0,051			$0,052		
01/12/2018	42,8	$0,12	$0,050			$0,050	-3,62%	
01/01/2019	45,8	$0,12	$0,053			$0,042	-17,07%	
01/02/2019	45,8	$0,12	$0,054			$0,063	40,02%	
01/03/2019	45,8	$0,12	$0,054			$0,043	-37,91%	
01/04/2019	35,5	$0,12	$0,041		-25,48%	$0,024	-57,90%	-55,78%
01/05/2019	35,5	$0,12	$0,041			$0,021	-14,63%	
01/06/2019	35,5	$0,11	$0,041			$0,026	21,69%	
01/07/2019	32,8	$0,12	$0,038		-7,91%	$0,036	32,45%	39,52%
01/08/2019	32,8	$0,11	$0,037			$0,035	-2,17%	
01/09/2019	32,8	$0,11	$0,036			$0,033	-4,93%	
01/10/2019	38,0	$0,11	$0,042		14,72%	$0,032	-4,81%	-11,91%
01/11/2019	38,0	$0,11	$0,041			$0,038	17,36%	
01/12/2019	38,0	$0,11	$0,041			$0,036	-6,49%	
01/01/2020	15,5	$0,11	$0,018		-89,67%	$0,026	-32,36%	-21,49%
01/02/2020	15,5	$0,11	$0,017			$0,022	-14,77%	
01/03/2020	15,5	$0,11	$0,016			$0,023	2,89%	
01/04/2020	8,3	$0,10	$0,008		-62,46%	$0,019	-20,18%	-32,06%
01/05/2020	8,3	$0,10	$0,008			$0,017	-6,62%	
01/06/2020	8,3	$0,10	$0,009			$0,023	27,31%	
01/07/2020	6,8	$0,10	$0,007		-19,93%	$0,031	30,37%	51,06%
01/08/2020	6,8	$0,11	$0,007			$0,095	111,56%	
01/09/2020	6,8	$0,12	$0,008			$0,046	-71,70%	
01/10/2020	14,7	$0,11	$0,016		77,09%	$0,038	-20,38%	19,48%
01/11/2020	14,7	$0,10	$0,015			$0,029	-25,21%	
01/12/2020	14,7	$0,11	$0,017			$0,034	14,16%	
01/01/2021	46,0	$0,12	$0,054		114,08%	$0,032	-5,71%	-16,75%
01/02/2021	46,0	$0,12	$0,054			$0,071	79,65%	
01/03/2021	46,0	$0,12	$0,053			$0,029	-88,04%	
01/04/2021	42,1	$0,12	$0,049		-8,86%	$0,032	7,85%	-0,55%
01/05/2021	42,1	$0,12	$0,051			$0,033	3,42%	
01/06/2021	42,1	$0,12	$0,051			$0,080	88,66%	
01/07/2021	66,6	$0,12	$0,077		45,87%	$0,079	-1,04%	91,04%
01/08/2021	66,6	$0,11	$0,075			$0,065	-19,53%	
01/09/2021	66,6	$0,11	$0,077			$0,071	8,51%	
01/10/2021	102,0	$0,11	$0,117		42,63%	$0,063	-11,61%	-22,63%
01/11/2021	102,0	$0,12	$0,121			$0,056	-12,16%	
01/12/2021	102,0	$0,11	$0,112			$0,060	7,57%	
01/01/2022	108,2	$0,11	$0,123		5,90%	$0,070	15,62%	11,03%
01/02/2022	108,2	$0,11	$0,121			$0,056	-23,63%	
01/03/2022	108,2	$0,11	$0,123			$0,044	-24,19%	
01/04/2022	116,8	$0,11	$0,134		7,65%	$0,072	50,27%	2,45%
01/05/2022	116,8	$0,11	$0,125			$0,074	2,28%	
01/06/2022	116,8	$0,11	$0,124			$0,080	7,88%	
01/07/2022	186,2	$0,10	$0,188		46,64%	$0,101	23,40%	33,55%
01/08/2022	186,2	$0,10	$0,193			$0,134	28,46%	
01/09/2022	186,2	$0,10	$0,188			$0,131	-2,60%	
01/10/2022	155,6	$0,09	$0,143		-17,95%	$0,067	-67,06%	-41,20%
01/11/2022	155,6	$0,10	$0,150			$0,081	19,15%	
01/12/2022	155,6	$0,10	$0,156			$0,196	88,25%	
01/01/2023	97,1	$0,10	$0,099		-47,15%	$0,113	-54,99%	52,42%
01/02/2023	97,1	$0,10	$0,097			$0,066	-53,74%	
01/03/2023	97,1	$0,10	$0,094			$0,060	-10,11%	
01/04/2023	78,0	$0,10	$0,074		-21,90%	$0,057	-4,26%	-68,11%
01/05/2023	78,0	$0,09	$0,073			$0,028	-73,02%	
01/06/2023	78,0	$0,09	$0,070			$0,038	33,19%	
01/07/2023	35,7	$0,09	$0,033		-78,16%	$0,077	70,18%	30,35%
01/08/2023	35,7	$0,10	$0,035			$0,091	16,62%	
01/09/2023	35,7	$0,09	$0,034			$0,046	-69,21%	
01/10/2023	77,3	$0,09	$0,073		77,25%	$0,060	27,90%	-24,68%
01/11/2023	77,3	$0,09	$0,069			$0,054	-10,81%	
01/12/2023	77,3	$0,09	$0,072			$0,046	-16,28%	
01/01/2024	69,1	$0,10	$0,068		-11,21%	$0,093	70,54%	43,45%
01/02/2024	69,1	$0,10	$0,066			$0,035	-98,57%	
01/03/2024	69,1	$0,09	$0,065			$0,024	-37,46%	
01/04/2024	49,5	$0,09	$0,046		-33,36%	$0,023	-3,43%	-139,47%
01/05/2024	49,5	$0,09	$0,045			$0,024	3,66%	
01/06/2024	49,5	$0,10	$0,047			$0,038	46,91%	
01/07/2024	30,4	$0,09	$0,029			$0,067	55,73%	
01/08/2024	30,4	$0,09	$0,028			$0,047	-35,56%	
01/09/2024	30,4	$0,09	$0,029			$0,041	-12,90%	
01/10/2024						$0,044	7,55%	
01/11/2024						$0,032		
AVERAGE	62,8		$0,066		0,37%	$0,054	-0,22%	-2,87%
					52%			41%

Fecha	c/kWh	ZAR/kWh	ZAR/USD	$/kWh	Monthly Fluctuations	Quarterly Fluctuations
			South Africa			
01/11/2018	85,12c	R0,851	$0,068	$0,058		
01/12/2018	85,12c	R0,851	$0,072	$0,061		
01/01/2019	85,12c	R0,851	$0,070	$0,059		
01/02/2019	85,12c	R0,851	$0,075	$0,064		
01/03/2019	85,12c	R0,851	$0,071	$0,061		
01/04/2019	95,95c	R0,960	$0,069	$0,067		11,98%
01/05/2019	95,95c	R0,960	$0,070	$0,067		
01/06/2019	95,95c	R0,960	$0,069	$0,066		
01/07/2019	95,95c	R0,960	$0,071	$0,068		
01/08/2019	95,95c	R0,960	$0,071	$0,068		
01/09/2019	95,95c	R0,960	$0,066	$0,063		
01/10/2019	95,95c	R0,960	$0,066	$0,063		
01/11/2019	95,95c	R0,960	$0,066	$0,064		
01/12/2019	95,95c	R0,960	$0,068	$0,065		
01/01/2020	95,95c	R0,960	$0,072	$0,069		
01/02/2020	95,95c	R0,960	$0,067	$0,064		
01/03/2020	95,95c	R0,960	$0,064	$0,061		
01/04/2020	105,62c	R1,056	$0,056	$0,059		9,61%
01/05/2020	105,62c	R1,056	$0,054	$0,058		
01/06/2020	105,62c	R1,056	$0,057	$0,060		
01/07/2020	105,62c	R1,056	$0,058	$0,061		
01/08/2020	105,62c	R1,056	$0,059	$0,062		
01/09/2020	105,62c	R1,056	$0,059	$0,062		
01/10/2020	105,62c	R1,056	$0,060	$0,063		
01/11/2020	105,62c	R1,056	$0,062	$0,065		
01/12/2020	105,62c	R1,056	$0,065	$0,068		
01/01/2021	105,62c	R1,056	$0,068	$0,072		
01/02/2021	105,62c	R1,056	$0,066	$0,070		
01/03/2021	105,62c	R1,056	$0,066	$0,070		
01/04/2021	122,75c	R1,227	$0,068	$0,083		15,02%
01/05/2021	122,75c	R1,227	$0,069	$0,085		
01/06/2021	122,75c	R1,227	$0,073	$0,089		
01/07/2021	122,75c	R1,227	$0,070	$0,086		
01/08/2021	122,75c	R1,227	$0,068	$0,084		
01/09/2021	122,75c	R1,227	$0,069	$0,085		
01/10/2021	122,75c	R1,227	$0,066	$0,082		
01/11/2021	122,75c	R1,227	$0,066	$0,081		
01/12/2021	122,75c	R1,227	$0,062	$0,077		
01/01/2022	122,75c	R1,227	$0,063	$0,077		
01/02/2022	122,75c	R1,227	$0,065	$0,079		
01/03/2022	122,75c	R1,227	$0,065	$0,079		
01/04/2022	136,86c	R1,369	$0,068	$0,094		10,88%
01/05/2022	136,86c	R1,369	$0,063	$0,087		
01/06/2022	136,86c	R1,369	$0,064	$0,088		
01/07/2022	136,86c	R1,369	$0,061	$0,084		
01/08/2022	136,86c	R1,369	$0,060	$0,082		
01/09/2022	136,86c	R1,369	$0,059	$0,080		
01/10/2022	136,86c	R1,369	$0,056	$0,076		
01/11/2022	136,86c	R1,369	$0,054	$0,074		
01/12/2022	136,86c	R1,369	$0,059	$0,081		
01/01/2023	136,86c	R1,369	$0,059	$0,080		
01/02/2023	136,86c	R1,369	$0,057	$0,079		
01/03/2023	136,86c	R1,369	$0,054	$0,075		
01/04/2023	162,38c	R1,624	$0,056	$0,092		17,10%
01/05/2023	162,38c	R1,624	$0,055	$0,089		
01/06/2023	162,38c	R1,624	$0,050	$0,082		
01/07/2023	162,38c	R1,624	$0,053	$0,086		
01/08/2023	162,38c	R1,624	$0,056	$0,091		
01/09/2023	162,38c	R1,624	$0,053	$0,086		
01/10/2023	162,38c	R1,624	$0,053	$0,086		
01/11/2023	162,38c	R1,624	$0,053	$0,087		
01/12/2023	162,38c	R1,624	$0,053	$0,086		
01/01/2024	162,38c	R1,624	$0,055	$0,089		
01/02/2024	162,38c	R1,624	$0,054	$0,087		
01/03/2024	162,38c	R1,624	$0,052	$0,085		
01/04/2024	183,07c	R1,831	$0,053	$0,097		11,99%
01/05/2024	183,07c	R1,831	$0,053	$0,097		
01/06/2024	183,07c	R1,831	$0,053	$0,097		
01/07/2024	183,07c	R1,831	$0,055	$0,100		
01/08/2024	183,07c	R1,831	$0,055	$0,101		
01/09/2024	183,07c	R1,831	$0,056	$0,103		
01/10/2024	183,07c	R1,831	$0,058	$0,106		
01/11/2024	183,07c	R1,831	$0,057	$0,104		
AVERAGE	128,39			$0,078		12,76%

Appendix 10. Macros for Optimal Production Allocation

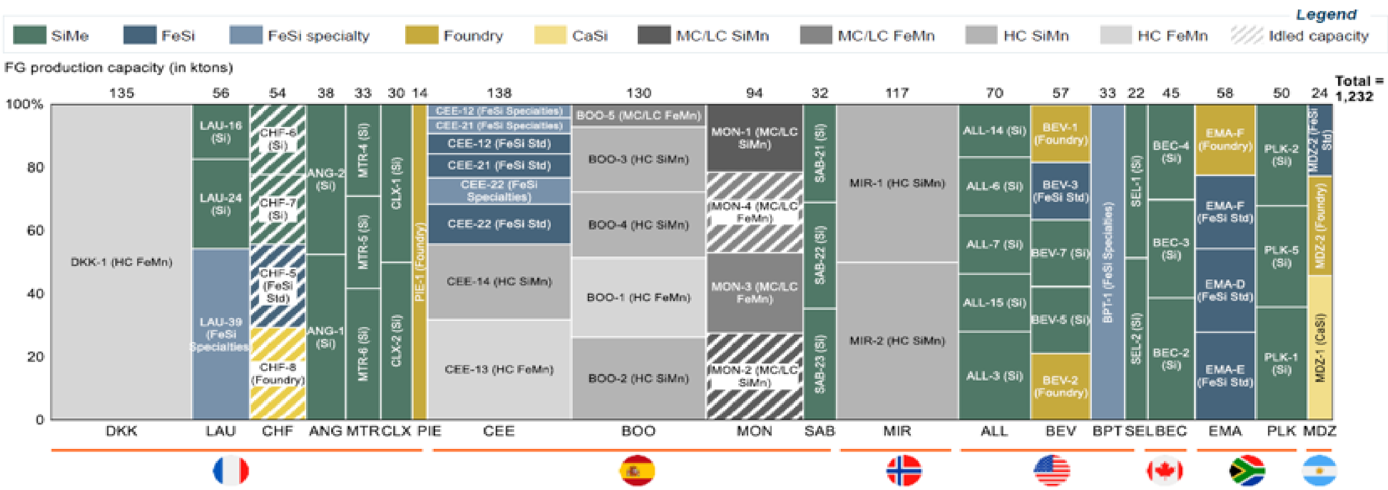
```
Sub AsignarToneladasPesimistic()

    Dim ws As Worksheet
    Dim precios(1 To 5) As Double
    Dim capacidades(1 To 5) As Double
    Dim asignaciones(1 To 5) As Double
    Dim maxCapacidades(1 To 5) As Double
    Dim restantes As Double
    Dim orden(1 To 5) As Long
    Dim mes As Long, i As Long, j As Long
    Dim tempPrecio As Double, tempIndex As Long

    Set ws = ThisWorkbook.Sheets("Sheet1")

    ' Max capacidades prod
    maxCapacidades(1) = ws.Range("D40").Value ' Spain
    maxCapacidades(2) = ws.Range("D41").Value ' France
    maxCapacidades(3) = ws.Range("D42").Value ' Norway
    maxCapacidades(4) = ws.Range("D43").Value ' USA
    maxCapacidades(5) = ws.Range("D44").Value ' SA

    ' All future months to estimate (excel columns)
    For mes = 99 To 160
        For i = 1 To 5
            capacidades(i) = maxCapacidades(i)
            asignaciones(i) = 0
        Next i
        restantes = ws.Range("K40").Value ' Tons to allocate

        ' Leer precios para este mes
        precios(1) = ws.Cells(mes, "N").Value ' Spain
        precios(2) = ws.Cells(mes, "T").Value ' France
        precios(3) = ws.Cells(mes, "Z").Value ' Norway
        precios(4) = ws.Cells(mes, "AF").Value ' USA
        precios(5) = ws.Cells(mes, "AL").Value ' SA

        ' Order countries by their pirce (lower first)
        For i = 1 To 5
            orden(i) = i
        Next i
        For i = 1 To 4
            For j = i + 1 To 5
                If precios(orden(i)) > precios(orden(j)) Then
                    tempIndex = orden(i)
                    orden(i) = orden(j)
                    orden(j) = tempIndex
                End If
            Next j
        Next i

        ' Allocate tons
        For i = 1 To 5
            Dim paisIndex As Long
            paisIndex = orden(i) ' Actual country

            ' Tons to assign to the country
            If restantes > 0 Then
                Dim asignar As Double
                asignar = WorksheetFunction.Min(restantes, capacidades(paisIndex))
                asignaciones(paisIndex) = asignar
                restantes = restantes - asignar
            Else
                Exit For
            End If
        Next i

        ' Write allocations on Excel
        ws.Cells(mes, "O").Value = asignaciones(1) ' Spain
        ws.Cells(mes, "U").Value = asignaciones(2) ' France
        ws.Cells(mes, "AA").Value = asignaciones(3) ' Norway
        ws.Cells(mes, "AG").Value = asignaciones(4) ' USA
        ws.Cells(mes, "AM").Value = asignaciones(5) ' SA

    Next mes

    MsgBox "Allocation completed", vbInformation
End Sub
```

```
Sub AsignarToneladasNeutral()

    Dim ws As Worksheet
    Dim precios(1 To 5) As Double
    Dim capacidades(1 To 5) As Double
    Dim asignaciones(1 To 5) As Double
    Dim maxCapacidades(1 To 5) As Double
    Dim restantes As Double
    Dim orden(1 To 5) As Long
    Dim mes As Long, i As Long, j As Long
    Dim tempPrecio As Double, tempIndex As Long

    Set ws = ThisWorkbook.Sheets("Sheet1")

    ' Max capacidades prod
    maxCapacidades(1) = ws.Range("D40").Value ' Spain
    maxCapacidades(2) = ws.Range("D41").Value ' France
    maxCapacidades(3) = ws.Range("D42").Value ' Norway
    maxCapacidades(4) = ws.Range("D43").Value ' USA
    maxCapacidades(5) = ws.Range("D44").Value ' SA

    ' All future months to estimat
    For mes = 99 To 160
        For i = 1 To 5
            capacidades(i) = maxCapacidades(i)
            asignaciones(i) = 0
        Next i
        restantes = ws.Range("K40").Value ' Total tons to allocate

        ' Leer precios para este mes
        precios(1) = ws.Cells(mes, "P").Value ' Spain
        precios(2) = ws.Cells(mes, "V").Value ' France
        precios(3) = ws.Cells(mes, "AB").Value ' Norway
        precios(4) = ws.Cells(mes, "AH").Value ' USA
        precios(5) = ws.Cells(mes, "AN").Value ' SA

        ' Order countries by their price (lower first)
        For i = 1 To 5
            orden(i) = i
        Next i
        For i = 1 To 4
            For j = i + 1 To 5
                If precios(orden(i)) > precios(orden(j)) Then
                    tempIndex = orden(i)
                    orden(i) = orden(j)
                    orden(j) = tempIndex
                End If
            Next j
        Next i

        ' Allocate tons
        For i = 1 To 5
            Dim paisIndex As Long
            paisIndex = orden(i) ' Actual country

            ' Tons to assign to the country
            If restantes > 0 Then
                Dim asignar As Double
                asignar = WorksheetFunction.Min(restantes, capacidades(paisIndex))
                asignaciones(paisIndex) = asignar
                restantes = restantes - asignar
            Else
                Exit For
            End If
        Next i

        ' Write allocations on Excel
        ws.Cells(mes, "Q").Value = asignaciones(1) ' Spain
        ws.Cells(mes, "W").Value = asignaciones(2) ' France
        ws.Cells(mes, "AC").Value = asignaciones(3) ' Norway
        ws.Cells(mes, "AI").Value = asignaciones(4) ' USA
        ws.Cells(mes, "AO").Value = asignaciones(5) ' SA

    Next mes

    MsgBox "Allocation completed", vbInformation
End Sub
```

```vba
Sub AsignarToneladasOptimistic()

    Dim ws As Worksheet
    Dim precios(1 To 5) As Double
    Dim capacidades(1 To 5) As Double
    Dim asignaciones(1 To 5) As Double
    Dim maxCapacidades(1 To 5) As Double
    Dim restantes As Double
    Dim orden(1 To 5) As Long
    Dim mes As Long, i As Long, j As Long
    Dim tempPrecio As Double, tempIndex As Long

    Set ws = ThisWorkbook.Sheets("Sheet1")

    ' Max capacidades prod
    maxCapacidades(1) = ws.Range("D40").Value ' Spain
    maxCapacidades(2) = ws.Range("D41").Value ' France
    maxCapacidades(3) = ws.Range("D42").Value ' Norway
    maxCapacidades(4) = ws.Range("D43").Value ' USA
    maxCapacidades(5) = ws.Range("D44").Value ' SA

    ' All future months to estimate
    For mes = 99 To 160
        For i = 1 To 5
            capacidades(i) = maxCapacidades(i)
            asignaciones(i) = 0
        Next i
        restantes = ws.Range("K40").Value ' Total tons to allocate

        ' Leer precios para este mes
        precios(1) = ws.Cells(mes, "R").Value ' Spain
        precios(2) = ws.Cells(mes, "X").Value ' France
        precios(3) = ws.Cells(mes, "AD").Value ' Norway
        precios(4) = ws.Cells(mes, "AJ").Value ' USA
        precios(5) = ws.Cells(mes, "AP").Value ' SA

        ' Order countries by their prices (lower first)
        For i = 1 To 5
            orden(i) = i
        Next i
        For i = 1 To 4
            For j = i + 1 To 5
                If precios(orden(i)) > precios(orden(j)) Then
                    tempIndex = orden(i)
                    orden(i) = orden(j)
                    orden(j) = tempIndex
                End If
            Next j
        Next i

        ' Allocate tons
        For i = 1 To 5
            Dim paisIndex As Long
            paisIndex = orden(i) ' Actual country

            ' Tons to assign to the country
            If restantes > 0 Then
                Dim asignar As Double
                asignar = WorksheetFunction.Min(restantes, capacidades(paisIndex))
                asignaciones(paisIndex) = asignar
                restantes = restantes - asignar
            Else
                Exit For
            End If
        Next i

        ' Write allocations on Excel
        ws.Cells(mes, "S").Value = asignaciones(1) ' Spain
        ws.Cells(mes, "Y").Value = asignaciones(2) ' France
        ws.Cells(mes, "AE").Value = asignaciones(3) ' Norway
        ws.Cells(mes, "AK").Value = asignaciones(4) ' USA
        ws.Cells(mes, "AQ").Value = asignaciones(5) ' SA

    Next mes

    MsgBox "Allocation completed", vbInformation
End Sub
```

