New Energy Exploitation and Application
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Article

Integrated Energy Management and Its Impact on Financial Performance: Evidence from the National Plastics Company

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Received: 2 April 2025; **Revised:** 11 May 2025; **Accepted:** 15 May 2025; **Published:** 21 May 2025

Abstract: This study examines the impact of implementing the ISO 50001 Energy Management System (EnMS) at the National Plastics Company (CNP), a leading Tunisian manufacturer in the plastics sector. The purpose of the study is to evaluate how ISO 50001 adoption affects energy efficiency, financial performance, and sustainability outcomes in an energy-intensive industrial environment. A qualitative case study approach was employed, supported by internal company data covering the period 2020–2023. The analysis used a pre- and post-comparison design, with key performance indicators (KPIs) including energy consumption (kWh/kg), energy cost (DT/kg), and waste reduction (tonnes). Real-time data visualization was achieved through Power BI dashboards. The results indicate that ISO 50001 implementation led to measurable improvements across all KPIs. Energy consumption per kilogram of production decreased steadily, and energy costs were better controlled despite market volatility. Waste reduction improved significantly, with over 72,000 kg of material saved in 2023. These outcomes demonstrate that ISO 50001 is not only an effective environmental management tool, but also a strategic driver of financial and operational performance. The study contributes to the literature by providing empirical evidence from Tunisia's industrial sector and by highlighting the value of digital analytics in energy management. It also identifies opportunities for future research, including the use of econometric modeling and multi-firm comparative analysis to further validate the findings.

Keywords: Energy Management; ISO 50001; Financial Performance; National Plastics Company (CNP)

1. Introduction

In recent years, Tunisia's energy landscape has been characterized by mounting demand pressures and sectoral imbalances. In 2022, the transportation sector emerged as the largest energy consumer, accounting for 32.5% of national final energy use, equivalent to 2.76 million tonnes of oil equivalent (Mtoe). This reflects the country's deep dependence on fossil fuels for mobility. The residential sector followed closely with 27.6%, ahead of the industrial sector (24.9%), while the tertiary (8.7%) and agricultural (6.3%) sectors remained comparatively minor contributors. Natural gas consumption saw a notable increase of 11.8% in 2022, driven mainly by industrial activity, which absorbed over half of the total consumption. The transportation sector consumed 20%, largely due to the trans-Mediterranean gas pipeline's compressor stations, while the residential and tertiary sectors accounted for 16% and 12%, respectively. The agriculture and fishing sectors represented just 2.2% of gas demand. Electricity consumption also rose by 6%, with the residential sector leading at approximately one-third of total usage, followed by the industrial sector (32%) and the tertiary sector (27%). Electricity use in agriculture and fishing stood at 12%, while the transportation sector's share remained negligible at just 0.4%, highlighting the limited electrification of transport in Tunisia (**Figure 1**).

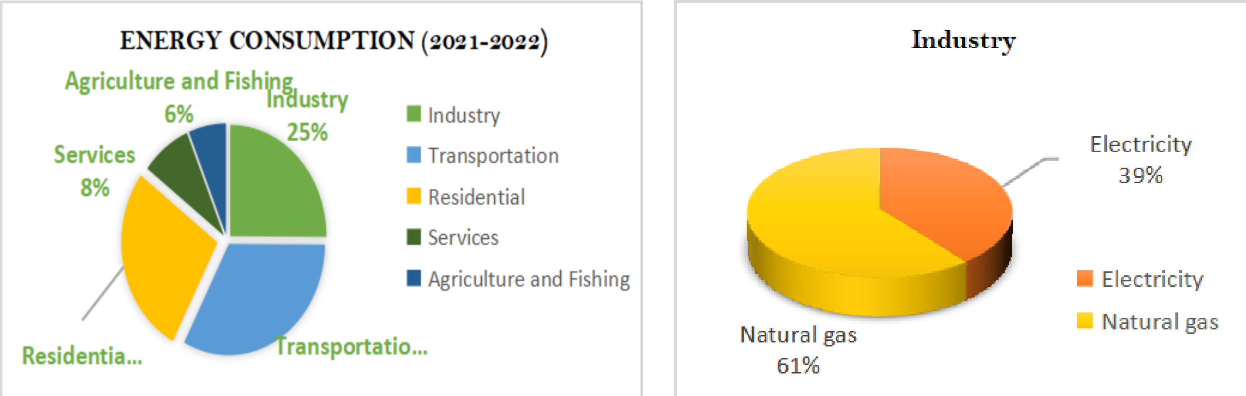

Figure 1. Structure of Sectoral Final Energy Use (2021–2022).

Source: National Observatory of Energy and Mines.