Appendix 11. Ferroglobe Production Data

Ferroglobe
Advancing Materials Innovation



	FG aporx. Motnhly Production Capacity (in ktons)		Raw materials and energy consumption for production 2023 (in $million)	Estimated kWh consumption	Shipments in ktons
SPAIN	32,8	32%	$281,20	2.977.227.727 kW	51,09 t
FRANCE	30,0	29%	$256,93	2.449.109.292 kW	
NORWAY	9,8	9%	$83,50	1.217.860.092 kW	
US	15,2	15%	$129,89	2.116.260.040 kW	
SOUTH AFRICA	9,0	9%	$77,08	909.230.332 kW	
Total	97	94%			
Overall Ferroglobe	102,6666667	100%	$879,28	9.669.687.483 kW	

Appendix 12. Projected electricity prices

	SPAIN					
	$/kWh Pesimistic Scenario Rate		$/kWh Neutral		$/kWh Optimistic Scenario Rate	
	1,50%	Optimal allocation	Normal fluctuations	Optimal allocation	-1,00%	Optimal allocation
01/11/2024	$0,102	26,17 t	$0,102	26,17 t	$0,102	26,17 t
01/12/2024	$0,104	17,17 t	$0,101	26,17 t	$0,101	26,17 t
01/01/2025	$0,106	17,17 t	$0,097	26,17 t	$0,100	26,17 t
01/02/2025	$0,107	17,17 t	$0,102	0,00 t	$0,099	26,17 t
01/03/2025	$0,109	17,17 t	$0,113	0,00 t	$0,098	26,17 t
01/04/2025	$0,110	17,17 t	$0,112	26,17 t	$0,097	26,17 t
01/05/2025	$0,112	17,17 t	$0,116	0,00 t	$0,096	26,17 t
01/06/2025	$0,114	17,17 t	$0,105	0,00 t	$0,096	26,17 t
01/07/2025	$0,115	17,17 t	$0,107	0,00 t	$0,095	26,17 t
01/08/2025	$0,117	17,17 t	$0,119	17,17 t	$0,094	26,17 t
01/09/2025	$0,119	17,17 t	$0,108	0,00 t	$0,093	26,17 t
01/10/2025	$0,121	17,17 t	$0,110	0,00 t	$0,092	26,17 t
01/11/2025	$0,123	17,17 t	$0,114	0,00 t	$0,091	26,17 t
01/12/2025	$0,124	17,17 t	$0,117	17,17 t	$0,090	26,17 t
01/01/2026	$0,126	17,17 t	$0,124	0,00 t	$0,089	26,17 t
01/02/2026	$0,128	17,17 t	$0,114	0,00 t	$0,088	26,17 t
01/03/2026	$0,130	17,17 t	$0,125	0,00 t	$0,087	26,17 t
01/04/2026	$0,132	17,17 t	$0,135	0,00 t	$0,086	26,17 t
01/05/2026	$0,134	17,17 t	$0,121	0,00 t	$0,086	26,17 t
01/06/2026	$0,136	17,17 t	$0,138	17,17 t	$0,085	26,17 t
01/07/2026	$0,138	17,17 t	$0,131	0,00 t	$0,084	26,17 t
01/08/2026	$0,140	17,17 t	$0,131	0,00 t	$0,083	26,17 t
01/09/2026	$0,142	17,17 t	$0,130	0,00 t	$0,082	26,17 t
01/10/2026	$0,144	17,17 t	$0,133	0,00 t	$0,081	26,17 t
01/11/2026	$0,147	17,17 t	$0,145	0,00 t	$0,081	26,17 t
01/12/2026	$0,149	17,17 t	$0,137	0,00 t	$0,080	26,17 t
01/01/2027	$0,151	17,17 t	$0,148	0,00 t	$0,079	26,17 t
01/02/2027	$0,153	17,17 t	$0,140	0,00 t	$0,078	26,17 t
01/03/2027	$0,156	17,17 t	$0,148	0,00 t	$0,077	26,17 t
01/04/2027	$0,158	17,17 t	$0,143	0,00 t	$0,077	26,17 t
01/05/2027	$0,160	17,17 t	$0,144	0,00 t	$0,076	26,17 t
01/06/2027	$0,163	17,17 t	$0,148	0,00 t	$0,075	26,17 t
01/07/2027	$0,165	17,17 t	$0,151	0,00 t	$0,074	26,17 t
01/08/2027	$0,168	17,17 t	$0,159	0,00 t	$0,074	26,17 t
01/09/2027	$0,170	17,17 t	$0,159	0,00 t	$0,073	26,17 t
01/10/2027	$0,173	17,17 t	$0,161	0,00 t	$0,072	26,17 t
01/11/2027	$0,175	17,17 t	$0,169	0,00 t	$0,071	26,17 t
01/12/2027	$0,178	17,17 t	$0,158	0,00 t	$0,071	26,17 t
01/01/2028	$0,180	17,17 t	$0,174	0,00 t	$0,070	26,17 t
01/02/2028	$0,183	17,17 t	$0,175	0,00 t	$0,069	26,17 t
01/03/2028	$0,186	17,17 t	$0,182	0,00 t	$0,069	26,17 t
01/04/2028	$0,189	17,17 t	$0,176	0,00 t	$0,068	26,17 t
01/05/2028	$0,192	17,17 t	$0,176	0,00 t	$0,067	26,17 t
01/06/2028	$0,194	17,17 t	$0,177	0,00 t	$0,067	26,17 t
01/07/2028	$0,197	17,17 t	$0,181	0,00 t	$0,066	26,17 t
01/08/2028	$0,200	17,17 t	$0,185	0,00 t	$0,065	26,17 t
01/09/2028	$0,203	17,17 t	$0,188	0,00 t	$0,065	26,17 t
01/10/2028	$0,206	17,17 t	$0,195	0,00 t	$0,064	26,17 t
01/11/2028	$0,209	17,17 t	$0,196	0,00 t	$0,063	26,17 t
01/12/2028	$0,213	17,17 t	$0,193	0,00 t	$0,063	26,17 t
01/01/2029	$0,216	17,17 t	$0,201	0,00 t	$0,062	26,17 t
01/02/2029	$0,219	17,17 t	$0,209	0,00 t	$0,061	26,17 t
01/03/2029	$0,222	17,17 t	$0,198	0,00 t	$0,061	26,17 t
01/04/2029	$0,226	17,17 t	$0,216	0,00 t	$0,060	26,17 t
01/05/2029	$0,229	17,17 t	$0,205	0,00 t	$0,060	26,17 t
01/06/2029	$0,232	17,17 t	$0,222	0,00 t	$0,059	26,17 t
01/07/2029	$0,236	17,17 t	$0,223	0,00 t	$0,058	26,17 t
01/08/2029	$0,239	17,17 t	$0,228	0,00 t	$0,058	26,17 t
01/09/2029	$0,243	17,17 t	$0,223	0,00 t	$0,057	26,17 t
01/10/2029	$0,247	17,17 t	$0,221	0,00 t	$0,057	26,17 t
01/11/2029	$0,250	17,17 t	$0,232	0,00 t	$0,056	26,17 t
02/11/2029	$0,254	17,17 t	$0,241	0,00 t	$0,056	26,17 t

	FRANCE					
	$/kWh Pesimistic Scenario Rate		$/kWh Neutral		$/kWh Optimistic Scenario Rate	
	1,50%	Optimal allocation	Normal fluctuations	Optimal allocation	-1,00%	Optimal allocation
01/11/2024	$0,103	0,00 t	$0,103	0,00 t	$0,103	0,00 t
01/12/2024	$0,105	0,00 t	$0,101	0,00 t	$0,102	0,00 t
01/01/2025	$0,106	0,00 t	$0,097	0,00 t	$0,101	0,00 t
01/02/2025	$0,108	0,00 t	$0,104	26,17 t	$0,100	0,00 t
01/03/2025	$0,110	0,00 t	$0,115	17,17 t	$0,099	0,00 t
01/04/2025	$0,111	0,00 t	$0,118	0,00 t	$0,098	0,00 t
01/05/2025	$0,113	0,00 t	$0,112	26,17 t	$0,097	0,00 t
01/06/2025	$0,115	0,00 t	$0,113	17,17 t	$0,096	0,00 t
01/07/2025	$0,116	0,00 t	$0,106	26,17 t	$0,095	0,00 t
01/08/2025	$0,118	0,00 t	$0,096	0,00 t	$0,094	0,00 t
01/09/2025	$0,120	0,00 t	$0,108	26,17 t	$0,093	0,00 t
01/10/2025	$0,122	0,00 t	$0,104	26,17 t	$0,092	0,00 t
01/11/2025	$0,123	0,00 t	$0,098	17,17 t	$0,091	0,00 t
01/12/2025	$0,125	0,00 t	$0,105	0,00 t	$0,091	0,00 t
01/01/2026	$0,127	0,00 t	$0,112	17,17 t	$0,090	0,00 t
01/02/2026	$0,129	0,00 t	$0,108	26,17 t	$0,089	0,00 t
01/03/2026	$0,131	0,00 t	$0,115	26,17 t	$0,088	0,00 t
01/04/2026	$0,133	0,00 t	$0,120	17,17 t	$0,087	0,00 t
01/05/2026	$0,135	0,00 t	$0,116	17,17 t	$0,086	0,00 t
01/06/2026	$0,137	0,00 t	$0,124	0,00 t	$0,085	0,00 t
01/07/2026	$0,139	0,00 t	$0,113	17,17 t	$0,084	0,00 t
01/08/2026	$0,141	0,00 t	$0,117	17,17 t	$0,084	0,00 t
01/09/2026	$0,143	0,00 t	$0,125	17,17 t	$0,083	0,00 t
01/10/2026	$0,145	0,00 t	$0,123	17,17 t	$0,082	0,00 t
01/11/2026	$0,147	0,00 t	$0,132	17,17 t	$0,081	0,00 t
01/12/2026	$0,150	0,00 t	$0,121	17,17 t	$0,080	0,00 t
01/01/2027	$0,152	0,00 t	$0,122	17,17 t	$0,079	0,00 t
01/02/2027	$0,154	0,00 t	$0,120	17,17 t	$0,079	0,00 t
01/03/2027	$0,157	0,00 t	$0,130	26,17 t	$0,078	0,00 t
01/04/2027	$0,159	0,00 t	$0,125	17,17 t	$0,077	0,00 t
01/05/2027	$0,161	0,00 t	$0,112	26,17 t	$0,076	0,00 t
01/06/2027	$0,164	0,00 t	$0,110	17,17 t	$0,076	0,00 t
01/07/2027	$0,166	0,00 t	$0,114	26,17 t	$0,075	0,00 t
01/08/2027	$0,169	0,00 t	$0,103	26,17 t	$0,074	0,00 t
01/09/2027	$0,171	0,00 t	$0,097	17,17 t	$0,073	0,00 t
01/10/2027	$0,174	0,00 t	$0,092	17,17 t	$0,073	0,00 t
01/11/2027	$0,176	0,00 t	$0,084	17,17 t	$0,072	0,00 t
01/12/2027	$0,179	0,00 t	$0,080	26,17 t	$0,071	0,00 t
01/01/2028	$0,182	0,00 t	$0,129	17,17 t	$0,070	0,00 t
01/02/2028	$0,184	0,00 t	$0,121	17,17 t	$0,070	0,00 t
01/03/2028	$0,187	0,00 t	$0,119	17,17 t	$0,069	0,00 t
01/04/2028	$0,190	0,00 t	$0,118	26,17 t	$0,068	0,00 t
01/05/2028	$0,193	0,00 t	$0,121	17,17 t	$0,068	0,00 t
01/06/2028	$0,196	0,00 t	$0,131	26,17 t	$0,067	0,00 t
01/07/2028	$0,199	0,00 t	$0,120	26,17 t	$0,066	0,00 t
01/08/2028	$0,202	0,00 t	$0,128	17,17 t	$0,066	0,00 t
01/09/2028	$0,205	0,00 t	$0,136	17,17 t	$0,065	0,00 t
01/10/2028	$0,208	0,00 t	$0,137	26,17 t	$0,064	0,00 t
01/11/2028	$0,211	0,00 t	$0,136	17,17 t	$0,064	0,00 t
01/12/2028	$0,214	0,00 t	$0,141	17,17 t	$0,063	0,00 t
01/01/2029	$0,217	0,00 t	$0,145	17,17 t	$0,062	0,00 t
01/02/2029	$0,220	0,00 t	$0,150	17,17 t	$0,062	0,00 t
01/03/2029	$0,224	0,00 t	$0,154	17,17 t	$0,061	0,00 t
01/04/2029	$0,227	0,00 t	$0,143	17,17 t	$0,061	0,00 t
01/05/2029	$0,231	0,00 t	$0,139	26,17 t	$0,060	0,00 t
01/06/2029	$0,234	0,00 t	$0,138	17,17 t	$0,059	0,00 t
01/07/2029	$0,237	0,00 t	$0,145	17,17 t	$0,059	0,00 t
01/08/2029	$0,241	0,00 t	$0,138	17,17 t	$0,058	0,00 t
01/09/2029	$0,245	0,00 t	$0,140	26,17 t	$0,058	0,00 t
01/10/2029	$0,248	0,00 t	$0,137	17,17 t	$0,057	0,00 t
01/11/2029	$0,252	0,00 t	$0,135	26,17 t	$0,056	0,00 t
02/11/2029	$0,256	0,00 t	$0,141	17,17 t	$0,056	0,00 t

	NORWAY					
	$/kWh Pesimistic Scenario Rate		$/kWh Neutral		$/kWh Optimistic Scenario Rate	
	1,50%	Optimal allocation	Normal fluctuations	Optimal allocation	-1,00%	Optimal allocation
01/11/2024	$0,029	9,75 t	$0,029	9,75 t	0,029	9,75 t
01/12/2024	$0,029	9,75 t	$0,032	9,75 t	$0,028	9,75 t
01/01/2025	$0,030	9,75 t	$0,041	9,75 t	$0,028	9,75 t
01/02/2025	$0,030	9,75 t	$0,039	9,75 t	$0,028	9,75 t
01/03/2025	$0,030	9,75 t	$0,047	9,75 t	$0,028	9,75 t
01/04/2025	$0,031	9,75 t	$0,044	9,75 t	$0,027	9,75 t
01/05/2025	$0,031	9,75 t	$0,051	9,75 t	$0,027	9,75 t
01/06/2025	$0,032	9,75 t	$0,046	9,75 t	$0,027	9,75 t
01/07/2025	$0,032	9,75 t	$0,052	9,75 t	$0,026	9,75 t
01/08/2025	$0,033	9,75 t	$0,059	9,75 t	$0,026	9,75 t
01/09/2025	$0,033	9,75 t	$0,056	9,75 t	$0,026	9,75 t
01/10/2025	$0,034	9,75 t	$0,056	9,75 t	$0,026	9,75 t
01/11/2025	$0,034	9,75 t	$0,054	9,75 t	$0,025	9,75 t
01/12/2025	$0,035	9,75 t	$0,060	9,75 t	$0,025	9,75 t
01/01/2026	$0,035	9,75 t	$0,067	9,75 t	$0,025	9,75 t
01/02/2026	$0,036	9,75 t	$0,065	9,75 t	$0,025	9,75 t
01/03/2026	$0,036	9,75 t	$0,065	9,75 t	$0,024	9,75 t
01/04/2026	$0,037	9,75 t	$0,065	9,75 t	$0,024	9,75 t
01/05/2026	$0,038	9,75 t	$0,060	9,75 t	$0,024	9,75 t
01/06/2026	$0,038	9,75 t	$0,062	9,75 t	$0,024	9,75 t
01/07/2026	$0,039	9,75 t	$0,061	9,75 t	$0,023	9,75 t
01/08/2026	$0,039	9,75 t	$0,059	9,75 t	$0,023	9,75 t
01/09/2026	$0,040	9,75 t	$0,055	9,75 t	$0,023	9,75 t
01/10/2026	$0,040	9,75 t	$0,060	9,75 t	$0,023	9,75 t
01/11/2026	$0,041	9,75 t	$0,058	9,75 t	$0,023	9,75 t
01/12/2026	$0,042	9,75 t	$0,063	9,75 t	$0,022	9,75 t
01/01/2027	$0,042	9,75 t	$0,060	9,75 t	$0,022	9,75 t
01/02/2027	$0,043	9,75 t	$0,056	9,75 t	$0,022	9,75 t
01/03/2027	$0,044	9,75 t	$0,063	9,75 t	$0,022	9,75 t
01/04/2027	$0,044	9,75 t	$0,059	9,75 t	$0,021	9,75 t
01/05/2027	$0,045	9,75 t	$0,060	9,75 t	$0,021	9,75 t
01/06/2027	$0,046	9,75 t	$0,055	9,75 t	$0,021	9,75 t
01/07/2027	$0,046	9,75 t	$0,051	9,75 t	$0,021	9,75 t
01/08/2027	$0,047	9,75 t	$0,058	9,75 t	$0,021	9,75 t
01/09/2027	$0,048	9,75 t	$0,056	9,75 t	$0,020	9,75 t
01/10/2027	$0,048	9,75 t	$0,057	9,75 t	$0,020	9,75 t
01/11/2027	$0,049	9,75 t	$0,058	9,75 t	$0,020	9,75 t
01/12/2027	$0,050	9,75 t	$0,058	9,75 t	$0,020	9,75 t
01/01/2028	$0,051	9,75 t	$0,049	9,75 t	$0,020	9,75 t
01/02/2028	$0,051	9,75 t	$0,047	9,75 t	$0,019	9,75 t
01/03/2028	$0,052	9,75 t	$0,054	9,75 t	$0,019	9,75 t
01/04/2028	$0,053	9,75 t	$0,055	9,75 t	$0,019	9,75 t
01/05/2028	$0,054	9,75 t	$0,049	9,75 t	$0,019	9,75 t
01/06/2028	$0,054	9,75 t	$0,056	9,75 t	$0,019	9,75 t
01/07/2028	$0,055	9,75 t	$0,057	9,75 t	$0,018	9,75 t
01/08/2028	$0,056	9,75 t	$0,063	9,75 t	$0,018	9,75 t
01/09/2028	$0,057	9,75 t	$0,061	9,75 t	$0,018	9,75 t
01/10/2028	$0,058	9,75 t	$0,067	9,75 t	$0,018	9,75 t
01/11/2028	$0,059	9,75 t	$0,062	9,75 t	$0,018	9,75 t
01/12/2028	$0,060	9,75 t	$0,059	9,75 t	$0,018	9,75 t
01/01/2029	$0,060	9,75 t	$0,061	9,75 t	$0,017	9,75 t
01/02/2029	$0,061	9,75 t	$0,059	9,75 t	$0,017	9,75 t
01/03/2029	$0,062	9,75 t	$0,066	9,75 t	$0,017	9,75 t
01/04/2029	$0,063	9,75 t	$0,071	9,75 t	$0,017	9,75 t
01/05/2029	$0,064	9,75 t	$0,068	9,75 t	$0,017	9,75 t
01/06/2029	$0,065	9,75 t	$0,062	9,75 t	$0,017	9,75 t
01/07/2029	$0,066	9,75 t	$0,061	9,75 t	$0,016	9,75 t
01/08/2029	$0,067	9,75 t	$0,062	9,75 t	$0,016	9,75 t
01/09/2029	$0,068	9,75 t	$0,067	9,75 t	$0,016	9,75 t
01/10/2029	$0,069	9,75 t	$0,066	9,75 t	$0,016	9,75 t
01/11/2029	$0,070	9,75 t	$0,064	9,75 t	$0,016	9,75 t
02/11/2029	$0,071	9,75 t	$0,062	9,75 t	$0,016	9,75 t

	UNITED STATES					
	$/kWh Pesimistic Scenario Rate		$/kWh Neutral		$/kWh Optimistic Scenario Rate	
	1,50%	Optimal allocation	Normal fluctuations	Optimal allocation	-1,00%	Optimal allocation
01/11/2024	$0,044	15,17 t	$0,044	15,17 t	$0,044	15,17 t
01/12/2024	$0,045	15,17 t	$0,040	15,17 t	$0,044	15,17 t
01/01/2025	$0,046	15,17 t	$0,036	15,17 t	$0,044	15,17 t
01/02/2025	$0,047	15,17 t	$0,043	15,17 t	$0,043	15,17 t
01/03/2025	$0,047	15,17 t	$0,047	15,17 t	$0,043	15,17 t
01/04/2025	$0,048	15,17 t	$0,049	15,17 t	$0,042	15,17 t
01/05/2025	$0,049	15,17 t	$0,052	15,17 t	$0,042	15,17 t
01/06/2025	$0,049	15,17 t	$0,056	15,17 t	$0,041	15,17 t
01/07/2025	$0,050	15,17 t	$0,059	15,17 t	$0,041	15,17 t
01/08/2025	$0,051	15,17 t	$0,057	15,17 t	$0,041	15,17 t
01/09/2025	$0,052	15,17 t	$0,055	15,17 t	$0,040	15,17 t
01/10/2025	$0,052	15,17 t	$0,055	15,17 t	$0,040	15,17 t
01/11/2025	$0,053	15,17 t	$0,056	15,17 t	$0,039	15,17 t
01/12/2025	$0,054	15,17 t	$0,050	15,17 t	$0,039	15,17 t
01/01/2026	$0,055	15,17 t	$0,046	15,17 t	$0,039	15,17 t
01/02/2026	$0,056	15,17 t	$0,049	15,17 t	$0,038	15,17 t
01/03/2026	$0,056	15,17 t	$0,053	15,17 t	$0,038	15,17 t
01/04/2026	$0,057	15,17 t	$0,054	15,17 t	$0,038	15,17 t
01/05/2026	$0,058	15,17 t	$0,056	15,17 t	$0,037	15,17 t
01/06/2026	$0,059	15,17 t	$0,061	15,17 t	$0,037	15,17 t
01/07/2026	$0,060	15,17 t	$0,063	15,17 t	$0,036	15,17 t
01/08/2026	$0,061	15,17 t	$0,063	15,17 t	$0,036	15,17 t
01/09/2026	$0,062	15,17 t	$0,057	15,17 t	$0,036	15,17 t
01/10/2026	$0,063	15,17 t	$0,055	15,17 t	$0,035	15,17 t
01/11/2026	$0,064	15,17 t	$0,050	15,17 t	$0,035	15,17 t
01/12/2026	$0,065	15,17 t	$0,053	15,17 t	$0,035	15,17 t
01/01/2027	$0,066	15,17 t	$0,050	15,17 t	$0,034	15,17 t
01/02/2027	$0,067	15,17 t	$0,047	15,17 t	$0,034	15,17 t
01/03/2027	$0,068	15,17 t	$0,048	15,17 t	$0,034	15,17 t
01/04/2027	$0,069	15,17 t	$0,047	15,17 t	$0,033	15,17 t
01/05/2027	$0,070	15,17 t	$0,049	15,17 t	$0,033	15,17 t
01/06/2027	$0,071	15,17 t	$0,054	15,17 t	$0,033	15,17 t
01/07/2027	$0,072	15,17 t	$0,059	15,17 t	$0,032	15,17 t
01/08/2027	$0,073	15,17 t	$0,059	15,17 t	$0,032	15,17 t
01/09/2027	$0,074	15,17 t	$0,062	15,17 t	$0,032	15,17 t
01/10/2027	$0,075	15,17 t	$0,061	15,17 t	$0,031	15,17 t
01/11/2027	$0,076	15,17 t	$0,057	15,17 t	$0,031	15,17 t
01/12/2027	$0,077	15,17 t	$0,061	15,17 t	$0,031	15,17 t
01/01/2028	$0,078	15,17 t	$0,058	15,17 t	$0,030	15,17 t
01/02/2028	$0,080	15,17 t	$0,054	15,17 t	$0,030	15,17 t
01/03/2028	$0,081	15,17 t	$0,055	15,17 t	$0,030	15,17 t
01/04/2028	$0,082	15,17 t	$0,059	15,17 t	$0,029	15,17 t
01/05/2028	$0,083	15,17 t	$0,061	15,17 t	$0,029	15,17 t
01/06/2028	$0,084	15,17 t	$0,065	15,17 t	$0,029	15,17 t
01/07/2028	$0,086	15,17 t	$0,060	15,17 t	$0,029	15,17 t
01/08/2028	$0,087	15,17 t	$0,060	15,17 t	$0,028	15,17 t
01/09/2028	$0,088	15,17 t	$0,055	15,17 t	$0,028	15,17 t
01/10/2028	$0,090	15,17 t	$0,052	15,17 t	$0,028	15,17 t
01/11/2028	$0,091	15,17 t	$0,055	15,17 t	$0,027	15,17 t
01/12/2028	$0,092	15,17 t	$0,054	15,17 t	$0,027	15,17 t
01/01/2029	$0,094	15,17 t	$0,048	15,17 t	$0,027	15,17 t
01/02/2029	$0,095	15,17 t	$0,054	15,17 t	$0,027	15,17 t
01/03/2029	$0,096	15,17 t	$0,053	15,17 t	$0,026	15,17 t
01/04/2029	$0,098	15,17 t	$0,055	15,17 t	$0,026	15,17 t
01/05/2029	$0,099	15,17 t	$0,050	15,17 t	$0,026	15,17 t
01/06/2029	$0,101	15,17 t	$0,053	15,17 t	$0,026	15,17 t
01/07/2029	$0,102	15,17 t	$0,053	15,17 t	$0,025	15,17 t
01/08/2029	$0,104	15,17 t	$0,049	15,17 t	$0,025	15,17 t
01/09/2029	$0,106	15,17 t	$0,045	15,17 t	$0,025	15,17 t
01/10/2029	$0,107	15,17 t	$0,043	15,17 t	$0,025	15,17 t
01/11/2029	$0,109	15,17 t	$0,039	15,17 t	$0,024	15,17 t
02/11/2029	$0,110	15,17 t	$0,037	15,17 t	$0,024	15,17 t

	SOUTH AFRICA					
	$/kWh Pesimistic Scenario Rate		$/kWh Neutral		$/kWh Optimistic Scenario Rate	
	10,00%	Optimal allocation	Normal fluctuations	Optimal allocation	-7,50%	Optimal alloca
01/11/2024	$0,104	0,00 t	$0,104	0,00 t	$0,104	0,00 t
01/12/2024	$0,104	9,00 t	$0,104	0,00 t	$0,104	0,00 t
01/01/2025	$0,104	9,00 t	$0,104	0,00 t	$0,104	0,00 t
01/02/2025	$0,104	9,00 t	$0,104	0,00 t	$0,104	0,00 t
01/03/2025	$0,104	9,00 t	$0,104	9,00 t	$0,104	0,00 t
01/04/2025	$0,104	9,00 t	$0,104	0,00 t	$0,104	0,00 t
01/05/2025	$0,104	9,00 t	$0,104	0,00 t	$0,104	0,00 t
01/06/2025	$0,104	9,00 t	$0,104	9,00 t	$0,104	0,00 t
01/07/2025	$0,104	9,00 t	$0,104	0,00 t	$0,104	0,00 t
01/08/2025	$0,104	9,00 t	$0,104	9,00 t	$0,104	0,00 t
01/09/2025	$0,104	9,00 t	$0,104	0,00 t	$0,104	0,00 t
01/10/2025	$0,104	9,00 t	$0,104	0,00 t	$0,104	0,00 t
01/11/2025	$0,104	9,00 t	$0,104	9,00 t	$0,104	0,00 t
01/12/2025	$0,104	9,00 t	$0,104	9,00 t	$0,104	0,00 t
01/01/2026	$0,104	9,00 t	$0,104	9,00 t	$0,104	0,00 t
01/02/2026	$0,104	9,00 t	$0,104	0,00 t	$0,104	0,00 t
01/03/2026	$0,104	9,00 t	$0,104	0,00 t	$0,104	0,00 t
01/04/2026	$0,114	9,00 t	$0,098	9,00 t	$0,096	0,00 t
01/05/2026	$0,114	9,00 t	$0,098	9,00 t	$0,096	0,00 t
01/06/2026	$0,114	9,00 t	$0,098	9,00 t	$0,096	0,00 t
01/07/2026	$0,114	9,00 t	$0,098	9,00 t	$0,096	0,00 t
01/08/2026	$0,114	9,00 t	$0,098	9,00 t	$0,096	0,00 t
01/09/2026	$0,114	9,00 t	$0,098	9,00 t	$0,096	0,00 t
01/10/2026	$0,114	9,00 t	$0,098	9,00 t	$0,096	0,00 t
01/11/2026	$0,114	9,00 t	$0,098	9,00 t	$0,096	0,00 t
01/12/2026	$0,114	9,00 t	$0,098	9,00 t	$0,096	0,00 t
01/01/2027	$0,114	9,00 t	$0,098	9,00 t	$0,096	0,00 t
01/02/2027	$0,114	9,00 t	$0,098	9,00 t	$0,096	0,00 t
01/03/2027	$0,114	9,00 t	$0,098	0,00 t	$0,096	0,00 t
01/04/2027	$0,125	9,00 t	$0,096	9,00 t	$0,089	0,00 t
01/05/2027	$0,125	9,00 t	$0,096	0,00 t	$0,089	0,00 t
01/06/2027	$0,125	9,00 t	$0,096	9,00 t	$0,089	0,00 t
01/07/2027	$0,125	9,00 t	$0,096	0,00 t	$0,089	0,00 t
01/08/2027	$0,125	9,00 t	$0,096	0,00 t	$0,089	0,00 t
01/09/2027	$0,125	9,00 t	$0,096	9,00 t	$0,089	0,00 t
01/10/2027	$0,125	9,00 t	$0,096	9,00 t	$0,089	0,00 t
01/11/2027	$0,125	9,00 t	$0,096	9,00 t	$0,089	0,00 t
01/12/2027	$0,125	9,00 t	$0,096	0,00 t	$0,089	0,00 t
01/01/2028	$0,125	9,00 t	$0,096	9,00 t	$0,089	0,00 t
01/02/2028	$0,125	9,00 t	$0,096	9,00 t	$0,089	0,00 t
01/03/2028	$0,125	9,00 t	$0,096	9,00 t	$0,089	0,00 t
01/04/2028	$0,138	9,00 t	$0,097	0,00 t	$0,082	0,00 t
01/05/2028	$0,138	9,00 t	$0,097	9,00 t	$0,082	0,00 t
01/06/2028	$0,138	9,00 t	$0,097	0,00 t	$0,082	0,00 t
01/07/2028	$0,138	9,00 t	$0,097	0,00 t	$0,082	0,00 t
01/08/2028	$0,138	9,00 t	$0,097	9,00 t	$0,082	0,00 t
01/09/2028	$0,138	9,00 t	$0,097	9,00 t	$0,082	0,00 t
01/10/2028	$0,138	9,00 t	$0,097	0,00 t	$0,082	0,00 t
01/11/2028	$0,138	9,00 t	$0,097	9,00 t	$0,082	0,00 t
01/12/2028	$0,138	9,00 t	$0,097	9,00 t	$0,082	0,00 t
01/01/2029	$0,138	9,00 t	$0,097	9,00 t	$0,082	0,00 t
01/02/2029	$0,138	9,00 t	$0,097	9,00 t	$0,082	0,00 t
01/03/2029	$0,138	9,00 t	$0,097	9,00 t	$0,082	0,00 t
01/04/2029	$0,152	9,00 t	$0,088	9,00 t	$0,076	0,00 t
01/05/2029	$0,152	9,00 t	$0,088	0,00 t	$0,076	0,00 t
01/06/2029	$0,152	9,00 t	$0,088	9,00 t	$0,076	0,00 t
01/07/2029	$0,152	9,00 t	$0,088	9,00 t	$0,076	0,00 t
01/08/2029	$0,152	9,00 t	$0,088	9,00 t	$0,076	0,00 t
01/09/2029	$0,152	9,00 t	$0,088	0,00 t	$0,076	0,00 t
01/10/2029	$0,152	9,00 t	$0,088	9,00 t	$0,076	0,00 t
01/11/2029	$0,152	9,00 t	$0,088	0,00 t	$0,076	0,00 t
02/11/2029	$0,152	9,00 t	$0,088	9,00 t	$0,076	0,00 t

Appendix 13. Weighted electricity prices and total costs

	Estimated Weighted Average Electricity Price for Ferroglobe in $/kWh & Estimated monthly costs in electricity											
	$/kWh Pesimistic with Max Cap Distribution		$/kWh Pesimistic with Optimal Distribution		$/kWh Neutral		$/kWh Neutral with Optimal Distribution		$/kWh Optimistic		$/kWh Optimistic with Optimal Distribution	
01/10/2024	$0,063	$51.021.035,872	$0,072	$57.763.047,339	$0,063	$51.021.035,872	$0,069	$55.945.205,969	$0,063	$51.021.035,872	$0,071	$57.080.697,803
01/11/2024	$0,081	$65.512.820,570	$0,071	$57.367.535,481	$0,081	$65.512.820,570	$0,071	$57.367.535,481	$0,081	$65.512.820,570	$0,071	$57.367.535,481
01/12/2024	$0,082	$66.385.799,132	$0,072	$58.158.559,198	$0,082	$66.261.138,724	$0,068	$54.522.876,458	$0,081	$64.930.834,863	$0,070	$56.793.860,126
01/01/2025	$0,083	$67.271.872,372	$0,073	$58.810.457,443	$0,089	$71.615.128,247	$0,074	$59.669.544,995	$0,080	$64.354.669,012	$0,070	$56.225.921,525
01/02/2025	$0,085	$68.171.236,711	$0,074	$59.472.134,161	$0,094	$75.431.769,361	$0,087	$70.134.257,930	$0,079	$63.784.264,820	$0,069	$55.663.662,309
01/03/2025	$0,086	$69.084.091,515	$0,075	$60.143.736,030	$0,090	$72.201.072,466	$0,082	$66.427.197,891	$0,078	$63.219.564,670	$0,068	$55.107.025,686
01/04/2025	$0,087	$70.010.639,140	$0,075	$60.825.411,927	$0,087	$70.477.386,168	$0,074	$59.770.272,616	$0,078	$62.660.511,521	$0,068	$54.555.955,429
01/05/2025	$0,088	$70.951.084,981	$0,076	$61.517.312,963	$0,095	$76.465.558,729	$0,091	$73.084.897,477	$0,077	$62.107.048,904	$0,067	$54.010.395,875
01/06/2025	$0,089	$71.905.637,508	$0,077	$62.219.592,514	$0,098	$78.975.890,421	$0,090	$72.151.143,911	$0,076	$61.559.120,913	$0,066	$53.470.291,916
01/07/2025	$0,090	$72.874.508,324	$0,078	$62.932.406,258	$0,093	$74.835.173,614	$0,090	$72.652.572,821	$0,076	$61.016.672,201	$0,066	$52.935.588,997
01/08/2025	$0,092	$73.857.912,202	$0,079	$63.655.912,208	$0,097	$77.973.998,038	$0,084	$67.644.756,759	$0,075	$60.479.647,977	$0,065	$52.406.233,107
01/09/2025	$0,093	$74.856.067,138	$0,080	$64.390.270,748	$0,095	$76.349.557,409	$0,091	$73.206.815,034	$0,074	$59.947.993,995	$0,064	$51.882.170,776
01/10/2025	$0,094	$75.869.194,398	$0,081	$65.135.644,666	$0,094	$75.468.069,323	$0,087	$70.485.849,548	$0,074	$59.421.656,553	$0,064	$51.363.349,068
01/11/2025	$0,095	$76.897.518,567	$0,082	$65.892.199,193	$0,096	$77.458.212,591	$0,084	$67.913.319,976	$0,073	$58.900.582,486	$0,063	$50.849.715,578
01/12/2025	$0,097	$77.941.267,599	$0,083	$66.660.102,037	$0,098	$79.130.005,717	$0,087	$69.914.184,705	$0,072	$58.384.719,159	$0,062	$50.341.218,422
01/01/2026	$0,098	$79.000.672,866	$0,084	$67.439.523,424	$0,100	$80.304.007,573	$0,085	$68.230.548,525	$0,072	$57.874.014,465	$0,062	$49.837.806,238
01/02/2026	$0,099	$80.075.969,212	$0,085	$68.230.636,132	$0,098	$79.247.496,670	$0,087	$70.249.276,143	$0,071	$57.368.416,819	$0,061	$49.339.428,175
01/03/2026	$0,101	$81.167.395,003	$0,086	$69.033.615,531	$0,092	$74.255.503,004	$0,084	$67.859.443,608	$0,071	$56.867.875,148	$0,061	$48.846.033,894
01/04/2026	$0,103	$83.006.617,161	$0,089	$71.318.507,243	$0,100	$80.190.854,306	$0,084	$67.545.669,452	$0,069	$55.823.770,160	$0,060	$48.357.573,555
01/05/2026	$0,104	$84.131.031,297	$0,090	$72.145.756,694	$0,095	$76.405.655,693	$0,083	$67.001.362,226	$0,069	$55.333.189,269	$0,059	$47.873.997,819
01/06/2026	$0,106	$85.272.311,644	$0,091	$72.985.414,887	$0,098	$79.260.292,785	$0,093	$75.011.213,104	$0,068	$54.847.514,187	$0,059	$47.395.257,841
01/07/2026	$0,107	$86.430.711,198	$0,092	$73.837.667,952	$0,096	$77.678.357,645	$0,083	$67.117.782,440	$0,067	$54.366.695,856	$0,058	$46.921.305,262
01/08/2026	$0,109	$87.606.486,744	$0,093	$74.702.704,814	$0,098	$78.621.408,162	$0,083	$66.583.921,889	$0,067	$53.890.685,708	$0,058	$46.452.092,210
01/09/2026	$0,110	$88.799.898,923	$0,094	$75.580.717,228	$0,099	$79.487.001,198	$0,084	$67.889.469,134	$0,066	$53.419.435,661	$0,057	$45.987.571,288
01/10/2026	$0,112	$90.011.212,286	$0,095	$76.471.899,829	$0,100	$80.613.539,299	$0,082	$66.355.348,616	$0,066	$52.952.898,115	$0,056	$45.527.695,575
01/11/2026	$0,113	$91.240.695,348	$0,096	$77.376.450,169	$0,099	$79.889.648,728	$0,081	$65.463.393,084	$0,065	$52.491.025,945	$0,056	$45.072.418,619
01/12/2026	$0,115	$92.488.620,657	$0,097	$78.294.568,764	$0,103	$83.336.267,089	$0,084	$67.780.488,569	$0,065	$52.033.772,496	$0,055	$44.621.694,433
01/01/2027	$0,116	$93.755.264,845	$0,098	$79.226.459,137	$0,107	$86.534.204,087	$0,085	$68.666.651,036	$0,064	$51.581.091,582	$0,055	$44.175.477,489
01/02/2027	$0,118	$95.040.908,696	$0,099	$80.172.327,867	$0,104	$83.736.514,057	$0,085	$68.688.607,301	$0,063	$51.132.937,476	$0,054	$43.733.722,714
01/03/2027	$0,120	$96.345.837,205	$0,101	$81.132.384,627	$0,108	$87.178.664,973	$0,096	$77.116.496,616	$0,063	$50.689.264,912	$0,054	$43.296.385,487
01/04/2027	$0,122	$98.474.907,119	$0,104	$83.723.696,624	$0,112	$90.416.272,724	$0,091	$72.996.345,553	$0,062	$49.742.602,994	$0,053	$42.863.421,632
01/05/2027	$0,124	$99.819.277,092	$0,105	$84.712.771,099	$0,114	$91.641.574,735	$0,098	$79.136.214,258	$0,061	$49.307.759,514	$0,053	$42.434.787,415
01/06/2027	$0,126	$101.183.812,615	$0,106	$85.716.681,692	$0,109	$87.679.043,116	$0,088	$70.547.322,871	$0,061	$48.877.264,469	$0,052	$42.010.439,541
01/07/2027	$0,127	$102.568.816,170	$0,108	$86.735.650,944	$0,105	$84.474.279,264	$0,090	$72.335.830,904	$0,060	$48.451.074,374	$0,052	$41.590.335,146
01/08/2027	$0,129	$103.974.594,779	$0,109	$87.769.904,735	$0,109	$88.217.430,853	$0,093	$75.011.653,699	$0,060	$48.029.146,180	$0,051	$41.174.431,794
01/09/2027	$0,131	$105.401.460,067	$0,110	$88.819.672,333	$0,110	$88.442.998,154	$0,085	$68.634.902,626	$0,059	$47.611.437,268	$0,051	$40.762.687,476
01/10/2027	$0,133	$106.849.728,334	$0,112	$89.885.186,444	$0,109	$88.179.168,081	$0,082	$66.035.634,115	$0,059	$47.197.905,445	$0,050	$40.355.060,602
01/11/2027	$0,134	$108.319.720,625	$0,113	$90.966.683,267	$0,110	$89.006.251,926	$0,083	$67.214.566,872	$0,058	$46.788.508,941	$0,050	$39.951.509,996
01/12/2027	$0,136	$109.811.762,801	$0,114	$92.064.402,543	$0,111	$89.182.754,978	$0,088	$70.835.196,970	$0,058	$46.383.206,401	$0,049	$39.551.994,896
01/01/2028	$0,138	$111.326.185,609	$0,116	$93.178.587,607	$0,115	$92.527.228,604	$0,087	$69.914.814,654	$0,057	$45.981.956,887	$0,049	$39.156.474,947
01/02/2028	$0,140	$112.863.324,759	$0,117	$94.309.485,448	$0,112	$90.526.321,476	$0,083	$66.644.018,904	$0,057	$45.584.719,868	$0,048	$38.764.910,197
01/03/2028	$0,142	$114.423.520,997	$0,118	$95.457.346,756	$0,115	$92.410.139,249	$0,084	$67.365.610,097	$0,056	$45.191.455,219	$0,048	$38.377.261,095
01/04/2028	$0,145	$116.892.144,403	$0,122	$98.400.965,807	$0,113	$91.245.100,747	$0,088	$71.200.876,588	$0,055	$44.332.754,093	$0,047	$37.993.488,484
01/05/2028	$0,147	$118.499.497,572	$0,124	$99.583.521,224	$0,114	$91.715.085,938	$0,085	$68.660.104,459	$0,055	$43.947.315,410	$0,047	$37.613.553,600
01/06/2028	$0,149	$120.130.961,039	$0,125	$100.783.814,971	$0,118	$95.273.453,875	$0,097	$78.176.681,181	$0,054	$43.565.731,115	$0,046	$37.237.418,064
01/07/2028	$0,151	$121.786.896,457	$0,127	$102.002.113,125	$0,116	$93.144.010,485	$0,090	$72.406.314,950	$0,054	$43.187.962,662	$0,046	$36.865.043,883
01/08/2028	$0,153	$123.467.670,907	$0,128	$103.238.685,751	$0,120	$96.621.686,163	$0,090	$72.567.627,689	$0,053	$42.813.971,894	$0,045	$36.496.393,444
01/09/2028	$0,155	$125.173.656,973	$0,130	$104.493.806,966	$0,122	$98.505.003,864	$0,091	$73.136.582,250	$0,053	$42.443.721,034	$0,045	$36.131.429,510
01/10/2028	$0,157	$126.905.232,831	$0,131	$105.767.755,000	$0,125	$100.705.804,999	$0,099	$79.523.472,170	$0,052	$42.077.172,682	$0,044	$35.770.115,215
01/11/2028	$0,160	$128.662.782,326	$0,133	$107.060.812,254	$0,125	$100.712.513,908	$0,091	$73.200.830,434	$0,052	$41.714.289,814	$0,044	$35.412.414,062
01/12/2028	$0,162	$130.446.695,064	$0,134	$108.373.265,367	$0,125	$100.814.819,029	$0,092	$73.912.703,605	$0,051	$41.355.035,774	$0,044	$35.058.289,922
01/01/2029	$0,164	$132.257.366,492	$0,136	$109.705.405,277	$0,128	$103.214.996,133	$0,092	$74.012.549,069	$0,051	$40.999.374,275	$0,043	$34.707.707,023
01/02/2029	$0,166	$134.095.197,993	$0,138	$111.057.527,285	$0,133	$107.023.926,379	$0,095	$76.470.872,227	$0,050	$40.647.269,391	$0,043	$34.360.629,952
01/03/2029	$0,169	$135.960.596,965	$0,140	$112.429.931,124	$0,131	$105.456.687,641	$0,097	$78.374.035,844	$0,050	$40.298.685,556	$0,042	$34.017.023,653
01/04/2029	$0,172	$138.827.503,570	$0,144	$115.779.314,825	$0,133	$107.428.584,333	$0,093	$75.260.468,001	$0,049	$39.519.421,119	$0,042	$33.676.853,416
01/05/2029	$0,175	$140.749.284,227	$0,145	$117.193.199,570	$0,128	$102.792.623,237	$0,099	$79.668.574,019	$0,049	$39.177.774,102	$0,041	$33.340.084,882
01/06/2029	$0,177	$142.699.891,594	$0,147	$118.628.292,585	$0,133	$107.134.260,219	$0,090	$72.215.062,473	$0,048	$38.839.543,556	$0,041	$33.006.684,033
01/07/2029	$0,180	$144.679.758,071	$0,149	$120.084.911,996	$0,135	$108.745.954,408	$0,092	$73.881.893,136	$0,048	$38.504.695,314	$0,041	$32.676.617,193
01/08/2029	$0,182	$146.689.322,545	$0,151	$121.563.380,698	$0,134	$107.913.504,440	$0,088	$71.045.418,503	$0,047	$38.173.195,555	$0,040	$32.349.851,021
01/09/2029	$0,185	$148.729.030,486	$0,153	$123.064.026,431	$0,133	$107.141.642,174	$0,098	$78.720.720,322	$0,047	$37.845.010,794	$0,040	$32.026.352,511
01/10/2029	$0,187	$150.799.334,047	$0,155	$124.587.181,849	$0,131	$105.591.506,125	$0,087	$70.009.241,896	$0,047	$37.520.107,880	$0,039	$31.706.088,986
01/11/2029	$0,190	$152.900.692,160	$0,157	$126.133.184,599	$0,133	$107.182.916,504	$0,093	$74.812.076,693	$0,046	$37.198.453,995	$0,039	$31.389.028,096
02/11/2029	$0,192	$155.033.570,646	$0,158	$127.702.377,390	$0,137	$110.720.872,344	$0,086	$68.996.856,723	$0,046	$36.880.016,650	$0,039	$31.075.137,815