This sectoral energy profile underscores a critical urgency: Tunisia must accelerate its transition toward more efficient and sustainable energy practices, particularly within energy-intensive sectors like industry. Globally, energy efficiency has become more than a technical concern; it is now a strategic imperative. Rising energy costs, stricter environmental regulations, and evolving stakeholder expectations have pushed industrial firms to adopt proactive energy management as a core component of resilience and competitiveness. In this context, energy management is no longer just about reducing utility bills; it serves as a cornerstone for carbon reduction, cost control, and corporate sustainability. The ISO 50001 standard, introduced by the International Organization for Standardization in 2011 and revised in 2018, offers a structured and internationally recognized framework for continuous improvement in energy performance. It is grounded in the Plan-Do-Check-Act (PDCA) methodology, aligning with other well-known standards like ISO 9001 (quality management) and ISO 14001 (environmental management). ISO 50001 empowers organizations to develop robust Energy Management Systems (EnMS), enabling them to monitor energy use, identify inefficiencies, and implement performance-enhancing interventions. While ISO 50001 adoption is accelerating globally with over 22,000 certified facilities as of 2017 (ISO, 2018) its implementation in Tunisia remains limited and underexplored, particularly in the industrial sector. This presents a significant research gap and an opportunity for innovation. The present study addresses this gap by investigating the impact of ISO 50001 implementation on energy efficiency and financial performance in the Tunisian industrial context. Focusing on the National Plastics Company (CNP), a leading player in Tunisia's plastics manufacturing industry, this research explores how adopting ISO 50001 can serve as a catalyst for both operational improvement and economic value creation. What sets this study apart is its dual contribution: first, it provides empirical evidence on the benefits of ISO 50001 adoption in a developing economy; second, it integrates digital analytics tools, specifically Power Business Intelligence (Power BI), to enhance the monitoring and visualization of energy performance data, offering a replicable model for other firms seeking to align with energy transition goals. Overall, this article aims to evaluate how the adoption of an ISO 50001-based Energy Management System can enhance both energy efficiency and financial performance within Tunisia's industrial sector. By bridging an existing research gap and providing actionable insights, this study offers a valuable framework for industrial firms in Tunisia and similar contexts seeking to improve their energy management practices and strengthen competitiveness. The central research question is: To what extent can the adoption of an ISO 50001-based Energy Management System transform industrial energy practices and enhance the financial performance of the National Plastics Company (CNP) in Tunisia?

To answer this question, the paper is organized as follows: following this introduction and contextual overview, Section 2 provides a critical review of the literature on energy management and corporate performance. Section 3 presents the case study of the National Plastics Company (CNP), detailing the operational, environmental, and financial impacts of ISO 50001 implementation. The final section summarizes the key findings, and offers policy and managerial recommendations.