Appendix 14. Ferroglobe Historic Income Statement

Ferroglobe PLC
GSM G33856108 BYW6GV6 NASDAQ Common stock
FactSet Fundamentals

	30 SEP '24	30 JUN '24 RECAP	31 MAR '24	31 DEC '23 RECAP	30 SEP '23 RECAP	30 JUN '23 RECAP	31 MAR '23 RECAP	31 DEC '22 RECAP	30 SEP '22 RECAP	30 JUN '22 RECAP	31 MAR '22 RECAP	31 DEC '21 RECAP
Net sales	433,53	451,05	391,85	375,95	416,81	456,44	400,87	448,63	593,22	840,81	715,27	569,77
Selling, general, and administrative expenses												
Selling, general, and administrative expenses excluding research and development and gain / loss on sale of business												
Research and development												
Gain / loss on sale of business												
Contract acquisition cost												
Curtailment gain												
Business interruption insurance recovery												
Restructuring charges												
Goodwill and intangible asset impairment												
Goodwill impairment												
Other operating income	27,20	27,45	10,84	34,94	23,55	27,69	14,81	78,41	19,71	26,22	23,01	39,62
Raw materials and energy consumption for production	-255,06	-262,02	-259,29	-199,57	-195,60	-252,27	-231,84	-289,57	-285,21	-369,75	-340,55	-371,52
Cost of goods sold	-256,22	-264,29	-257,36	-199,91	-195,60	-229,08	-255,04	-289,57	-285,21	-369,75	-340,55	-371,52
Energy consumption for production (PPA impact)	1,16	2,27	-1,93	0,34	0,00	-23,19	23,19	0,00	0,00	0,00	0,00	
Staff costs	-71,89	-67,22	-70,52	-79,76	-83,58	-74,97	-67,54	-76,43	-75,69	-80,70	-81,99	-72,07
Other operating expense	-74,47	-86,07	-52,35	-73,07	-65,71	-77,20	-54,15	-54,13	-77,95	-130,99	-83,18	-87,01
Depreciation and amortization charges, operating allowances and write-downs	-18,90	-18,88	-18,67	-20,09	-19,00	-16,45	-17,99	-20,55	-19,72	-20,18	-21,11	-24,55
Impairment of long-lived assets	0,00	0,00	0,00	-23,61	-1,04	-0,89	0,25	-57,00	0,00	0,00	0,00	0,50
Other gain / loss	0,19	0,24	0,70	-0,56	-0,01	0,50	0,05	0,34	0,07	-0,10	-0,32	1,15
Net loss / gain due to changes in the value of assets												
Loss / gain on disposal of non-current assets												
Other loss / gain excluding net loss / gain due to changes in the value of assets and loss / gain on disposal of non-current assets												
Bargain purchase gain												
Net gain due to changes in the value of assets												
Loss / gain on disposal of non-current assets												
Other loss / gain												
Operating income / loss	40,60	44,55	2,56	14,22	75,42	62,85	44,45	29,70	154,42	265,30	211,13	55,88
Gain / loss on remeasurement of equity investment												
Bargain purchase gain												
Net finance expense	-2,15	-5,32	-7,67	-12,33	-9,17	-0,90	-10,98	-16,83	-16,63	-12,83	-12,46	-18,52
Interest income												
Interest expense, net of capitalized interest												
Financial derivatives loss												0,00
Foreign exchange loss / gain	-6,58	3,59	1,38	-4,90	1,26	-5,37	1,46	4,05	-1,77	-7,88	-4,39	9,88
Other income / expense												
Income / loss before provision for / benefit from income taxes	31,87	42,83	-3,73	-3,00	67,51	56,58	34,93	16,92	136,02	244,59	194,28	47,24
Provision for / benefit from income taxes	-13,30	-8,48	1,16	-4,16	-23,40	-20,52	-9,46	-7,78	-37,18	-59,53	-43,49	2,79
Loss / profit for the period from continuing operations	18,57	34,35	-2,57	-7,16	44,11	36,06	25,47	9,14	98,84	185,06	150,79	50,03
Loss / profit for discontinued operations												
Loss / profit for the period	18,57	34,35	-2,57	-7,16	44,11	36,06	25,47	9,14	98,84	185,06	150,79	50,03
Income / loss attributable to noncontrolling interest, net of tax	0,24	0,53	0,55	-3,95	-3,23	-4,16	-4,48	-2,94	-1,21	0,27	0,38	1,41
Deferred interest attributable to common stock subject to redemption												
Profit / loss attributable to the parent	18,81	34,88	-2,02	-11,12	40,88	31,91	20,99	6,20	97,63	185,32	151,16	51,45
Weighted average shares												
Basic	188,3	189,3	187,9	187,9	187,9	187,9	187,9	187,5	187,4	187,4	187,4	187,4
Diluted	190,4	191,0	187,9	187,9	190,5	190,2	189,6	188,9	188,9	188,5	188,6	188,6
Per share												
Basic	0,10	0,18	-0,01	-0,06	0,22	0,17	0,11	0,03	0,52	0,99	0,81	0,27
Continued operations												
Discontinued operations												
Diluted	0,10	0,18	-0,01	-0,06	0,21	0,17	0,11	0,03	0,52	0,98	0,80	0,27
Continued operations												
Discontinued operations												

	30 SEP '21	30 JUN '21 RECAP	31 MAR '21 RECAP	31 DEC '20 RECAP	30 SEP '20 RECAP	JN '20 AP	31 MAR '20 RECAP	31 DEC '19 RECAP	30 SEP '19 RECAP	30 JUN '19 RECAP	31 MAR '19 RECAP	31 DEC '18 RECAP	30 SEP '18 RECAP
Net sales	429,21	418,54	361,39	320,54	262,67	250,00	311,22	376,61	381,74	409,48	447,39	603,52	524,41
Selling, general, and administrative expenses													
Selling, general, and administrative expenses excluding research and development and gain / loss on sale of business													
Research and development													
Gain / loss on sale of business													
Contract acquisition cost													
Curtailment gain													
Business interruption insurance recovery													
Restructuring charges													
Goodwill and intangible asset impairment													
Goodwill impairment													
Other operating income	31,45	37,11	1,91	8,10	7,60	10,16	7,77	12,45	13,22	14,53	14,02	25,04	5,63
Raw materials and energy consumption for production	-295,27	-267,94	-250,16	-272,60	-166,23	-153,29	-243,36	-314,90	-277,69	-292,43	-329,37	-448,33	-334,34
Cost of goods sold	-295,27	-267,94	-250,16	-272,60	-166,23	-153,29	-243,36	-314,90	-277,69	-292,43	-329,37	-448,33	-334,34
Energy consumption for production (PPA impact)													
Staff costs	-50,39	-63,20	-95,27	-54,44	-56,33	-48,91	-55,10	-63,38	-72,54	-74,85	-74,26	-81,23	-88,13
Other operating expense	-79,79	-93,17	-36,83	-29,14	-26,90	-35,95	-40,07	-58,80	-50,06	-62,92	-53,92	-73,16	-63,92
Depreciation and amortization charges, operating allowances and write-downs	-23,97	-23,52	-25,29	-25,54	-26,52	-27,46	-28,67	-30,03	-29,59	-30,20	-30,37	-30,06	-29,59
Impairment of long-lived assets	-0,36		0,00	-39,07	-34,27		0,00	-0,55	-174,02	-1,20	-0,14	-58,92	0,00
Other gain / loss	0,38	0,61	0,07	0,82	1,21	0,09	-0,67	0,10	-3,77	0,28	-0,40	4,01	0,22
Net loss / gain due to changes in the value of assets													
Loss / gain on disposal of non-current assets													
Other loss / gain excluding net loss / gain due to changes in the value of assets and loss / gain on disposal of non-current assets													0,22
Bargain purchase gain								0,00			0,00	-4,49	0,00
Net gain due to changes in the value of assets													
Loss / gain on disposal of non-current assets													
Other loss / gain													
Operating income / loss	11,26	8,42	-44,18	-91,34	-38,77	-5,37	-48,87	-78,51	-212,71	-37,32	-27,04	-63,63	14,28
Gain / loss on remeasurement of equity investment													
Bargain purchase gain													
Net finance expense	-103,38	-11,18	-15,86	-19,63	-13,99	-16,69	-16,48	-16,48	-16,49	-15,05	-13,82	-15,13	-12,99
Interest income													
Interest expense, net of capitalized interest													
Financial derivatives loss	0,00		0,00	0,00	0,00	0,00	3,17	-1,15	2,91	-0,30	1,26	1,38	0,39
Foreign exchange loss / gain	-6,18	3,24	-9,31	7,33	13,16	2,63	2,44	4,37	-5,08	5,08	-1,48	-3,09	-3,07
Other income / expense													
Income / loss before provision for / benefit from income taxes	-98,30	0,48	-69,36	-103,65	-39,59	-19,42	-59,75	-91,78	-231,37	-47,58	-41,08	-80,46	-1,40
Provision for / benefit from income taxes	0,68	0,25	0,84	-36,19	-1,84	5,39	10,70	14,12	14,32	4,89	8,21	6,31	-0,66
Loss / profit for the period from continuing operations	-97,62	0,73	-68,52	-139,83	-41,44	-14,04	-49,06	-77,66	-217,05	-42,70	-32,87	-74,15	-2,06
Loss / profit for discontinued operations	0,00			0,00	-5,40		0,00	4,37	76,91	-0,96	4,32		-0,86
Loss / profit for the period	-97,62	0,73	-68,52	-139,83	-46,83	-14,04	-49,06	-73,29	-140,14	-43,66	-28,55	-74,15	-2,92
Income / loss attributable to noncontrolling interest, net of tax	1,02	1,18	1,14	0,78	-0,45	1,93	1,16	0,87	-0,39	2,84	1,72	14,94	1,67
Deferred interest attributable to common stock subject to redemption													
Profit / loss attributable to the parent	-96,60	1,91	-67,38	-139,05	-47,28	-12,11	-47,90	-72,42	-140,52	-40,82	-26,83	-59,21	-1,25
Weighted average shares													
Basic	179,8	169,3	169,3	169,3	169,3	169,3	169,2	169,2	169,1	169,1	169,1	170,2	171,9
Diluted	179,8	169,3	169,3	169,3	169,3	169,3	169,2	169,2	169,1	169,1	169,1	170,2	171,9
Per share													
Basic	-0,54	0,01	-0,40	-0,82	-0,28	-0,07	-0,28	-0,43	-0,83	-0,24	-0,16	-0,35	-0,01
Continued operations													
Discontinued operations													
Diluted	-0,54	0,01	-0,40	-0,82	-0,28	-0,07	-0,28	-0,43	-0,83	-0,24	-0,16	-0,35	-0,01
Continued operations													
Discontinued operations													

Appendix 15. Pessimistic Scenario with Max Cap and Optimal Distribution

PESSIMISTIC SCENARIO with Max Capacity Distribution

GSM-US		Sales Estimations by FactSet				Personal Sales Estimations				Historic Data from Historical GSM IS (FactSet)		
Income Statement (M)	sep-18	dic-18	mar-19	jun-19	sep-19	dic-19	mar-20	jun-20	sep-20	dic-20	mar-21	jun-21
	30 SEP '18 RECAP	31 DEC '18 RECAP	31 MAR '19 RECAP	30 JUN '19 RECAP	30 SEP '19 RECAP	31 DEC '19 RECAP	31 MAR '20 RECAP	30 JUN '20 RECAP	30 SEP '20 RECAP	31 DEC '20 RECAP	31 MAR '21 RECAP	30 JUN '21 RECAP
Sales	524,41	603,52	447,39	409,48	381,74	376,61	311,22	250,00	262,67	320,54	361,39	418,54
COGS (Raw materials & energy consumption for materials)	-334,34	-448,33	-329,37	-292,43	-277,69	-314,90	-243,36	-153,29	-166,23	-272,60	-250,16	-267,94
	64%	74%	74%	71%	73%	84%	78%	61%	63%	85%	69%	64%
Gross Income	190,07	155,19	118,02	117,05	104,05	61,70	67,86	96,71	96,44	47,93	111,23	150,60
	36%	26%	26%	29%	27%	16%	22%	39%	37%	15%	31%	36%
Staff Costs	-88,13	-81,23	-74,26	-74,85	-72,54	-63,38	-55,10	-48,91	-56,33	-54,44	-95,27	-63,20
	46%	52%	63%	64%	70%	103%	81%	51%	58%	114%	86%	42%
EBITDA	101,93	73,96	43,76	42,20	31,52	-1,68	12,77	47,80	40,11	-6,51	15,96	87,40
	19%	12%	10%	10%	8%	0%	4%	19%	15%	-2%	4%	21%
Depr. & Amort.	-29,59	-30,06	-30,37	-30,20	-29,59	-30,03	-28,67	-27,46	-26,52	-25,54	-25,29	-23,52
	29%	41%	69%	72%	94%	-1792%	225%	57%	66%	-392%	158%	27%
pairment of Long-Lived Asse	0,00	-58,92	-0,14	-1,20	-174,02	-0,55	0,00	0,00	-34,27	-39,07	0,00	0,00
	0%	80%	0%	3%	552%	-33%	0%	0%	85%	-600%	0%	0%
Other Operating Income	5,63	25,04	14,02	14,53	13,22	12,45	7,77	10,16	7,60	8,10	1,91	37,11
	6%	34%	32%	34%	42%	-743%	61%	21%	19%	-124%	12%	42%
Other Operating Expense	-63,92	-73,16	-53,92	-62,92	-50,06	-58,80	-40,07	-35,95	-26,90	-29,14	-36,83	-93,17
	63%	99%	123%	149%	159%	-3509%	314%	75%	67%	-448%	231%	107%
Other gain / loss	0,22	4,01	-0,40	0,28	-3,77	0,10	-0,67	0,09	1,21	0,82	0,07	0,61
	0%	-5%	1%	-1%	12%	6%	5%	0%	-3%	13%	0%	-1%
EBIT	14,28	-59,14	-27,04	-37,32	-212,71	-78,51	-48,87	-5,37	-38,77	-91,34	-44,18	8,42
	3%	-10%	-6%	-9%	-56%	-21%	-16%	-2%	-15%	-28%	-12%	2%

GSM-US			Cost of electricity based on assumptions			1	2	3	4	5	6	7	8
Income Statement (M)	sep-21	dic-21	mar-22	jun-22	sep-22	dic-22	mar-23	jun-23	sep-23	dic-23	mar-24	jun-24	sep-24
	30 SEP '21 RECAP	31 DEC '21 RECAP	31 MAR '22 RECAP	30 JUN '22 RECAP	30 SEP '22 RECAP	31 DEC '22 RECAP	31 MAR '23 RECAP	30 JUN '23 RECAP	30 SEP '23 RECAP	31 DEC '23 RECAP	Mar '24 Q1	Jun '24 Q2	Sep '24 Q3
Sales	429,21	569,77	715,27	840,81	593,22	448,63	400,87	456,44	416,81	375,95	391,85	451,05	433,53
COGS (Raw materials & energy consumption for materials)	-295,27	-371,52	-340,55	-369,75	-285,21	-289,57	-231,84	-252,27	-195,60	-199,57	-259,29	-262,02	-255,06
	69%	65%	48%	44%	48%	65%	58%	55%	47%	53%	66%	58%	59%
Gross Income	133,94	198,25	374,71	471,06	308,01	159,05	169,03	204,17	221,21	176,38	132,56	189,03	178,47
	31%	35%	52%	56%	52%	35%	42%	45%	53%	47%	34%	42%	41%
Staff Costs	-50,39	-72,07	-81,99	-80,70	-75,69	-76,43	-67,54	-74,97	-83,58	-79,76	-70,52	-67,22	-71,89
	38%	36%	22%	17%	25%	48%	40%	37%	38%	45%	53%	36%	40%
EBITDA	83,55	126,18	292,72	390,35	232,32	82,62	101,48	129,20	137,63	96,62	62,05	121,81	106,59
	19%	22%	41%	46%	39%	18%	25%	28%	33%	26%	16%	27%	25%
Depr. & Amort.	-23,97	-24,55	-21,11	-20,18	-19,72	-20,55	-17,99	-16,45	-19,00	-20,09	-18,67	-18,88	-18,90
	29%	19%	7%	5%	8%	25%	18%	13%	14%	21%	30%	15%	18%
pairment of Long-Lived Asse	-0,36	0,50	0,00	0,00	0,00	-57,00	0,25	-0,89	-1,04	-23,61	0,00	0,00	0,00
	0%	0%	0%	0%	0%	69%	0%	1%	1%	24%	0%	0%	0%
Other Operating Income	31,45	39,62	23,01	26,22	19,71	78,41	14,81	27,69	23,55	34,94	10,84	27,45	27,20
	38%	31%	8%	7%	8%	95%	15%	21%	17%	36%	17%	23%	26%
Other Operating Expense	-79,79	-87,01	-83,18	-130,99	-77,95	-54,13	-54,15	-77,20	-65,71	-73,07	-52,35	-86,07	-74,47
	95%	69%	28%	34%	34%	66%	53%	60%	48%	76%	84%	71%	70%
Other gain / loss	0,38	1,15	-0,32	-0,10	0,07	0,34	0,05	0,50	-0,01	-0,56	0,70	0,24	0,19
	0%	-1%	0%	0%	0%	0%	0%	0%	0%	1%	-1%	0%	0%
EBIT	11,26	55,88	211,13	265,30	154,42	29,70	44,45	62,85	75,42	14,22	2,56	44,55	40,60
	3%	10%	30%	32%	26%	7%	11%	14%	18%	4%	1%	10%	9%

GSM-US	9	10	11	12	13	14	15	16	17	18
Income Statement (M)	dic-24	mar-25	jun-25	sep-25	dic-25	mar-26	jun-26	sep-26	dic-26	mar-27
	Dec '24E Q4	Mar '25E Q1	Jun '25E Q2	Sep '25E Q3	Dec '25E Q4	Mar '26E Q1	Jun '26E Q2	Sep '26E Q3	Dec '26E Q4	Mar '27E Q1
Sales	393,87	433,78	490,60	448,67	419,32	431,61	467,88	457,94	442,96	457,51
COGS (Raw materials & energy consumption for materials)	-182,92	-204,53	-212,87	-221,59	-230,71	-240,24	-252,41	-262,84	-273,74	-285,14
	46%	47%	43%	49%	55%	56%	54%	57%	62%	62%
Gross Income	210,95	229,25	277,73	227,08	188,62	191,37	215,47	195,11	169,22	172,36
	54%	53%	57%	51%	45%	44%	46%	43%	38%	38%
Staff Costs	-110,01	-119,55	-144,83	-118,42	-98,36	-99,80	-112,37	-101,75	-88,24	-89,89
	60%	56%	68%	53%	43%	42%	45%	39%	32%	32%
EBITDA	100,94	109,70	132,90	108,66	90,25	91,57	103,11	93,36	80,97	82,48
	26%	25%	27%	24%	22%	21%	22%	20%	18%	18%
Depr. & Amort.	-23,88	-23,88	-23,88	-23,88	-23,88	-23,88	-23,88	-23,88	-23,88	-23,88
	24%	22%	18%	22%	26%	26%	23%	26%	29%	29%
pairment of Long-Lived Asse	-15,61	-15,61	-15,61	-15,61	-15,61	-15,61	-15,61	-15,61	-15,61	-15,61
	15%	14%	12%	14%	17%	17%	15%	17%	19%	19%
Other Operating Income	32,14	29,08	30,92	30,00	32,14	29,08	30,92	30,00	32,14	29,08
	32%	27%	23%	28%	36%	32%	30%	32%	40%	35%
Other Operating Expense	-67,82	-63,79	-70,50	-65,80	-67,82	-63,79	-70,50	-65,80	-67,82	-63,79
	67%	58%	53%	61%	75%	70%	68%	70%	84%	77%
Other gain / loss	0,21	0,21	0,21	0,21	0,21	0,21	0,21	0,21	0,21	0,21
	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
EBIT	25,99	35,71	54,03	33,58	15,30	17,59	24,24	18,28	6,02	8,49
	7%	8%	11%	7%	4%	4%	5%	4%	1%	2%

GSM-US	19	20	21	22	23	24	25	26	27	28	29
Income Statement (M)	jun-27	sep-27	dic-27	mar-28	jun-28	sep-28	dic-28	mar-29	jun-29	sep-29	dic-29
	Jun '27E Q2	Sep '27E Q3	Dec '27E Q4	Mar '28E Q1	Jun '28E Q2	Sep '28E Q3	Dec '28E Q4	Mar '29E Q1	Jun '29E Q2	Sep '29E Q3	Dec '29E Q4
Sales	486,18	472,63	452,65	465,14	491,70	479,79	462,49	475,94	506,55	493,71	470,58
COGS (Raw materials & energy consumption for materials)	-299,48	-311,94	-324,98	-338,61	-355,52	-370,43	-386,01	-402,31	-422,28	-440,10	-458,73
	62%	66%	72%	73%	72%	77%	83%	85%	83%	89%	97%
Gross Income	186,70	160,69	127,67	126,53	136,18	109,37	76,48	73,62	84,28	53,61	11,84
	38%	34%	28%	27%	28%	23%	17%	15%	17%	11%	3%
Staff Costs	-97,36	-83,80	-66,58	-65,98	-71,02	-57,03	-39,88	-38,39	-43,95	-27,96	-6,18
	33%	27%	20%	19%	20%	15%	10%	10%	10%	6%	1%
EBITDA	89,34	76,89	61,09	60,55	65,16	52,33	36,59	35,23	40,33	25,65	5,67
	18%	16%	13%	13%	13%	11%	8%	7%	8%	5%	1%
Depr. & Amort.	-23,88	-23,88	-23,88	-23,88	-23,88	-23,88	-23,88	-23,88	-23,88	-23,88	-23,88
	27%	31%	39%	39%	37%	46%	65%	68%	59%	93%	421%
pairment of Long-Lived Asse	-15,61	-15,61	-15,61	-15,61	-15,61	-15,61	-15,61	-15,61	-15,61	-15,61	-15,61
	17%	20%	26%	26%	24%	30%	43%	44%	39%	61%	275%
Other Operating Income	30,92	30,00	32,14	29,08	30,92	30,00	32,14	29,08	30,92	30,00	32,14
	35%	39%	53%	48%	47%	57%	88%	83%	77%	117%	567%
Other Operating Expense	-70,50	-65,80	-67,82	-63,79	-70,50	-65,80	-67,82	-63,79	-70,50	-65,80	-67,82
	79%	86%	111%	105%	108%	126%	185%	181%	175%	257%	1196%
Other gain / loss	0,21	0,21	0,21	0,21	0,21	0,21	0,21	0,21	0,21	0,21	0,21
	0%	0%	0%	0%	0%	0%	-1%	-1%	-1%	-1%	-4%
EBIT	10,47	1,81	-13,87	-13,44	-13,70	-22,75	-38,36	-38,76	-38,54	-49,43	-69,29
	2%	0%	-3%	-3%	-3%	-5%	-8%	-8%	-8%	-10%	-15%

Sensitivity Analysis

		9	10	11	12	13	14	15	16	17	18
10% Price UP	COGS	-201,21	-224,98	-234,15	-243,75	-253,78	-264,27	-277,65	-289,12	-301,11	-313,66
	Staff Costs	-110,01	-119,55	-144,83	-118,42	-98,36	-99,80	-112,37	-101,75	-88,24	-89,89
	EBITDA	82,65	89,25	111,61	86,50	67,18	67,55	77,87	67,08	53,60	53,96
	%	21%	21%	23%	19%	16%	16%	17%	15%	12%	12%
	% diff	-4,64%	-4,72%	-4,34%	-4,94%	-5,50%	-5,57%	-5,39%	-5,74%	-6,18%	-6,23%
10% Price DOWN	COGS	-164,63	-184,07	-191,58	-199,43	-207,64	-216,22	-227,17	-236,55	-246,37	-256,63
	Staff Costs	-110,01	-119,55	-144,83	-118,42	-98,36	-99,80	-112,37	-101,75	-88,24	-89,89
	EBITDA	119,23	130,15	154,18	130,82	113,33	115,60	128,35	119,65	108,35	110,99
	%	30%	30%	31%	29%	27%	27%	27%	26%	24%	24%
	% diff	4,64%	4,72%	4,34%	4,94%	5,50%	5,57%	5,39%	5,74%	6,18%	6,23%

		19	20	21	22	23	24	25	26	27	28	29	
10% Price UP	COGS	-329,43	-343,14	-357,48	-372,47	-391,07	-407,47	-424,62	-442,54	-464,50	-484,11	-504,61	
	Staff Costs	-97,36	-83,80	-66,58	-65,98	-71,02	-57,03	-39,88	-38,39	-43,95	-27,96	-6,18	
	EBITDA	59,39	45,70	28,59	26,69	29,61	15,29	-2,01	-5,00	-1,90	-18,36	-40,21	
	%	12%	10%	6%	6%	6%	3%	0%	-1%	0%	-4%	-9%	
	% diff	-6,16%	-6,60%	-7,18%	-7,28%	-7,23%	-7,72%	-8,35%	-8,45%	-8,34%	-8,91%	-9,75%	-6,47%
10% Price DOWN	COGS	-269,53	-280,75	-292,48	-304,75	-319,97	-333,39	-347,41	-362,08	-380,05	-396,09	-412,86	
	Staff Costs	-97,36	-83,80	-66,58	-65,98	-71,02	-57,03	-39,88	-38,39	-43,95	-27,96	-6,18	
	EBITDA	119,29	108,09	93,59	94,41	100,72	89,38	75,20	75,46	82,56	69,66	51,54	
	%	25%	23%	21%	20%	20%	19%	16%	16%	16%	14%	11%	
	% diff	6,16%	6,60%	7,18%	7,28%	7,23%	7,72%	8,35%	8,45%	8,34%	8,91%	9,75%	6,47%

PESSIMISTIC SCENARIO with Optimal Distribution

GSM-US Income Statement (M)	sep-18	dic-18	mar-19	jun-19	sep-19	dic-19	mar-20	jun-20	sep-20	dic-20	mar-21	jun-21	sep-21
		Sales Estimations by FactSet				Personal Sales Estimations				Historic Data from Historical GSM IS (FactSet)			
	30 SEP '18 RECAP	31 DEC '18 RECAP	31 MAR '19 RECAP	30 JUN '19 RECAP	30 SEP '19 RECAP	31 DEC '19 RECAP	31 MAR '20 RECAP	30 JUN '20 RECAP	30 SEP '20 RECAP	31 DEC '20 RECAP	31 MAR '21 RECAP	30 JUN '21 RECAP	30 SEP '21 RECAP
Sales	524,41	603,52	447,39	409,48	381,74	376,61	311,22	250,00	262,67	320,54	361,39	418,54	429,21
COGS (Raw materials & energy consumption for materials)	-334,34	-448,33	-329,37	-292,43	-277,69	-314,90	-243,36	-153,29	-166,23	-272,60	-250,16	-267,94	-295,27
	64%	74%	74%	71%	73%	84%	78%	61%	63%	85%	69%	64%	69%
Gross Income	190,07	155,19	118,02	117,05	104,05	61,70	67,86	96,71	96,44	47,93	111,23	150,60	133,94
	36%	26%	26%	29%	27%	16%	22%	39%	37%	15%	31%	36%	31%
Staff Costs	-88,13	-81,23	-74,26	-74,85	-72,54	-63,38	-55,10	-48,91	-56,33	-54,44	-95,27	-63,20	-50,39
	46%	52%	63%	64%	70%	103%	81%	51%	58%	114%	86%	42%	38%
EBITDA	101,93	73,96	43,76	42,20	31,52	-1,68	12,77	47,80	40,11	-6,51	15,96	87,40	83,55
	19%	12%	10%	10%	8%	0%	4%	19%	15%	-2%	4%	21%	19%
Depr. & Amort.	-29,59	-30,06	-30,37	-30,20	-29,59	-30,03	-28,67	-27,46	-26,52	-25,54	-25,29	-23,52	-23,97
	29%	41%	69%	72%	94%	-1792%	225%	57%	66%	-392%	158%	27%	29%
pairment of Long-Lived Asse	0,00	-58,92	-0,14	-1,20	-174,02	-0,55	0,00	0,00	-34,27	-39,07	0,00	0,00	-0,36
	0%	80%	0%	3%	552%	-33%	0%	0%	85%	-600%	0%	0%	0%
Other Operating Income	5,63	25,04	14,02	14,53	13,22	12,45	7,77	10,16	7,60	8,10	1,91	37,11	31,45
	6%	34%	32%	34%	42%	-743%	61%	21%	19%	-124%	12%	42%	38%
Other Operating Expense	-63,92	-73,16	-53,92	-62,92	-50,06	-58,80	-40,07	-35,95	-26,90	-29,14	-36,83	-93,17	-79,79
	63%	99%	123%	149%	159%	-3509%	314%	75%	67%	-448%	231%	107%	95%
Other gain / loss	0,22	4,01	-0,40	0,28	-3,77	0,10	-0,67	0,09	1,21	0,82	0,07	0,61	0,38
	0%	-5%	1%	-1%	12%	6%	5%	0%	-3%	13%	0%	-1%	0%
EBIT	14,28	-59,14	-27,04	-37,32	-212,71	-78,51	-48,87	-5,37	-38,77	-91,34	-44,18	8,42	11,26
	3%	-10%	-6%	-9%	-56%	-21%	-16%	-2%	-15%	-28%	-12%	2%	3%

GSM-US Income Statement (M)	dic-21	mar-22	jun-22	sep-22	dic-22	mar-23	jun-23	sep-23	dic-23	mar-24	jun-24	sep-24
		Cost of electricity based on assumptions			1	2	3	4	5	6	7	8
	31 DEC '21 RECAP	31 MAR '22 RECAP	30 JUN '22 RECAP	30 SEP '22 RECAP	31 DEC '22 RECAP	31 MAR '23 RECAP	30 JUN '23 RECAP	30 SEP '23 RECAP	31 DEC '23 RECAP	Mar '24 Q1	Jun '24 Q2	Sep '24 Q3
Sales	569,77	715,27	840,81	593,22	448,63	400,87	456,44	416,81	375,95	391,85	451,05	433,53
COGS (Raw materials & energy consumption for materials)	-371,52	-340,55	-369,75	-285,21	-289,57	-231,84	-252,27	-195,60	-199,57	-259,29	-262,02	-255,06
	65%	48%	44%	48%	65%	58%	55%	47%	53%	66%	58%	59%
Gross Income	198,25	374,71	471,06	308,01	159,05	169,03	204,17	221,21	176,38	132,56	189,03	178,47
	35%	52%	56%	52%	35%	42%	45%	53%	47%	34%	42%	41%
Staff Costs	-72,07	-81,99	-80,70	-75,69	-76,43	-67,54	-74,97	-83,58	-79,76	-70,52	-67,22	-71,89
	36%	22%	17%	25%	48%	40%	37%	38%	45%	53%	36%	40%
EBITDA	126,18	292,72	390,35	232,32	82,62	101,48	129,20	137,63	96,62	62,05	121,81	106,59
	22%	41%	46%	39%	18%	25%	28%	33%	26%	16%	27%	25%
Depr. & Amort.	-24,55	-21,11	-20,18	-19,72	-20,55	-17,99	-16,45	-19,00	-20,09	-18,67	-18,88	-18,90
	19%	7%	5%	8%	25%	18%	13%	14%	21%	30%	15%	18%
pairment of Long-Lived Asse	0,50	0,00	0,00	0,00	-57,00	0,25	-0,89	-1,04	-23,61	0,00	0,00	0,00
	0%	0%	0%	0%	69%	0%	1%	1%	24%	0%	0%	0%
Other Operating Income	39,62	23,01	26,22	19,71	78,41	14,81	27,69	23,55	34,94	10,84	27,45	27,20
	31%	8%	7%	8%	95%	15%	21%	17%	36%	17%	23%	26%
Other Operating Expense	-87,01	-83,18	-130,99	-77,95	-54,13	-54,15	-77,20	-65,71	-73,07	-52,35	-86,07	-74,47
	69%	28%	34%	34%	66%	53%	60%	48%	76%	84%	71%	70%
Other gain / loss	1,15	-0,32	-0,10	0,07	0,34	0,05	0,50	-0,01	-0,56	0,70	0,24	0,19
	-1%	0%	0%	0%	0%	0%	0%	0%	1%	-1%	0%	0%
EBIT	55,88	211,13	265,30	154,42	29,70	44,45	62,85	75,42	14,22	2,56	44,55	40,60
	10%	30%	32%	26%	7%	11%	14%	18%	4%	1%	10%	9%

GSM-US Income Statement (M)	9 dic-24	10 mar-25	11 jun-25	12 sep-25	13 dic-25	14 mar-26	15 jun-26	16 sep-26	17 dic-26	18 mar-27
	Dec '24E Q4	Mar '25E Q1	Jun '25E Q2	Sep '25E Q3	Dec '25E Q4	Mar '26E Q1	Jun '26E Q2	Sep '26E Q3	Dec '26E Q4	Mar '27E Q1
Sales	393,87	433,78	490,60	448,67	419,32	431,61	467,88	457,94	442,96	457,51
COGS (Raw materials & energy consumption for materials)	-173,29	-178,43	-184,56	-190,98	-197,69	-204,70	-216,45	-224,12	-232,14	-240,53
	44%	41%	38%	43%	47%	47%	46%	49%	52%	53%
Gross Income	220,58	255,35	306,03	257,69	221,64	226,91	251,43	233,82	210,82	216,97
	56%	59%	62%	57%	53%	53%	54%	51%	48%	47%
Staff Costs	-115,03	-133,16	-159,59	-134,38	-115,58	-118,33	-131,12	-121,94	-109,94	-113,15
	66%	75%	86%	70%	58%	58%	61%	54%	47%	47%
EBITDA	105,55	122,19	146,44	123,31	106,06	108,58	120,31	111,89	100,88	103,83
	27%	28%	30%	27%	25%	25%	26%	24%	23%	23%
Depr. & Amort.	-23,88	-23,88	-23,88	-23,88	-23,88	-23,88	-23,88	-23,88	-23,88	-23,88
pairment of Long-Lived Asse	-15,61	-15,61	-15,61	-15,61	-15,61	-15,61	-15,61	-15,61	-15,61	-15,61
Other Operating Income	32,14	29,08	30,92	30,00	32,14	29,08	30,92	30,00	32,14	29,08
Other Operating Expense	-67,82	-63,79	-70,50	-65,80	-67,82	-63,79	-70,50	-65,80	-67,82	-63,79
Other gain / loss	0,21	0,21	0,21	0,21	0,21	0,21	0,21	0,21	0,21	0,21
EBIT	30,60	48,20	67,58	48,23	31,10	34,59	41,45	36,80	25,92	29,84
	8%	11%	14%	11%	7%	8%	9%	8%	6%	7%

GSM-US Income Statement (M)	19 jun-27	20 sep-27	21 dic-27	22 mar-28	23 jun-28	24 sep-28	25 dic-28	26 mar-29	27 jun-29	28 sep-29	29 dic-29
	Jun '27E Q2	Sep '27E Q3	Dec '27E Q4	Mar '28E Q1	Jun '28E Q2	Sep '28E Q3	Dec '28E Q4	Mar '29E Q1	Jun '29E Q2	Sep '29E Q3	Dec '29E Q4
Sales	486,18	472,63	452,65	465,14	491,70	479,79	462,49	475,94	506,55	493,71	470,58
COGS (Raw materials & energy consumption for materials)	-254,15	-263,33	-272,92	-282,95	-298,77	-309,73	-321,20	-333,19	-351,60	-364,71	-378,42
	52%	56%	60%	61%	61%	65%	69%	70%	69%	74%	80%
Gross Income	232,02	209,31	179,73	182,20	192,93	170,06	141,29	142,75	154,95	128,99	92,16
	48%	44%	40%	39%	39%	35%	31%	30%	31%	26%	20%
Staff Costs	-121,00	-109,15	-93,73	-95,01	-100,61	-88,68	-73,68	-74,44	-80,81	-67,27	-48,06
	48%	41%	34%	34%	34%	29%	23%	22%	23%	18%	13%
EBITDA	111,03	100,16	86,00	87,18	92,32	81,38	67,61	68,31	74,15	61,73	44,10
	23%	21%	19%	19%	19%	17%	15%	14%	15%	13%	9%
Depr. & Amort.	-23,88	-23,88	-23,88	-23,88	-23,88	-23,88	-23,88	-23,88	-23,88	-23,88	-23,88
pairment of Long-Lived Asse	-15,61	-15,61	-15,61	-15,61	-15,61	-15,61	-15,61	-15,61	-15,61	-15,61	-15,61
Other Operating Income	30,92	30,00	32,14	29,08	30,92	30,00	32,14	29,08	30,92	30,00	32,14
Other Operating Expense	-70,50	-65,80	-67,82	-63,79	-70,50	-65,80	-67,82	-63,79	-70,50	-65,80	-67,82
Other gain / loss	0,21	0,21	0,21	0,21	0,21	0,21	0,21	0,21	0,21	0,21	0,21
EBIT	32,16	25,07	11,05	13,20	13,46	6,29	-7,35	-5,68	-4,72	-13,36	-30,86
	7%	5%	2%	3%	3%	1%	-2%	-1%	-1%	-3%	-7%

Sensitivity Analysis

10% Price UP

	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	
COGS	-190,62	-196,27	-203,02	-210,08	-217,46	-225,17	-238,09	-246,53	-255,36	-264,58	-279,57	-289,66	-300,21	-311,24	-328,65	-340,71	-353,32	-366,51	-386,76	-401,18	-416,27	
Staff Costs	-115,03	-133,16	-159,59	-134,38	-115,58	-118,33	-131,12	-121,94	-109,94	-113,15	-121,00	-109,15	-93,73	-95,01	-100,61	-88,68	-73,68	-74,44	-80,81	-67,27	-48,06	
EBITDA	88,22	104,35	127,98	104,21	86,29	88,11	98,67	89,48	77,66	79,77	85,61	73,82	58,71	58,89	62,44	50,40	35,49	34,99	38,99	25,25	6,26	
%	22%	24%	26%	23%	21%	20%	21%	20%	18%	17%	18%	16%	13%	13%	13%	11%	8%	7%	8%	5%	1%	
% diff	-4,40%	-4,11%	-3,76%	-4,26%	-4,71%	-4,74%	-4,63%	-4,89%	-5,24%	-5,26%	-5,23%	-5,57%	-6,03%	-6,08%	-6,08%	-6,46%	-6,95%	-7,00%	-6,94%	-7,39%	-8,04%	-5,49%

10% Price DOWN

	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	
COGS	-155,96	-160,58	-166,11	-171,88	-177,92	-184,23	-194,80	-201,71	-208,93	-216,48	-228,74	-236,99	-245,62	-254,65	-268,89	-278,76	-289,08	-299,87	-316,44	-328,24	-340,58	
Staff Costs	-115,03	-133,16	-159,59	-134,38	-115,58	-118,33	-131,12	-121,94	-109,94	-113,15	-121,00	-109,15	-93,73	-95,01	-100,61	-88,68	-73,68	-74,44	-80,81	-67,27	-48,06	
EBITDA	122,88	140,03	164,90	142,41	125,82	129,05	141,96	134,30	124,09	127,88	136,44	126,49	113,30	115,48	122,20	112,35	99,73	101,62	109,31	98,20	81,94	
%	31%	32%	34%	32%	30%	30%	30%	29%	28%	28%	28%	27%	25%	25%	25%	23%	22%	21%	22%	20%	17%	
% diff	4,40%	4,11%	3,76%	4,26%	4,71%	4,74%	4,63%	4,89%	5,24%	5,26%	5,23%	5,57%	6,03%	6,08%	6,08%	6,46%	6,95%	7,00%	6,94%	7,39%	8,04%	5,49%

Appendix 16. Neutral Scenario with Max Cap and Optimal Distribution

NEUTRAL SCENARIO with Max Capacity Distribution

GSM-US		Sales Estimations by FactSet				Personal Sales Estimations				Historic Data from Historical GSM IS (FactSet)			
Income Statement (M)	sep-18	dic-18	mar-19	jun-19	sep-19	dic-19	mar-20	jun-20	sep-20	dic-20	mar-21	jun-21	sep-21
	30 SEP '18 RECAP	31 DEC '18 RECAP	31 MAR '19 RECAP	30 JUN '19 RECAP	30 SEP '19 RECAP	31 DEC '19 RECAP	31 MAR '20 RECAP	30 JUN '20 RECAP	30 SEP '20 RECAP	31 DEC '20 RECAP	31 MAR '21 RECAP	30 JUN '21 RECAP	30 SEP '21 RECAP
Sales	524,41	603,52	447,39	409,48	381,74	376,61	311,22	250,00	262,67	320,54	361,39	418,54	429,21
COGS (Raw materials & energy consumption for materials)	-334,34	-448,33	-329,37	-292,43	-277,69	-314,90	-243,36	-153,29	-166,23	-272,60	-250,16	-267,94	-295,27
	64%	74%	74%	71%	73%	84%	78%	61%	63%	85%	69%	64%	69%
Gross Income	190,07	155,19	118,02	117,05	104,05	61,70	67,86	96,71	96,44	47,93	111,23	150,60	133,94
	36%	26%	26%	29%	27%	16%	22%	39%	37%	15%	31%	36%	31%
Staff Costs	-88,13	-81,23	-74,26	-74,85	-72,54	-63,38	-55,10	-48,91	-56,33	-54,44	-95,27	-63,20	-50,39
	46%	52%	63%	64%	70%	103%	81%	51%	58%	114%	86%	42%	38%
EBITDA	101,93	73,96	43,76	42,20	31,52	-1,68	12,77	47,80	40,11	-6,51	15,96	87,40	83,55
	19%	12%	10%	10%	8%	0%	4%	19%	15%	-2%	4%	21%	19%
Depr. & Amort.	-29,59	-30,06	-30,37	-30,20	-29,59	-30,03	-28,67	-27,46	-26,52	-25,54	-25,29	-23,52	-23,97
	29%	41%	69%	72%	94%	-1792%	225%	57%	66%	-392%	158%	27%	29%
irment of Long-Lived A:	0,00	-58,92	-0,14	-1,20	-174,02	-0,55	0,00	0,00	-34,27	-39,07	0,00	0,00	-0,36
	0%	80%	0%	3%	552%	-33%	0%	0%	85%	-600%	0%	0%	0%
Other Operating Income	5,63	25,04	14,02	14,53	13,22	12,45	7,77	10,16	7,60	8,10	1,91	37,11	31,45
	6%	34%	32%	34%	42%	-743%	61%	21%	19%	-124%	12%	42%	38%
)ther Operating Expens	-63,92	-73,16	-53,92	-62,92	-50,06	-58,80	-40,07	-35,95	-26,90	-29,14	-36,83	-93,17	-79,79
	63%	99%	123%	149%	159%	-3509%	314%	75%	67%	-448%	231%	107%	95%
Other gain / loss	0,22	4,01	-0,40	0,28	-3,77	0,10	-0,67	0,09	1,21	0,82	0,07	0,61	0,38
	0%	-5%	1%	-1%	12%	6%	5%	0%	-3%	13%	0%	-1%	0%
EBIT	14,28	-59,14	-27,04	-37,32	-212,71	-78,51	-48,87	-5,37	-38,77	-91,34	-44,18	8,42	11,26
	3%	-10%	-6%	-9%	-56%	-21%	-16%	-2%	-15%	-28%	-12%	2%	3%