2. Literature Review

ISO 50001 is an internationally recognized standard designed to support organizations in systematically improving their energy performance. It provides a comprehensive framework for establishing, implementing, maintaining, and continually improving an energy management system (EnMS). The standard's main objective is to reduce energy consumption, lower operational costs, and minimize greenhouse gas emissions. Applicable to all types of organizations regardless of size, sector, or geographical location, ISO 50001 is founded on the principles of continuous improvement, similar to ISO 9001 (quality management) and ISO 14001 (environmental management). The standard promotes a proactive approach to energy management, involving strategic planning, top management commitment, employee engagement, and performance monitoring through key energy metrics. By adopting ISO 50001, organizations not only realize direct energy and cost savings but also strengthen their competitive advantage and demonstrate their commitment to environmental and social responsibility. A growing body of research has explored the relationship between ISO 50001 implementation and improvements in energy and organizational performance. Aouragh and Bouteldja conducted a case study on the Ain Touta Cement Company in Algeria [1], applying a descriptive-analytical methodology. Their findings highlighted a substantial reduction in electrical energy consumption and improvements in energy performance. However, challenges in managing thermal energy indicators were noted, suggesting areas where further enhancement is needed. Hernández-Rivera et al. investigated the implementation of an energy management system in a clinic in Veracruz, Mexico [2], following the Mexican standard NMX-J-SAA-50001-ANCE-IMNC-2019, aligned with ISO 50001. Utilizing the Plan-Do-Check-Act (PDCA) cycle, the authors reported a compliance rate of only 38%, with daily energy consumption emerging as the most influential factor. Their analysis revealed an energy savings potential of approximately 15.85%, underscoring the importance of data-driven decision-making in energy planning. In the industrial sector, Bernabé-Custodio et al. demonstrated that adopting ISO 50001 significantly reduced electricity use while generating substantial financial savings [3]. These results confirmed both the technical feasibility and economic benefits of implementing a structured energy management system based on the ISO 50001 framework. In the context of the aviation sector, Pushpo and Uddin examined the strategic advantages of adopting ISO 50001 as an energy management system, drawing insights from cases studies of recipients of the 2021–2023 Energy Management Leadership Award [4]. This international recognition honors organizations that demonstrate exceptional performance in energy efficiency and climate action through ISO 50001 implementation. The study highlights several key benefits, including enhanced energy efficiency, cost reductions, lower CO_2 emissions, and increased global awareness of climate-related issues. These findings offer valuable guidance to businesses and policymakers by showcasing ISO 50001's role in driving energy excellence and supporting organizational success. Baxter analyzed ISO 50001 adoption in various international airports [5]. The study found that implementing a certified EnMS led to enhanced energy and environmental performance, particularly through operational measures focused on energy efficiency and sustainability. This highlights the strategic importance of energy management in managing complex infrastructure systems. Zimon et al. contributed further by assessing the standard's impact on supply chain performance in Poland and Slovakia [6]. Through a survey of managers from certified firms, the study concluded that ISO 50001 enhances supply chain efficiency and sustainability, contributing to improved overall organizational performance. Kaselofsky et al. explored a strategy in which consultants provided guidance to 28 European municipalities in developing and implementing energy management systems [7]. By the conclusion of the study, 71% of these municipalities had successfully obtained ISO 50001 certifications. To better understand the driving factors and obstacles related to the adoption of these systems, the researchers conducted two surveys. The findings revealed that the most significant challenges faced by municipalities were organizational complexity and limited resources. Drawing from these practical experiences, the authors outlined key lessons for effectively supporting municipalities in the implementation of energy management systems. Fuchs et al. conducted an extensive review of 72 cases studies across various economic sectors [8], offering valuable global insights into ISO 50001 implementation from the perspective of certified organizations. Their analysis revealed that while organizations pursued ISO 50001 certifications for diverse reasons and experienced a wide range of benefits beyond energy savings and reductions in greenhouse gas emissions, several key patterns emerged. The most commonly cited motivations included alignment with existing organizational values and goals, a commitment to environmental sustainability, and compliance with governmental incentives or regulatory frameworks. The study also emphasized that strong and sustained support from top management is essential for successful implementation. Among the primary benefits reported were cost reductions, enhanced productivity, and improved operational efficiency. Conversely, the lack of an established energy management culture was identified as the principal obstacle. The authors concluded that policymakers aiming to promote wider adoption of ISO 50001 should leverage these findings by emphasizing the tangible benefits and aligning incentives with the priorities of corporate decision-makers.

Marimon and Casadesús provided a comprehensive evaluation of ISO 50001's benefits, reporting gains in financial performance, environmental outcomes, operational safety, and productivity [9]. They also identified positive spillover effects, with certified organizations often influencing their partners and stakeholders to adopt similar practices. Nevertheless, the study acknowledged obstacles such as certification costs, the complexity of energy data collection, and occasional gaps in executive engagement. Rampasso et al. examined the difficulties organizations face when adopting ISO 50001:2011, as highlighted in existing academic literature [10]. Their study employed a systematic review method, drawing from major international databases such as ScienceDirect, Emerald Insight, Scopus, Springer, Wiley, and Taylor & Francis. The search included combinations of keywords like "ISO 50001" with "Challenges," "Barriers," "Lacks," "Gaps," "Obstacles," "Problems," and "Limitations." This process initially identified 206 documents. After excluding duplicates, conference papers, book chapters, and sources that did not directly address implementation challenges, only 17 relevant studies remained. These revealed 11 distinct barriers, with the most frequently cited being limitations in resources (human, technological, infrastructure, financial, and time), difficulties in establishing energy baselines and performance indicators, skill and knowledge shortages among staff, and a lack of commitment or support from management. The recurrence of these challenges underscores the importance of thorough preparation and strategic organizational assessment before implementing ISO 50001. The authors note that despite its relevance, this topic remains insufficiently explored, and their findings could help shape future industrial policies to enhance economic performance. A report revealed that 78% of organizations adopting ISO 50001 already held other ISO certifications [11]. Key motivations for implementation included energy cost reduction, compliance with environmental regulations, eligibility for energy subsidies, and the integration of energy efficiency into broader corporate strategies. Yücel and Halis described the process of adopting the ISO 50001 standard and analyze how companies can enhance their organizational performance by integrating energy management models with the standard [12]. They argue that ISO 50001 and other energy management frameworks are mutually supportive and should not be viewed in isolation. In this context, implementing an integrated energy management system based on ISO 50001 is more effective than adopting the standard alone, as it enables organizations to assess their performance more accurately. Mohamad et al. conducted a case study on the implementation of the ISO 50001 Energy Management System in a Malaysian copper manufacturing facility [13]. Their analysis revealed that the company achieved an energy savings of approximately 3% by June 2013. This outcome highlights the critical role of a structured energy management system in supporting operational efficiency and ensuring long-term business sustainability. Finally, Fiedler and Mircea emphasized that reducing operational costs remains the predominant driver for ISO 50001 adoption [14]. Beyond the pursuit of energy efficiency, the standard also enhances corporate image by publicly affirming the organization's environmental responsibility, an increasingly valuable asset for investors, customers, and other stakeholders.