GSM-US		Cost of electricity based on assumptions			1	2	3	4	5	6	7	8
Income Statement (M)	dic-21	mar-22	jun-22	sep-22	dic-22	mar-23	jun-23	sep-23	dic-23	mar-24	jun-24	sep-24
	31 DEC '21 RECAP	31 MAR '22 RECAP	30 JUN '22 RECAP	30 SEP '22 RECAP	31 DEC '22 RECAP	31 MAR '23 RECAP	30 JUN '23 RECAP	30 SEP '23 RECAP	31 DEC '23 RECAP	Mar '24 Q1	Jun '24 Q2	Sep '24 Q3
Sales	569,77	715,27	840,81	593,22	448,63	400,87	456,44	416,81	375,95	391,85	451,05	433,53
COGS (Raw materials & energy consumption for materials)	-371,52	-340,55	-369,75	-285,21	-289,57	-231,84	-252,27	-195,60	-199,57	-259,29	-262,02	-255,06
	65%	48%	44%	48%	65%	58%	55%	47%	53%	66%	58%	59%
Gross Income	198,25	374,71	471,06	308,01	159,05	169,03	204,17	221,21	176,38	132,56	189,03	178,47
	35%	52%	56%	52%	35%	42%	45%	53%	47%	34%	42%	41%
Staff Costs	-72,07	-81,99	-80,70	-75,69	-76,43	-67,54	-74,97	-83,58	-79,76	-70,52	-67,22	-71,89
	36%	22%	17%	25%	48%	40%	37%	38%	45%	53%	36%	40%
EBITDA	126,18	292,72	390,35	232,32	82,62	101,48	129,20	137,63	96,62	62,05	121,81	106,59
	22%	41%	46%	39%	18%	25%	28%	33%	26%	16%	27%	25%
Depr. & Amort.	-24,55	-21,11	-20,18	-19,72	-20,55	-17,99	-16,45	-19,00	-20,09	-18,67	-18,88	-18,90
	19%	7%	5%	8%	25%	18%	13%	14%	21%	30%	15%	18%
irment of Long-Lived A:	0,50	0,00	0,00	0,00	-57,00	0,25	-0,89	-1,04	-23,61	0,00	0,00	0,00
	0%	0%	0%	0%	69%	0%	1%	1%	24%	0%	0%	0%
Other Operating Income	39,62	23,01	26,22	19,71	78,41	14,81	27,69	23,55	34,94	10,84	27,45	27,20
	31%	8%	7%	8%	95%	15%	21%	17%	36%	17%	23%	26%
)ther Operating Expens	-87,01	-83,18	-130,99	-77,95	-54,13	-54,15	-77,20	-65,71	-73,07	-52,35	-86,07	-74,47
	69%	28%	34%	34%	66%	53%	60%	48%	76%	84%	71%	70%
Other gain / loss	1,15	-0,32	-0,10	0,07	0,34	0,05	0,50	-0,01	-0,56	0,70	0,24	0,19
	-1%	0%	0%	0%	0%	0%	0%	0%	1%	-1%	0%	0%
EBIT	55,88	211,13	265,30	154,42	29,70	44,45	62,85	75,42	14,22	2,56	44,55	40,60
	10%	30%	32%	26%	7%	11%	14%	18%	4%	1%	10%	9%

GSM-US	10	11	12	13	14	15	16	17	18	19
Income Statement (M)	mar-25	jun-25	sep-25	dic-25	mar-26	jun-26	sep-26	dic-26	mar-27	jun-27
	Mar '25E Q1	Jun '25E Q2	Sep '25E Q3	Dec '25E Q4	Mar '26E Q1	Jun '26E Q2	Sep '26E Q3	Dec '26E Q4	Mar '27E Q1	Jun '27E Q2
Sales	433,78	490,60	448,67	419,32	431,61	467,88	457,94	442,96	457,51	486,18
COGS (Raw materials & energy consumption for materials)	-219,25	-225,92	-229,16	-232,06	-233,81	-235,86	-235,79	-243,84	-257,45	-269,74
	51%	46%	51%	55%	54%	50%	51%	55%	56%	55%
Gross Income	214,53	264,68	219,51	187,27	197,81	232,02	222,16	199,12	200,06	216,44
	49%	54%	49%	45%	46%	50%	49%	45%	44%	45%
Staff Costs	-111,88	-138,03	-114,47	-97,66	-103,15	-121,00	-115,85	-103,84	-104,33	-112,87
	51%	61%	50%	42%	44%	51%	49%	43%	41%	42%
EBITDA	102,66	126,65	105,04	89,61	94,65	111,03	106,31	95,28	95,73	103,57
	24%	26%	23%	21%	22%	24%	23%	22%	21%	21%
Depr. & Amort.	-23,88	-23,88	-23,88	-23,88	-23,88	-23,88	-23,88	-23,88	-23,88	-23,88
irment of Long-Lived A:	-15,61	-15,61	-15,61	-15,61	-15,61	-15,61	-15,61	-15,61	-15,61	-15,61
Other Operating Income	29,08	30,92	30,00	32,14	29,08	30,92	30,00	32,14	29,08	30,92
)ther Operating Expens	-63,79	-70,50	-65,80	-67,82	-63,79	-70,50	-65,80	-67,82	-63,79	-70,50
Other gain / loss	0,21	0,21	0,21	0,21	0,21	0,21	0,21	0,21	0,21	0,21
	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
EBIT	28,67	47,79	29,96	14,65	20,67	32,16	31,22	20,33	21,74	24,70
	7%	10%	7%	3%	5%	7%	7%	5%	5%	5%

GSM-US	20	21	22	23	24	25	26	27	28	29
Income Statement (M)	sep-27	dic-27	mar-28	jun-28	sep-28	dic-28	mar-29	jun-29	sep-29	dic-29
	Sep '27E Q3	Dec '27E Q4	Mar '28E Q1	Jun '28E Q2	Sep '28E Q3	Dec '28E Q4	Mar '29E Q1	Jun '29E Q2	Sep '29E Q3	Dec '29E Q4
Sales	472,63	452,65	465,14	491,70	479,79	462,49	475,94	506,55	493,71	470,58
COGS (Raw materials & energy consumption for materials)	-261,13	-266,37	-275,46	-278,23	-288,27	-302,23	-315,70	-317,36	-323,80	-323,50
	55%	59%	59%	57%	60%	65%	66%	63%	66%	69%
Gross Income	211,50	186,28	189,68	213,47	191,52	160,26	160,24	189,20	169,91	147,08
	45%	41%	41%	43%	40%	35%	34%	37%	34%	31%
Staff Costs	-110,29	-97,14	-98,92	-111,32	-99,88	-83,57	-83,56	-98,66	-88,60	-76,70
	42%	36%	36%	40%	35%	28%	26%	31%	27%	24%
EBITDA	101,21	89,14	90,76	102,15	91,65	76,69	76,68	90,53	81,30	70,38
	21%	20%	20%	21%	19%	17%	16%	18%	16%	15%
Depr. & Amort.	-23,88	-23,88	-23,88	-23,88	-23,88	-23,88	-23,88	-23,88	-23,88	-23,88
irment of Long-Lived A:	-15,61	-15,61	-15,61	-15,61	-15,61	-15,61	-15,61	-15,61	-15,61	-15,61
Other Operating Income	30,00	32,14	29,08	30,92	30,00	32,14	29,08	30,92	30,00	32,14
)ther Operating Expens	-65,80	-67,82	-63,79	-70,50	-65,80	-67,82	-63,79	-70,50	-65,80	-67,82
Other gain / loss	0,21	0,21	0,21	0,21	0,21	0,21	0,21	0,21	0,21	0,21
	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
EBIT	26,12	14,18	16,78	23,28	16,56	1,73	2,69	11,67	6,22	-4,57
	6%	3%	4%	5%	3%	0%	1%	2%	1%	-1%

Sensitivity Analysis

10% Price UP	COGS	-241,17	-248,51	-252,07	-255,26	-257,19	-259,44	-259,37	-268,22	-283,19	-296,71
	Staff Costs	-111,88	-138,03	-114,47	-97,66	-103,15	-121,00	-115,85	-103,84	-104,33	-112,87
	EBITDA	80,73	104,06	82,12	66,40	71,27	87,44	82,73	70,90	69,98	76,60
	%	21%	27%	18%	15%	18%	20%	17%	16%	17%	18%
	% diff	-2,19%	0,74%	-5,20%	-6,05%	-3,83%	-3,57%	-6,35%	-5,71%	-4,23%	-3,56%
10% Price DOWN	COGS	-197,32	-203,33	-206,24	-208,85	-210,43	-212,27	-212,21	-219,46	-231,70	-242,76
	Staff Costs	-111,88	-138,03	-114,47	-97,66	-103,15	-121,00	-115,85	-103,84	-104,33	-112,87
	EBITDA	124,58	149,24	127,95	112,82	118,03	134,61	129,88	119,66	121,47	130,54
	%	29%	30%	29%	27%	27%	29%	28%	27%	27%	27%
	% diff	5,05%	4,60%	5,11%	5,53%	5,42%	5,04%	5,15%	5,50%	5,63%	5,55%

10% Price UP	COGS	-287,25	-293,00	-303,01	-306,06	-317,10	-332,46	-347,27	-349,09	-356,18	-355,84
	Staff Costs	-110,29	-97,14	-98,92	-111,32	-99,88	-83,57	-83,56	-98,66	-88,60	-76,70
	EBITDA	75,09	62,50	63,22	74,32	62,82	46,46	45,11	58,80	48,92	38,03
	%	16%	14%	14%	16%	13%	10%	10%	13%	10%	8%
	% diff	-5,36%	-6,04%	-5,24%	-4,53%	-6,18%	-6,75%	-6,15%	-5,23%	-6,52%	-7,03%
10% Price DOWN	COGS	-235,02	-239,73	-247,92	-250,41	-259,44	-272,01	-284,13	-285,62	-291,42	-291,15
	Staff Costs	-110,29	-97,14	-98,92	-111,32	-99,88	-83,57	-83,56	-98,66	-88,60	-76,70
	EBITDA	127,32	115,77	118,31	129,97	120,47	106,91	108,25	122,27	113,68	102,73
	%	27%	26%	25%	26%	25%	23%	23%	24%	23%	22%
	% diff	5,53%	5,88%	5,92%	5,66%	6,01%	6,53%	6,63%	6,26%	6,56%	6,87%

NEUTRAL SCENARIO with Optimal Distribution

GSM-US		Sales Estimations by FactSet				Personal Sales Estimations				Historic Data from Historical GSM IS (FactSet)		
Income Statement (M)	sep-18	dic-18	mar-19	jun-19	sep-19	dic-19	mar-20	jun-20	sep-20	dic-20	mar-21	jun-21	sep-21
	30 SEP '18 RECAP	31 DEC '18 RECAP	31 MAR '19 RECAP	30 JUN '19 RECAP	30 SEP '19 RECAP	31 DEC '19 RECAP	31 MAR '20 RECAP	30 JUN '20 RECAP	30 SEP '20 RECAP	31 DEC '20 RECAP	31 MAR '21 RECAP	30 JUN '21 RECAP	30 SEP '21 RECAP
Sales	524,41	603,52	447,39	409,48	381,74	376,61	311,22	250,00	262,67	320,54	361,39	418,54	429,21
COGS (Raw materials & energy consumption for	-334,34	-448,33	-329,37	-292,43	-277,69	-314,90	-243,36	-153,29	-166,23	-272,60	-250,16	-267,94	-295,27
	64%	74%	74%	71%	73%	84%	78%	61%	63%	85%	69%	64%	69%
Gross Income	190,07	155,19	118,02	117,05	104,05	61,70	67,86	96,71	96,44	47,93	111,23	150,60	133,94
	36%	26%	26%	29%	27%	16%	22%	39%	37%	15%	31%	36%	31%
Staff Costs	-88,13	-81,23	-74,26	-74,85	-72,54	-63,38	-55,10	-48,91	-56,33	-54,44	-95,27	-63,20	-50,39
	46%	52%	63%	64%	70%	103%	81%	51%	58%	114%	86%	42%	38%
EBITDA	101,93	73,96	43,76	42,20	31,52	-1,68	12,77	47,80	40,11	-6,51	15,96	87,40	83,55
	19%	12%	10%	10%	8%	0%	4%	19%	15%	-2%	4%	21%	19%
Depr. & Amort.	-29,59	-30,06	-30,37	-30,20	-29,59	-30,03	-28,67	-27,46	-26,52	-25,54	-25,29	-23,52	-23,97
	29%	41%	69%	72%	94%	-1792%	225%	57%	66%	-392%	158%	27%	29%
irment of Long-Lived A:	0,00	-58,92	-0,14	-1,20	-174,02	-0,55	0,00	0,00	-34,27	-39,07	0,00	0,00	-0,36
	0%	80%	0%	3%	552%	-33%	0%	0%	85%	-600%	0%	0%	0%
Other Operating Income	5,63	25,04	14,02	14,53	13,22	12,45	7,77	10,16	7,60	8,10	1,91	37,11	31,45
	6%	34%	32%	34%	42%	-743%	61%	21%	19%	-124%	12%	42%	38%
)ther Operating Expens	-63,92	-73,16	-53,92	-62,92	-50,06	-58,80	-40,07	-35,95	-26,90	-29,14	-36,83	-93,17	-79,79
	63%	99%	123%	149%	159%	-3509%	314%	75%	67%	-448%	231%	107%	95%
Other gain / loss	0,22	4,01	-0,40	0,28	-3,77	0,10	-0,67	0,09	1,21	0,82	0,07	0,61	0,38
	0%	-5%	1%	-1%	12%	6%	5%	0%	-3%	13%	0%	-1%	0%
EBIT	14,28	-59,14	-27,04	-37,32	-212,71	-78,51	-48,87	-5,37	-38,77	-91,34	-44,18	8,42	11,26
	3%	-10%	-6%	-9%	-56%	-21%	-16%	-2%	-15%	-28%	-12%	2%	3%

GSM-US		Cost of electricity based on assumptions			1	2	3	4	5	6	7	8
Income Statement (M)	dic-21	mar-22	jun-22	sep-22	dic-22	mar-23	jun-23	sep-23	dic-23	mar-24	jun-24	sep-24
	31 DEC '21 RECAP	31 MAR '22 RECAP	30 JUN '22 RECAP	30 SEP '22 RECAP	31 DEC '22 RECAP	31 MAR '23 RECAP	30 JUN '23 RECAP	30 SEP '23 RECAP	31 DEC '23 RECAP	Mar '24 Q1	Jun '24 Q2	Sep '24 Q3
Sales	569,77	715,27	840,81	593,22	448,63	400,87	456,44	416,81	375,95	391,85	451,05	433,53
COGS (Raw materials & energy consumption for	-371,52	-340,55	-369,75	-285,21	-289,57	-231,84	-252,27	-195,60	-199,57	-259,29	-262,02	-255,06
	65%	48%	44%	48%	65%	58%	55%	47%	53%	66%	58%	59%
Gross Income	198,25	374,71	471,06	308,01	159,05	169,03	204,17	221,21	176,38	132,56	189,03	178,47
	35%	52%	56%	52%	35%	42%	45%	53%	47%	34%	42%	41%
Staff Costs	-72,07	-81,99	-80,70	-75,69	-76,43	-67,54	-74,97	-83,58	-79,76	-70,52	-67,22	-71,89
	36%	22%	17%	25%	48%	40%	37%	38%	45%	53%	36%	40%
EBITDA	126,18	292,72	390,35	232,32	82,62	101,48	129,20	137,63	96,62	62,05	121,81	106,59
	22%	41%	46%	39%	18%	25%	28%	33%	26%	16%	27%	25%
Depr. & Amort.	-24,55	-21,11	-20,18	-19,72	-20,55	-17,99	-16,45	-19,00	-20,09	-18,67	-18,88	-18,90
	19%	7%	5%	8%	25%	18%	13%	14%	21%	30%	15%	18%
irment of Long-Lived A:	0,50	0,00	0,00	0,00	-57,00	0,25	-0,89	-1,04	-23,61	0,00	0,00	0,00
	0%	0%	0%	0%	69%	0%	1%	1%	24%	0%	0%	0%
Other Operating Income	39,62	23,01	26,22	19,71	78,41	14,81	27,69	23,55	34,94	10,84	27,45	27,20
	31%	8%	7%	8%	95%	15%	21%	17%	36%	17%	23%	26%
)ther Operating Expens	-87,01	-83,18	-130,99	-77,95	-54,13	-54,15	-77,20	-65,71	-73,07	-52,35	-86,07	-74,47
	69%	28%	34%	34%	66%	53%	60%	48%	76%	84%	71%	70%
Other gain / loss	1,15	-0,32	-0,10	0,07	0,34	0,05	0,50	-0,01	-0,56	0,70	0,24	0,19
	-1%	0%	0%	0%	0%	0%	0%	0%	1%	-1%	0%	0%
EBIT	55,88	211,13	265,30	154,42	29,70	44,45	62,85	75,42	14,22	2,56	44,55	40,60
	10%	30%	32%	26%	7%	11%	14%	18%	4%	1%	10%	9%

GSM-US	10	11	12	13	14	15	16	17	18	19
Income Statement (M)	mar-25	jun-25	sep-25	dic-25	mar-26	jun-26	sep-26	dic-26	mar-27	jun-27
	Mar '25E Q1	Jun '25E Q2	Sep '25E Q3	Dec '25E Q4	Mar '26E Q1	Jun '26E Q2	Sep '26E Q3	Dec '26E Q4	Mar '27E Q1	Jun '27E Q2
Sales	433,78	490,60	448,67	419,32	431,61	467,88	457,94	442,96	457,51	486,18
COGS (Raw materials & energy consumption for materials)	-196,23	-205,01	-213,50	-208,31	-206,34	-209,56	-201,59	-199,60	-214,47	-222,68
	45%	42%	48%	50%	48%	45%	44%	45%	47%	46%
Gross Income	237,55	285,59	235,17	211,01	225,27	258,32	256,35	243,36	243,03	263,50
	55%	58%	52%	50%	52%	55%	56%	55%	53%	54%
Staff Costs	-123,88	-148,93	-122,64	-110,04	-117,48	-134,71	-133,68	-126,91	-126,74	-137,41
	63%	73%	57%	53%	57%	64%	66%	64%	59%	62%
EBITDA	113,67	136,66	112,53	100,97	107,80	123,61	122,67	116,45	116,30	126,09
	26%	28%	25%	24%	25%	26%	27%	26%	25%	26%
Depr. & Amort.	-23,88	-23,88	-23,88	-23,88	-23,88	-23,88	-23,88	-23,88	-23,88	-23,88
	21%	17%	21%	24%	22%	19%	19%	21%	21%	19%
)airment of Long-Lived Asse	-15,61	-15,61	-15,61	-15,61	-15,61	-15,61	-15,61	-15,61	-15,61	-15,61
	14%	11%	14%	15%	14%	13%	13%	13%	13%	12%
Other Operating Income	29,08	30,92	30,00	32,14	29,08	30,92	30,00	32,14	29,08	30,92
	26%	23%	27%	32%	27%	25%	24%	28%	25%	25%
Other Operating Expense	-63,79	-70,50	-65,80	-67,82	-63,79	-70,50	-65,80	-67,82	-63,79	-70,50
	56%	52%	58%	67%	59%	57%	54%	58%	55%	56%
Other gain / loss	0,21	0,21	0,21	0,21	0,21	0,21	0,21	0,21	0,21	0,21
	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
EBIT	39,68	57,79	37,45	26,02	33,81	44,75	47,59	41,50	42,31	47,22
	9%	12%	8%	6%	8%	10%	10%	9%	9%	10%

GSM-US	20	21	22	23	24	25	26	27	28	29
Income Statement (M)	sep-27	dic-27	mar-28	jun-28	sep-28	dic-28	mar-29	jun-29	sep-29	dic-29
	Sep '27E Q3	Dec '27E Q4	Mar '28E Q1	Jun '28E Q2	Sep '28E Q3	Dec '28E Q4	Mar '29E Q1	Jun '29E Q2	Sep '29E Q3	Dec '29E Q4
Sales	472,63	452,65	465,14	491,70	479,79	462,49	475,94	506,55	493,71	470,58
COGS (Raw materials & energy consumption for materials)	-215,98	-204,09	-203,92	-218,04	-218,11	-226,64	-228,86	-227,14	-223,65	-213,82
	46%	45%	44%	44%	45%	49%	48%	45%	45%	45%
Gross Income	256,65	248,56	261,22	273,66	261,68	235,85	247,08	279,41	270,06	256,76
	54%	55%	56%	56%	55%	51%	52%	55%	55%	55%
Staff Costs	-133,84	-129,62	-136,22	-142,71	-136,46	-122,99	-128,85	-145,71	-140,83	-133,90
	62%	64%	67%	65%	63%	54%	58%	64%	63%	63%
EBITDA	122,81	118,94	125,00	130,95	125,22	112,86	118,23	133,70	129,23	122,86
	26%	26%	27%	27%	26%	24%	25%	26%	26%	26%
Depr. & Amort.	-23,88	-23,88	-23,88	-23,88	-23,88	-23,88	-23,88	-23,88	-23,88	-23,88
	19%	20%	19%	18%	19%	21%	20%	18%	18%	19%
)airment of Long-Lived Asse	-15,61	-15,61	-15,61	-15,61	-15,61	-15,61	-15,61	-15,61	-15,61	-15,61
	13%	13%	12%	12%	12%	14%	13%	12%	12%	13%
Other Operating Income	30,00	32,14	29,08	30,92	30,00	32,14	29,08	30,92	30,00	32,14
	24%	27%	23%	24%	24%	28%	25%	23%	23%	26%
Other Operating Expense	-65,80	-67,82	-63,79	-70,50	-65,80	-67,82	-63,79	-70,50	-65,80	-67,82
	54%	57%	51%	54%	53%	60%	54%	53%	51%	55%
Other gain / loss	0,21	0,21	0,21	0,21	0,21	0,21	0,21	0,21	0,21	0,21
	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
EBIT	47,73	43,98	51,01	52,09	50,14	37,90	44,24	54,84	54,14	47,91
	10%	10%	11%	11%	10%	8%	9%	11%	11%	10%

Sensitivity Analysis

		10	11	12	13	14	15	16	17	18	19
10% Price UP	COGS	-215,85	-225,51	-234,85	-229,14	-226,97	-230,51	-221,75	-219,56	-235,92	-244,95
	Staff Costs	-123,88	-148,93	-122,64	-110,04	-117,48	-134,71	-133,68	-126,91	-126,74	-137,41
	EBITDA	94,05	116,16	91,18	80,14	87,16	102,66	102,51	96,49	94,85	103,82
	%	22%	24%	20%	19%	20%	22%	22%	22%	21%	21%
	% diff	-4,52%	-4,18%	-4,76%	-4,97%	-4,78%	-4,48%	-4,40%	-4,51%	-4,69%	-4,58%
10% Price DOWN	COGS	-176,61	-184,51	-192,15	-187,48	-185,71	-188,60	-181,43	-179,64	-193,02	-200,41
	Staff Costs	-123,88	-148,93	-122,64	-110,04	-117,48	-134,71	-133,68	-126,91	-126,74	-137,41
	EBITDA	133,29	157,16	133,88	121,80	128,43	144,57	142,83	136,41	137,74	148,36
	%	31%	32%	30%	29%	30%	31%	31%	31%	30%	31%
	% diff	4,52%	4,18%	4,76%	4,97%	4,78%	4,48%	4,40%	4,51%	4,69%	4,58%

		20	21	22	23	24	25	26	27	28	29
10% Price UP	COGS	-237,58	-224,49	-224,32	-239,84	-239,92	-249,30	-251,74	-249,86	-246,01	-235,20
	Staff Costs	-133,84	-129,62	-136,22	-142,71	-136,46	-122,99	-128,85	-145,71	-140,83	-133,90
	EBITDA	101,21	98,53	104,60	109,15	103,41	90,20	95,35	110,99	106,86	101,48
	%	21%	22%	22%	22%	22%	20%	20%	22%	22%	22%
	% diff	-4,57%	-4,51%	-4,38%	-4,43%	-4,55%	-4,90%	-4,81%	-4,48%	-4,53%	-4,54%
10% Price DOWN	COGS	-194,38	-183,68	-183,53	-196,23	-196,30	-203,97	-205,97	-204,43	-201,28	-192,44
	Staff Costs	-133,84	-129,62	-136,22	-142,71	-136,46	-122,99	-128,85	-145,71	-140,83	-133,90
	EBITDA	144,41	139,35	145,39	152,76	147,03	135,52	141,12	156,42	151,59	144,25
	%	31%	31%	31%	31%	31%	29%	30%	31%	31%	31%
	% diff	4,57%	4,51%	4,38%	4,43%	4,55%	4,90%	4,81%	4,48%	4,53%	4,54%

Appendix 17. Optimistic Scenario with Max Cap and Optimal Distribution

OPTIMISTIC SCENARIO with Max Capacity Distribution

Column groups: Sales Estimations by FactSet (dic-18 – jun-19); Personal Sales Estimations (dic-19 – jun-20); Historic Data from Historical GSM IS (FactSet) (dic-20 – sep-21); Cost of electricity based on assumptions (mar-22 – sep-22).

GSM-US Income Statement (M)	sep-18	dic-18	mar-19	jun-19	sep-19	dic-19	mar-20	jun-20	sep-20	dic-20	mar-21	jun-21	sep-21
	30 SEP '18 RECAP	31 DEC '18 RECAP	31 MAR '19 RECAP	30 JUN '19 RECAP	30 SEP '19 RECAP	31 DEC '19 RECAP	31 MAR '20 RECAP	30 JUN '20 RECAP	30 SEP '20 RECAP	31 DEC '20 RECAP	31 MAR '21 RECAP	30 JUN '21 RECAP	30 SEP '21 RECAP
Sales	524,41	603,52	447,39	409,48	381,74	376,61	311,22	250,00	262,67	320,54	361,39	418,54	429,21
COGS (Raw materials & energy consumption for materials)	-334,34	-448,33	-329,37	-292,43	-277,69	-314,90	-243,36	-153,29	-166,23	-272,60	-250,16	-267,94	-295,27
Gross Income	190,07	155,19	118,02	117,05	104,05	61,70	67,86	96,71	96,44	47,93	111,23	150,60	133,94
Staff Costs	-88,13	-81,23	-74,26	-74,85	-72,54	-63,38	-55,10	-48,91	-56,33	-54,44	-95,27	-63,20	-50,39
EBITDA	101,93	73,96	43,76	42,20	31,52	-1,68	12,77	47,80	40,11	-6,51	15,96	87,40	83,55
Depr. & Amort.	-29,59	-30,06	-30,37	-30,20	-29,59	-30,03	-28,67	-27,46	-26,52	-25,54	-25,29	-23,52	-23,97
Impairment of Long-Lived Asset	0,00	-58,92	-0,14	-1,20	-174,02	-0,55	0,00	0,00	-34,27	-39,07	0,00	0,00	-0,36
Other Operating Income	5,63	25,04	14,02	14,53	13,22	12,45	7,77	10,16	7,60	8,10	1,91	37,11	31,45
Other Operating Expense	-63,92	-73,16	-53,92	-62,92	-50,06	-58,80	-40,07	-35,95	-26,90	-29,14	-36,83	-93,17	-79,79
Other gain / loss	0,22	4,01	-0,40	0,28	-3,77	0,10	-0,67	0,09	1,21	0,82	0,07	0,61	0,38
EBIT	14,28	-59,14	-27,04	-37,32	-212,71	-78,51	-48,87	-5,37	-38,77	-91,34	-44,18	8,42	11,26

GSM-US Income Statement (M)	dic-21	mar-22	jun-22	sep-22	1 dic-22	2 mar-23	3 jun-23	4 sep-23	5 dic-23	6 mar-24	7 jun-24	8 sep-24
	31 DEC '21 RECAP	31 MAR '22 RECAP	30 JUN '22 RECAP	30 SEP '22 RECAP	31 DEC '22 RECAP	31 MAR '23 RECAP	30 JUN '23 RECAP	30 SEP '23 RECAP	31 DEC '23 RECAP	Mar '24 Q1	Jun '24 Q2	Sep '24 Q3
Sales	569,77	715,27	840,81	593,22	448,63	400,87	456,44	416,81	375,95	391,85	451,05	433,53
COGS (Raw materials & energy consumption for materials)	-371,52	-340,55	-369,75	-285,21	-289,57	-231,84	-252,27	-195,60	-199,57	-259,29	-262,02	-255,06
Gross Income	198,25	374,71	471,06	308,01	159,05	169,03	204,17	221,21	176,38	132,56	189,03	178,47
Staff Costs	-72,07	-81,99	-80,70	-75,69	-76,43	-67,54	-74,97	-83,58	-79,76	-70,52	-67,22	-71,89
EBITDA	126,18	292,72	390,35	232,32	82,62	101,48	129,20	137,63	96,62	62,05	121,81	106,59
Depr. & Amort.	-24,55	-21,11	-20,18	-19,72	-20,55	-17,99	-16,45	-19,00	-20,09	-18,67	-18,88	-18,90
Impairment of Long-Lived Asset	0,50	0,00	0,00	0,00	-57,00	0,25	-0,89	-1,04	-23,61	0,00	0,00	0,00
Other Operating Income	39,62	23,01	26,22	19,71	78,41	14,81	27,69	23,55	34,94	10,84	27,45	27,20
Other Operating Expense	-87,01	-83,18	-130,99	-77,95	-54,13	-54,15	-77,20	-65,71	-73,07	-52,35	-86,07	-74,47
Other gain / loss	1,15	-0,32	-0,10	0,07	0,34	0,05	0,50	-0,01	-0,56	0,70	0,24	0,19
EBIT	55,88	211,13	265,30	154,42	29,70	44,45	62,85	75,42	14,22	2,56	44,55	40,60

GSM-US Income Statement (M)	9 dic-24	10 mar-25	11 jun-25	12 sep-25	13 dic-25	14 mar-26	15 jun-26	16 sep-26	17 dic-26	18 mar-27	19 jun-27
	Dec '24E Q4	Mar '25E Q1	Jun '25E Q2	Sep '25E Q3	Dec '25E Q4	Mar '26E Q1	Jun '26E Q2	Sep '26E Q3	Dec '26E Q4	Mar '27E Q1	Jun '27E Q2
Sales	393,87	433,78	490,60	448,67	419,32	431,61	467,88	457,94	442,96	457,51	486,18
COGS (Raw materials & energy consumption for materials)	-181,46	-191,36	-186,33	-181,44	-176,71	-172,11	-166,00	-161,68	-157,48	-153,40	-147,93
Gross Income	212,41	242,42	304,27	267,23	242,62	259,50	301,88	296,27	285,48	304,10	338,25
Staff Costs	-110,77	-126,42	-158,67	-139,35	-126,52	-135,33	-157,42	-154,50	-148,87	-158,59	-176,39
EBITDA	101,64	116,00	145,60	127,87	116,10	124,18	144,45	141,77	136,61	145,52	161,86
Depr. & Amort.	-23,88	-23,88	-23,88	-23,88	-23,88	-23,88	-23,88	-23,88	-23,88	-23,88	-23,88
Impairment of Long-Lived Asset	-15,61	-15,61	-15,61	-15,61	-15,61	-15,61	-15,61	-15,61	-15,61	-15,61	-15,61
Other Operating Income	32,14	29,08	30,92	30,00	32,14	29,08	30,92	30,00	32,14	29,08	30,92
Other Operating Expense	-67,82	-63,79	-70,50	-65,80	-67,82	-63,79	-70,50	-65,80	-67,82	-63,79	-70,50
Other gain / loss	0,21	0,21	0,21	0,21	0,21	0,21	0,21	0,21	0,21	0,21	0,21
EBIT	26,68	42,01	66,73	52,79	41,14	50,19	65,59	66,68	61,65	71,53	82,99

GSM-US Income Statement (M)	20 sep-27	21 dic-27	22 mar-28	23 jun-28	24 sep-28	25 dic-28	26 mar-29	27 jun-29	28 sep-29	29 dic-29
	Sep '27E Q3	Dec '27E Q4	Mar '28E Q1	Jun '28E Q2	Sep '28E Q3	Dec '28E Q4	Mar '29E Q1	Jun '29E Q2	Sep '29E Q3	Dec '29E Q4
Sales	472,63	452,65	465,14	491,70	479,79	462,49	475,94	506,55	493,71	470,58
COGS (Raw materials & energy consumption for materials)	-144,09	-140,37	-136,76	-131,85	-128,45	-125,15	-121,95	-117,54	-114,52	-111,60
Gross Income	328,54	312,28	328,39	359,86	351,35	337,34	353,99	389,02	379,18	358,98
Staff Costs	-171,33	-162,85	-171,25	-187,66	-183,22	-175,92	-184,60	-202,87	-197,74	-187,20
EBITDA	157,21	149,43	157,14	172,20	168,12	161,42	169,39	186,15	181,44	171,78
Depr. & Amort.	-23,88	-23,88	-23,88	-23,88	-23,88	-23,88	-23,88	-23,88	-23,88	-23,88
Impairment of Long-Lived Asset	-15,61	-15,61	-15,61	-15,61	-15,61	-15,61	-15,61	-15,61	-15,61	-15,61
Other Operating Income	30,00	32,14	29,08	30,92	30,00	32,14	29,08	30,92	30,00	32,14
Other Operating Expense	-65,80	-67,82	-63,79	-70,50	-65,80	-67,82	-63,79	-70,50	-65,80	-67,82
Other gain / loss	0,21	0,21	0,21	0,21	0,21	0,21	0,21	0,21	0,21	0,21
EBIT	82,13	74,47	83,15	93,33	93,04	86,47	95,40	107,28	106,36	96,82

Sensitivity Analysis

		9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	
10% Price UP	COGS	-199,61	-210,49	-204,96	-199,59	-194,38	-189,32	-182,60	-177,84	-173,23	-168,74	-162,72	-158,50	-154,41	-150,43	-145,03	-141,29	-137,66	-134,14	-129,29	-125,98	-122,76	
	Staff Costs	-110,77	-126,42	-158,67	-139,35	-126,52	-135,33	-157,42	-154,50	-148,87	-158,59	-176,39	-171,33	-162,85	-171,25	-187,66	-183,22	-175,92	-184,60	-202,87	-197,74	-187,20	
	EBITDA	83,49	96,87	126,96	109,73	98,42	106,96	127,85	125,60	120,86	130,18	147,06	142,80	135,39	143,46	159,01	155,28	148,91	157,20	174,40	169,99	160,62	
	%	21%	22%	26%	24%	23%	25%	27%	27%	27%	28%	30%	30%	30%	31%	32%	32%	32%	33%	34%	34%	34%	
	% diff	-4,61%	-4,41%	-3,80%	-4,04%	-4,21%	-3,99%	-3,55%	-3,53%	-3,56%	-3,35%	-3,04%	-3,05%	-3,10%	-2,94%	-2,68%	-2,68%	-2,71%	-2,56%	-2,32%	-2,32%	-2,37%	-3,32%
10% Price DOWN	COGS	-163,32	-172,22	-167,69	-163,30	-159,04	-154,90	-149,40	-145,51	-141,73	-138,06	-133,13	-129,68	-126,33	-123,08	-118,66	-115,60	-112,63	-109,75	-105,78	-103,07	-100,44	
	Staff Costs	-110,77	-126,42	-158,67	-139,35	-126,52	-135,33	-157,42	-154,50	-148,87	-158,59	-176,39	-171,33	-162,85	-171,25	-187,66	-183,22	-175,92	-184,60	-202,87	-197,74	-187,20	
	EBITDA	119,79	135,14	164,23	146,02	133,77	141,39	161,05	157,94	152,35	160,86	176,65	171,62	163,47	170,81	185,38	180,97	173,94	181,58	197,90	192,90	182,94	
	%	30%	31%	33%	33%	32%	33%	34%	34%	34%	35%	36%	36%	36%	37%	38%	38%	38%	38%	39%	39%	39%	
	% diff	4,61%	4,41%	3,80%	4,04%	4,21%	3,99%	3,55%	3,53%	3,56%	3,35%	3,04%	3,05%	3,10%	2,94%	2,68%	2,68%	2,71%	2,56%	2,32%	2,32%	2,37%	3,32%

OPTIMISTIC SCENARIO with Optimal Distribution

GSM-US		Sales Estimations by FactSet				Personal Sales Estimations				Historic Data from Historical GSM IS (FactSet)		
Income Statement (M)	sep-18	dic-18	mar-19	jun-19	sep-19	dic-19	mar-20	jun-20	sep-20	dic-20	mar-21	jun-21	sep-21
	30 SEP '18 RECAP	31 DEC '18 RECAP	31 MAR '19 RECAP	30 JUN '19 RECAP	30 SEP '19 RECAP	31 DEC '19 RECAP	31 MAR '20 RECAP	30 JUN '20 RECAP	30 SEP '20 RECAP	31 DEC '20 RECAP	31 MAR '21 RECAP	30 JUN '21 RECAP	30 SEP '21 RECAP
Sales	524,41	603,52	447,39	409,48	381,74	376,61	311,22	250,00	262,67	320,54	361,39	418,54	429,21
COGS (Raw materials & energy consumption for materials)	-334,34	-448,33	-329,37	-292,43	-277,69	-314,90	-243,36	-153,29	-166,23	-272,60	-250,16	-267,94	-295,27
	64%	74%	74%	71%	73%	84%	78%	61%	63%	85%	69%	64%	69%
Gross Income	190,07	155,19	118,02	117,05	104,05	61,70	67,86	96,71	96,44	47,93	111,23	150,60	133,94
	36%	26%	26%	29%	27%	16%	22%	39%	37%	15%	31%	36%	31%
Staff Costs	-88,13	-81,23	-74,26	-74,85	-72,54	-63,38	-55,10	-48,91	-56,33	-54,44	-95,27	-63,20	-50,39
	46%	52%	63%	64%	70%	103%	81%	51%	58%	114%	86%	42%	38%
EBITDA	101,93	73,96	43,76	42,20	31,52	-1,68	12,77	47,80	40,11	-6,51	15,96	87,40	83,55
	19%	12%	10%	10%	8%	0%	4%	19%	15%	-2%	4%	21%	19%
Depr. & Amort.	-29,59	-30,06	-30,37	-30,20	-29,59	-30,03	-28,67	-27,46	-26,52	-25,54	-25,29	-23,52	-23,97
	29%	41%	69%	72%	94%	-1792%	225%	57%	66%	-392%	158%	27%	29%
Impairment of Long-Lived Asset	0,00	-58,92	-0,14	-1,20	-174,02	-0,55	0,00	0,00	-34,27	-39,07	0,00	0,00	-0,36
	0%	80%	0%	3%	552%	-33%	0%	0%	85%	-600%	0%	0%	0%
Other Operating Income	5,63	25,04	14,02	14,53	13,22	12,45	7,77	10,16	7,60	8,10	1,91	37,11	31,45
	6%	34%	32%	34%	42%	-743%	61%	21%	19%	-124%	12%	42%	38%
Other Operating Expense	-63,92	-73,16	-53,92	-62,92	-50,06	-58,80	-40,07	-35,95	-26,90	-29,14	-36,83	-93,17	-79,79
	63%	99%	123%	149%	159%	-3509%	314%	75%	67%	-448%	231%	107%	95%
Other gain / loss	0,22	4,01	-0,40	0,28	-3,77	0,10	-0,67	0,09	1,21	0,82	0,07	0,61	0,38
	0%	-5%	1%	-1%	12%	6%	5%	0%	-3%	13%	0%	-1%	0%
EBIT	14,28	-59,14	-27,04	-37,32	-212,71	-78,51	-48,87	-5,37	-38,77	-91,34	-44,18	8,42	11,26
	3%	-10%	-6%	-9%	-56%	-21%	-16%	-2%	-15%	-28%	-12%	2%	3%

GSM-US		Cost of electricity based on assumptions			1	2	3	4	5	6	7	8
Income Statement (M)	dic-21	mar-22	jun-22	sep-22	dic-22	mar-23	jun-23	sep-23	dic-23	mar-24	jun-24	sep-24
	31 DEC '21 RECAP	31 MAR '22 RECAP	30 JUN '22 RECAP	30 SEP '22 RECAP	31 DEC '22 RECAP	31 MAR '23 RECAP	30 JUN '23 RECAP	30 SEP '23 RECAP	31 DEC '23 RECAP	Mar '24 Q1	Jun '24 Q2	Sep '24 Q3
Sales	569,77	715,27	840,81	593,22	448,63	400,87	456,44	416,81	375,95	391,85	451,05	433,53
COGS (Raw materials & energy consumption for materials)	-371,52	-340,55	-369,75	-285,21	-289,57	-231,84	-252,27	-195,60	-199,57	-259,29	-262,02	-255,06
	65%	48%	44%	48%	65%	58%	55%	47%	53%	66%	58%	59%
Gross Income	198,25	374,71	471,06	308,01	159,05	169,03	204,17	221,21	176,38	132,56	189,03	178,47
	35%	52%	56%	52%	35%	42%	45%	53%	47%	34%	42%	41%
Staff Costs	-72,07	-81,99	-80,70	-75,69	-76,43	-67,54	-74,97	-83,58	-79,76	-70,52	-67,22	-71,89
	36%	22%	17%	25%	48%	40%	37%	38%	45%	53%	36%	40%
EBITDA	126,18	292,72	390,35	232,32	82,62	101,48	129,20	137,63	96,62	62,05	121,81	106,59
	22%	41%	46%	39%	18%	25%	28%	33%	26%	16%	27%	25%
Depr. & Amort.	-24,55	-21,11	-20,18	-19,72	-20,55	-17,99	-16,45	-19,00	-20,09	-18,67	-18,88	-18,90
	19%	7%	5%	8%	25%	18%	13%	14%	21%	30%	15%	18%
Impairment of Long-Lived Asset	0,50	0,00	0,00	0,00	-57,00	0,25	-0,89	-1,04	-23,61	0,00	0,00	0,00
	0%	0%	0%	0%	69%	0%	1%	1%	24%	0%	0%	0%
Other Operating Income	39,62	23,01	26,22	19,71	78,41	14,81	27,69	23,55	34,94	10,84	27,45	27,20
	31%	8%	7%	8%	95%	15%	21%	17%	36%	17%	23%	26%
Other Operating Expense	-87,01	-83,18	-130,99	-77,95	-54,13	-54,15	-77,20	-65,71	-73,07	-52,35	-86,07	-74,47
	69%	28%	34%	34%	66%	53%	60%	48%	76%	84%	71%	70%
Other gain / loss	1,15	-0,32	-0,10	0,07	0,34	0,05	0,50	-0,01	-0,56	0,70	0,24	0,19
	-1%	0%	0%	0%	0%	0%	0%	0%	1%	-1%	0%	0%
EBIT	55,88	211,13	265,30	154,42	29,70	44,45	62,85	75,42	14,22	2,56	44,55	40,60
	10%	30%	32%	26%	7%	11%	14%	18%	4%	1%	10%	9%

GSM-US	9	10	11	12	13	14	15	16	17	18	19
Income Statement (M)	dic-24	mar-25	jun-25	sep-25	dic-25	mar-26	jun-26	sep-26	dic-26	mar-27	jun-27
	Dec '24E Q4	Mar '25E Q1	Jun '25E Q2	Sep '25E Q3	Dec '25E Q4	Mar '26E Q1	Jun '26E Q2	Sep '26E Q3	Dec '26E Q4	Mar '27E Q1	Jun '27E Q2
Sales	394	434	491	449	419	445	434	470	429	452	438
COGS (Raw materials & energy consumption for materials)	-171,24	-167,00	-162,04	-157,22	-152,55	-148,02	-143,63	-139,36	-135,22	-131,21	-127,31
	43%	38%	33%	35%	36%	33%	33%	30%	32%	29%	29%
Gross Income	222,63	266,78	328,56	291,45	266,77	296,80	290,39	330,19	293,68	321,22	310,37
	57%	62%	67%	65%	64%	67%	67%	70%	68%	71%	71%
Staff Costs	-116,10	-139,12	-171,34	-151,99	-139,12	-154,78	-151,43	-172,19	-153,15	-167,51	-161,85
	68%	83%	106%	97%	91%	105%	105%	124%	113%	128%	127%
EBITDA	106,53	127,66	157,22	139,46	127,65	142,02	138,95	158,00	140,53	153,71	148,52
	27%	29%	32%	31%	30%	32%	32%	34%	33%	34%	34%
Depr. & Amort.	-23,88	-23,88	-23,88	-23,88	-23,88	-23,88	-23,88	-23,88	-23,88	-23,88	-23,88
	22%	19%	15%	17%	18%	17%	17%	15%	17%	16%	16%
Impairment of Long-Lived Asset	-15,61	-15,61	-15,61	-15,61	-15,61	-15,61	-15,61	-15,61	-15,61	-15,61	-15,61
	15%	12%	10%	11%	12%	10%	10%	10%	11%	10%	11%
Other Operating Income	32,14	29,08	30,92	30,00	32,14	29,08	30,92	30,00	32,14	29,08	30,92
	30%	23%	20%	22%	25%	20%	22%	18%	23%	19%	21%
Other Operating Expense	-67,82	-63,79	-70,50	-65,80	-67,82	-63,79	-70,50	-65,80	-67,82	-63,79	-70,50
	64%	50%	45%	47%	53%	45%	51%	42%	48%	41%	47%
Other gain / loss	0,21	0,21	0,21	0,21	0,21	0,21	0,21	0,21	0,21	0,21	0,21
	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
EBIT	31,58	53,67	78,35	64,38	52,70	68,04	60,09	82,92	65,58	79,72	69,65
	8%	12%	16%	14%	13%	15%	14%	18%	15%	18%	16%

GSM-US	20	21	22	23	24	25	26	27	28	29
Income Statement (M)	sep-27	dic-27	mar-28	jun-28	sep-28	dic-28	mar-29	jun-29	sep-29	dic-29
	Sep '27E Q3	Dec '27E Q4	Mar '28E Q1	Jun '28E Q2	Sep '28E Q3	Dec '28E Q4	Mar '29E Q1	Jun '29E Q2	Sep '29E Q3	Dec '29E Q4
Sales	473	427	451	443	477	422	447	441	475	424
COGS (Raw materials & energy consumption for materials)	-123,53	-119,86	-116,30	-112,84	-109,49	-106,24	-103,09	-100,02	-97,05	-94,17
	26%	28%	26%	25%	23%	25%	23%	23%	20%	22%
Gross Income	349,24	306,65	335,14	330,49	367,29	315,50	344,05	340,95	378,20	330,32
	74%	72%	74%	75%	77%	75%	77%	77%	80%	78%
Staff Costs	-182,12	-159,92	-174,77	-172,34	-191,54	-164,53	-179,42	-177,80	-197,23	-172,26
	147%	133%	150%	153%	175%	155%	174%	178%	203%	183%
EBITDA	167,11	146,74	160,37	158,14	175,75	150,97	164,63	163,15	180,97	158,06
	35%	34%	36%	36%	37%	36%	37%	37%	38%	37%
Depr. & Amort.	-23,88	-23,88	-23,88	-23,88	-23,88	-23,88	-23,88	-23,88	-23,88	-23,88
	14%	16%	15%	15%	14%	16%	15%	15%	13%	15%
Impairment of Long-Lived Asset	-15,61	-15,61	-15,61	-15,61	-15,61	-15,61	-15,61	-15,61	-15,61	-15,61
	9%	11%	10%	10%	9%	10%	9%	10%	9%	10%
Other Operating Income	30,00	32,14	29,08	30,92	30,00	32,14	29,08	30,92	30,00	32,14
	18%	22%	18%	20%	17%	21%	18%	19%	17%	20%
Other Operating Expense	-65,80	-67,82	-63,79	-70,50	-65,80	-67,82	-63,79	-70,50	-65,80	-67,82
	39%	46%	40%	45%	37%	45%	39%	43%	36%	43%
Other gain / loss	0,21	0,21	0,21	0,21	0,21	0,21	0,21	0,21	0,21	0,21
	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
EBIT	92,03	71,78	86,38	79,28	100,67	76,02	90,65	84,29	105,89	83,11
	19%	17%	19%	18%	21%	18%	20%	19%	22%	20%

Sensitivity Analysis

10% Price UP	COGS	-188,37	-183,70	-178,24	-172,95	-167,81	-162,83	-157,99	-153,30	-148,74	-144,33	-140,04
	Staff Costs	-116,10	-139,12	-171,34	-151,99	-139,12	-154,78	-151,43	-172,19	-153,15	-167,51	-161,85
	EBITDA	89,41	110,96	141,02	123,74	112,40	127,22	124,59	144,06	127,01	140,59	135,79
	%	23%	26%	29%	28%	27%	29%	29%	31%	30%	31%	31%
	% diff	-4,35%	-3,85%	-3,30%	-3,50%	-3,64%	-3,33%	-3,31%	-2,97%	-3,15%	-2,90%	-2,91%
10% Price DOWN	COGS	-154,12	-150,30	-145,83	-141,50	-137,30	-133,22	-129,26	-125,42	-121,70	-118,09	-114,58
	Staff Costs	-116,10	-139,12	-171,34	-151,99	-139,12	-154,78	-151,43	-172,19	-153,15	-167,51	-161,85
	EBITDA	123,65	144,36	173,42	155,18	142,91	156,83	153,32	171,94	154,05	166,83	161,25
	%	31%	33%	35%	35%	34%	35%	35%	37%	36%	37%	37%
	% diff	4,35%	3,85%	3,30%	3,50%	3,64%	3,33%	3,31%	2,97%	3,15%	2,90%	2,91%

10% Price UP	COGS	-135,88	-131,84	-127,93	-124,13	-120,44	-116,86	-113,39	-110,03	-106,76	-103,59	
	Staff Costs	-182,12	-159,92	-174,77	-172,34	-191,54	-164,53	-179,42	-177,80	-197,23	-172,26	
	EBITDA	154,76	134,75	148,74	146,86	164,80	140,35	154,32	153,15	171,27	148,65	
	%	33%	32%	33%	33%	35%	33%	35%	35%	36%	35%	
	% diff	-2,61%	-2,81%	-2,58%	-2,55%	-2,30%	-2,52%	-2,31%	-2,27%	-2,04%	-2,22%	-2,96%
10% Price DOWN	COGS	-111,17	-107,87	-104,67	-101,56	-98,54	-95,62	-92,78	-90,02	-87,35	-84,75	
	Staff Costs	-182,12	-159,92	-174,77	-172,34	-191,54	-164,53	-179,42	-177,80	-197,23	-172,26	
	EBITDA	179,47	158,72	172,00	169,43	186,70	161,60	174,94	173,15	190,68	167,48	
	%	38%	37%	38%	38%	39%	38%	39%	39%	40%	39%	
	% diff	2,61%	2,81%	2,58%	2,55%	2,30%	2,52%	2,31%	2,27%	2,04%	2,22%	2,96%

Declaración de Uso de Herramientas de Inteligencia Artificial Generativa en Trabajos Fin de Grado

ADVERTENCIA: Desde la Universidad consideramos que ChatGPT u otras herramientas similares son herramientas muy útiles en la vida académica, aunque su uso queda siempre bajo la responsabilidad del alumno, puesto que las respuestas que proporciona pueden no ser veraces. En este sentido, NO está permitido su uso en la elaboración del Trabajo fin de Grado para generar código porque estas herramientas no son fiables en esa tarea. Aunque el código funcione, no hay garantías de que metodológicamente sea correcto, y es altamente probable que no lo sea.

Por la presente, yo, [Nombre completo del estudiante], estudiante de [nombre del título] de la Universidad Pontificia Comillas al presentar mi Trabajo Fin de Grado titulado "[Título del trabajo]", declaro que he utilizado la herramienta de Inteligencia Artificial Generativa ChatGPT u otras similares de IAG de código sólo en el contexto de las actividades descritas a continuación [el alumno debe mantener solo aquellas en las que se ha usado ChatGPT o similares y borrar el resto. Si no se ha usado ninguna, borrar todas y escribir "no he usado ninguna"]:

1. **Corrector de estilo literario y de lenguaje:** Para mejorar la calidad lingüística y estilística del texto.
2. **Sintetizador y divulgador de libros complicados:** Para resumir y comprender literatura compleja.
3. **Traductor:** Para traducir textos de un lenguaje a otro.

Afirmo que toda la información y contenido presentados en este trabajo son producto de mi investigación y esfuerzo individual, excepto donde se ha indicado lo contrario y se han dado los créditos correspondientes (he incluido las referencias adecuadas en el TFG y he explicitado para que se ha usado ChatGPT u otras herramientas similares). Soy consciente de las implicaciones académicas y éticas de presentar un trabajo no original y acepto las consecuencias de cualquier violación a esta declaración.

Fecha: 4 de Diciembre de 2024

Firma: ______________________________

Bibliography

Becerra-Ruiz, J. D., Rangel-Vazquez, I., Jauregui-Correa, J. C., & Del Angel-Montes, G. A. (2021, June). *Photo-catalytic water splitting: TiO_2-GO for water splitting*. In 2021 XVII International Engineering Congress (CONIIN). IEEE. Retrieved from https://doi.org/10.1109/CONIIN54356.2021.9634773

Bernardo, C. P. C. V., Lameirinhas, R. A. M., de Melo Cunha, J. P., & Torres, J. P. N. (2024). A revision of the semiconductor theory from history to applications. *Discover Applied Sciences*, *6*(6), 316. Retrieved from https://doi.org/10.1007/s42452-024-06001-1

Chen, Y., Liu, Y., Wang, X., Li, K., & Chen, P. (2014). Preparation of High Purity Crystalline Silicon by Electro-Catalytic Reduction of Sodium Hexafluorosilicate with Sodium below 180° C. *Plos one*, *9*(8). Retrieved from https://doi.org/10.1371/journal.pone.0105537

De La Rocha, C., & Conley, D. J. (2017). *Silica stories*. Springer International Publishing. Retrieved from https://doi.org/10.1007/978-3-319-54054-2

Dolley, T. P. (2024). Silica. In *2019 Minerals Yearbook*. U.S. Department of the Interior. Retrieved from https://pubs.usgs.gov/myb/vol1/2019/myb1-2019-silica.pdf

Durmaz, A., Kahyaoğlu, I. M., Aytar, E. C. & Karakuş, S. (2024). Sensors Based on Semiconductors. In Gupta, R. K., (Ed.), *Handbook of Semiconductors: Fundamentals to Emerging Applications,* pp. 273-286. CRC Press. Retrieved from https://doi.org/10.1201/9781003450146-21

Farida, A. A. & Mali S. (2024). Fundamentals and Advanced Concepts of Microprocessors. In Gupta, R. K., (Ed.), *Handbook of Semiconductors: Fundamentals to Emerging Applications,* pp. 137-151. CRC Press. Retrieved from https://doi.org/10.1201/9781003450146-11

Ferroglobe PLC. (2024a). *Form 20-F: Annual report for the fiscal year ended December 31, 2023.* Retrieved from https://www.sec.gov/Archives/edgar/data/1639877/000155837024007862/tmb-20231231x20f.htm

(2024b). *About Ferroglobe*. Retrieved November 15, 2024, from https://www.ferroglobe.com/about-ferroglobe

Flörke, O. W., Graetsch, H. A., Brunk, F., Benda, L., Paschen, S., Bergna, H. E., Roberts, W. O., Welsh, W. A., Chapman, D. M., Ettlinger, M., Kerner, D., Maier, M., Meon, W., Schmoll, R., Gies, H. & Schiffmann, D. (2007). Silica. *Ullmann's Encyclopedia of Industrial Chemistry [electronic version]*. Wiley-VCH. Retrieved from https://doi.org/10.1002/14356007.a23_583.pub2

Fortune Business Insights. (2024). *Silica Sand Market Size, Share & Industry Analysis, By End-use Industry (Construction, Glass Manufacturing, Filtration, Foundry, Chemical Production, Paints & Coatings, Ceramics & Refractories, Oil & Gas, and Others) and Regional Forecast, 2024-2032*. Retrieved October 27, 2024, from https://www.fortunebusinessinsights.com/silica-sand-market-105302

Gasik, M. (2013a). Introduction. In Gasik, M., (Ed.), *Handbook of Ferroalloys: Theory and Technology*, pp. 9-7. Elsevier. Retrieved from https://doi.org/10.1016/B978-0-08-097753-9.00001-0

(2013b). Technology of Chromium and its Ferroalloys. In Gasik, M., (Ed.), *Handbook of Ferroalloys: Theory and Technology*, pp. 267-316. Elsevier. Retrieved from https://doi.org/10.1016/B978-0-08-097753-9.00008-3

(2013c). Technology of Nioubium Ferroalloys. In Gasik, M., (Ed.), *Handbook of Ferroalloys: Theory and Technology*, pp. 411-419. Elsevier. Retrieved from https://doi.org/10.1016/B978-0-08-097753-9.00014-9

Gasik, M., Dashevskii, V. & Bizhanov, A. (2020). *Ferroalloys: Theory and Practice.* Spinger Nature Switzerland AG. Retrieved from https://doi.org/10.1007/978-3-030-57502-1

Haramboure, A., Lalanne, G., Schwellnus, C. & Guilhoto, J. (2023). Vulnerabilities in the semiconductor supply chain. *OECD Science, Technology and Industry Working Papers*. Retrieved from https://doi.org/10.1787/6bed616f-en

Hilleringmann, U. (2023). *Silicon Semiconductor Technology: Processing and Integration of Microelectronic Devices*. Springer Fachmedien Wiesbaden. Retrieved from https://doi.org/10.1007/978-3-658-41041-4

Holappa, L. (2013). Basics of Ferroalloys. In Gasik, M., (Ed.), *Handbook of Ferroalloys: Theory and Technology*, pp. 9-28. Elsevier. Retrieved from https://doi.org/10.1016/B978-0-08-097753-9.00002-2

Juzeliunas, E. (2022). *Silicon: Electrochemistry, Production, Purification and Applications*. Wiley-VCH. Retrieved from https://doi.org/10.1002/9783527831913

Kocyigit, A. (2024). Semiconductor-based Photodiodes. In Gupta, R. K., (Ed.), *Handbook of Semiconductors: Fundamentals to Emerging Applications,* pp. 194-206. CRC Press. Retrieved from https://doi.org/10.1201/9781003450146-15

Lathe, A. & Palve A. M. (2024). Types and Properties of Semiconductors. In Gupta, R. K., (Ed.), *Handbook of Semiconductors: Fundamentals to Emerging*

Applications, pp. 26-39. CRC Press. Retrieved from https://doi.org/10.1201/9781003450146-3

Li, T., Guo, L., Wang, Z. & Guo, Z. (2020). Purification of metallurgical-grade silicon combining Sn–Si solvent refining with gas pressure filtration. RSC advances, 10(19), 11435-11443. Retrieved from https://doi.org/10.1039/c9ra09077k

Łukasiak, L. & Jakubowski, A. (2010). History of semiconductors. *Journal of Telecommunications and information technology*, (1), 3-9. Retrieved from https://doi.org/10.26636/jtit.2010.1.1015

Marjanovic, M. (June 4, 2024). *10 Biggest Semiconductor Companies in the World [2024].* Retrieved October 1, 2024, from https://finbold.com/guide/10-biggest-semiconductor-companies-in-the-world/

Mizutori, M. & Yamada, R. (2005). Semiconductors. *Ullmann's Encyclopedia of Industrial Chemistry [electronic version].* Wiley-VCH. Retrieved from https://doi.org/10.1002/14356007.a23_537

Mohammad, M., Elomri, A. & Kerbache, L. (2022). The Global Semiconductor Chip Shortage: Causes, Implications, and Potential Remedies. *IFAC Papers Online, 55*(10), 476-483. https://doi.org/10.1016/j.ifacol.2022.09.439

Mukherjee, S., Pal, D., Bhattacharyya, A. & Roy, S. (2024). Future of the Semiconductor Industry. In Gupta, R. K., (Ed.), *Handbook of Semiconductors: Fundamentals to Emerging Applications*, pp. 359-374. CRC Press. Retrieved from https://doi.org/10.1201/9781003450146-28

Nasajpour-Esfahani, N., Koohbor, A., Garmestani, H. & Liang, S. Y. (2024). Role of Semiconductors in Energy Devices. In Gupta, R. K., (Ed.), *Handbook of Semiconductors: Fundamentals to Emerging Applications,* pp. 301-315. CRC Press. Retrieved from https://doi.org/10.1201/9781003450146-23

Omran, H. (February 17, 2024). *Nvidia Leads The Pack: Top 5 Semiconductor Companies By Market Cap In 2024*. Retrieved October 1, 2024 from Retrieved October 1, 2024, from https://www.forbesmiddleeast.com/innovation/technology/nvidia-leads-the-pack-top-5-semiconductor-companies-by-market-cap-in-2024

Orton, J. W. (2004). *The story of semiconductors*. Oxford University Press. Retrieved from https://doi.org/10.1093/acprof:oso/9780199559107.001.0001

Patil, S. V. & Bhargava, K. (2024). Semiconductor for Solar Cells. In Gupta, R. K., (Ed.), *Handbook of Semiconductors: Fundamentals to Emerging Applications,* pp. 207-221. CRC Press. Retrieved from https://doi.org/10.1201/9781003450146-16

Raymer, M. G. (2009). *The silicon web: physics for the Internet age*. CRC press. Retrieved from https://doi.org/10.1201/9781439803127

Research and Markets. (2024). *Silicones Market Report by Product Type (Elastomers, Fluids, Gels, Resins), Application (Industrial Processes, Construction Materials, Home and Personal Care, Transportation, Energy, Healthcare, Electronics, and Others), and Region 2024-2032.* Retrieved November 2, 2024, from https://www.researchandmarkets.com/reports/5936230/silicones-market-report-product-type

Ryhänen, T. & Pohjonen, H. (2015). Impact of Silicon MEMS—40 Years After. In Tilli, M., Motooka, T., Airaksinen V-M., Franssila, S., Paulasto-Kröckel, M. & Lindroos, V. (Eds.), *Handbook of Silicon Based MEMS Materials and Technologies* (xix-xxxvii). Elsevier. Retrieved from https://doi.org/10.1016/B978-0-323-29965-7.00047-6

Sahoo, H. S., Ray, D., Ghosh, S. & Bhattacharya, C. (2024). Copper Oxide-based Semiconductors for Photo-Assisted Water Splitting. In Gupta, R. K., (Ed.), *Handbook of Semiconductors: Fundamentals to Emerging Applications*, pp. 333-346. CRC Press. Retrieved from https://doi.org/10.1201/9781003450146-26

Semiconductor Intelligence. (August 21, 2024). *Robust Market in 2024*. Retrieved October 1, 2024, from https://www.semiconductorintelligence.com/robust-market-in-2024/

Shaojun, C., & Kuangdi, X. (2024a). Ferroalloy Smelting Process. In *The ECPH Encyclopedia of Mining and Metallurgy* (pp. 646-649). Singapore: Springer Nature Singapore. Retrieved from https://doi.org/10.1007/978-981-99-2086-0_954

(2024b). Ferroalloys. In *The ECPH Encyclopedia of Mining and Metallurgy* (pp. 649-653). Singapore: Springer Nature Singapore. Retrieved from https://doi.org/10.1007/978-981-99-2086-0_955

Song, J. (2023). The history and trends of semiconductor materials development. In *Journal of Physics: Conference Series. 2608.* IOP Publishing. Retrieved from https://doi.org/10.1088/1742-6596/2608/1/012019

Tangstad, M. (2013a). Ferrosilicon and Silicon Technology. In Gasik, M., (Ed.), *Handbook of Ferroalloys: Theory and Technology*, pp. 179-220. Elsevier. Retrieved from https://doi.org/10.1016/B978-0-08-097753-9.00006-X

(2013b). Manganese Ferroalloys Technology. In Gasik, M., (Ed.), *Handbook of Ferroalloys: Theory and Technology*, pp. 221-266. Elsevier. Retrieved from https://doi.org/10.1016/B978-0-08-097753-9.00007-1

Team Counterpoint. (June 25, 2024). *Infographic: Q1 2024 | Semiconductors, Foundry Share and Smartphone AP Share*. Retrieved October 1, 2024 from https://www.counterpointresearch.com/insights/infographic-q1-2024-semiconductors-foundry-smartphone-ap-share/

U.S. Geological Survey. (March 2, 2019). *Hydraulic fracturing*. U.S. Department of the Interior. Retrieved October 27, 2024, from https://www.usgs.gov/mission-areas/water-resources/science/hydraulic-fracturing#overview

(2024). *Mineral commodity summaries 2024.* U.S. Department of the Interior. Retrieved from https://doi.org/10.3133/mcs2024

Voas, J., Kshetri, N. & DeFranco, J. F. (2021). Scarcity and Global Insecurity: The Semiconductor Shortage. *IT Professional, 23*(5), 78-82. https://doi.org/10.1109/MITP.2021.3105248

Wei, K., Yang, S., Wan, X., Ma, W., Wu, J. & Lei, Y. (2020). Review of silicon recovery and purification from saw silicon powder. *Jom*, *72*, 2633-2647. Retrieved from https://doi.org/10.1007/s11837-020-04183-8

Westberg, P. (July 10, 2024). *The 10 Largest Semiconductor Companies in the World*. Retrieved October 1, 2024 from https://quartr.com/insights/company-research/the-10-largest-semiconductor-companies-in-the-world