3. Methodology, Results, and Discussion

3.1. Methodological Approach

This study employs a qualitative case study approach to assess the impact of ISO 50001 implementation on the operational and financial performance of the National Plastics Company (CNP), a leading plastics manufacturer located in Sousse, Tunisia. The case study design was selected due to its suitability for capturing rich, contextual insights and for exploring organizational change processes in-depth. This method allows for an integrated assessment of energy use, cost dynamics, and waste reduction, core performance indicators relevant to energy management systems. Data for the analysis were collected from internal company reports and operational dashboards covering the period from 2020 to 2023. The dataset includes monthly records of energy consumption (kWh/kg), energy cost per unit (DT/kg), production variance, and waste regeneration volumes. Visual analytics were developed using Power BI to support real-time tracking and interpretation of trends. To improve methodological robustness, a pre- and post-comparison design was used to examine changes in key performance indicators before and after ISO 50001 implementation. While the study remains primarily descriptive, this design allows us to observe performance trends across multiple years and assess the practical outcomes of certification.

We acknowledge the limitations of focusing on a single firm without a formal control group. Although comparisons to similar firms were not feasible within this study's scope, we have included references to parallel case studies from other industries as informal benchmarks. Future research could enhance generalizability through multi-firm comparisons or panel data analysis. In addition, while this study does not currently employ econometric techniques, we recognize that methods such as difference-in-differences (DiD) analysis or regression modeling could help isolate the causal effects of ISO 50001 from external factors such as energy market trends, government incentives, or inflation. These methods are recommended for future extensions of this research. Furthermore, external influences such as seasonal variations, macroeconomic fluctuations, or changes in energy pricing were not controlled for. We acknowledge these as potential confounders and suggest their inclusion as control variables in future quantitative designs. Despite these limitations, this research provides valuable empirical insights into the operational and financial improvements associated with ISO 50001 adoption in an energy-intensive sector. It also offers a replicable model for performance monitoring through digital integration.

3.2. Results and Discussion

The National Plastics Company (CNP), established in 1958 in Sousse, Tunisia, operates as a public limited company with a core focus on the production of plastic films and packaging materials. In alignment with its long-term goals for sustainability and enhanced operational performance, CNP began the implementation of the ISO 50001 energy management standard in 2020. An in-depth review of internal energy performance data indicates significant progress across various operational metrics following the adoption of the system. As a recognized ISO-certified enterprise, CNP has solidified its position as a key player in Tunisia's plastics manufacturing sector, with an annual output exceeding 11,000 tons of plastic products. The company has continually invested in cutting-edge production technologies and process optimization strategies, reflecting its dedication to continuous innovation and high operational standards. CNP's product line includes a wide array of single- and multi-layer films tailored for use in food, beverage, and personal hygiene packaging. While it maintains a strong presence in the domestic market, the company also serves clients across multiple African and European countries, offering technical support and customer-focused services. CNP is guided by a set of core values environmental responsibility, sustainable development, technological innovation, ethical conduct, and excellence which shape its strategic direction. Its vision is to become a leader in the flexible packaging industry by generating value through responsible innovation, while its mission is centered on advancing eco-friendly packaging solutions through international collaboration and sustainable partnerships. This analysis is based on data collected from 2020 to 2023 to assess the impact of ISO 50001 on CNP's performance. It also highlights the key challenges faced during implementation, as well as the opportunities that arose. This research is inspired by the study conducted by Aouragh and Bouteldja [1]. The main findings of this empirical investigation are summarized in **Table 1**.

According to the applicable energy management standard, a Significant Energy Use (SEU) is defined as any energy use that represents a substantial share of total energy consumption and/or offers considerable opportunities for enhancing energy performance. Applying this definition, the company has successfully identified its SEUs, which correspond to specific stages of the production process where targeted improvements can yield meaningful energy savings. These findings are summarized in **Table 1**, which details the company's main energy sources: electricity, natural gas, and fuel, along with their respective shares of total energy consumption.

The data reveal that electricity is the dominant energy source, accounting for 80.46% of total consumption, underscoring its critical role in powering the production process. Natural gas follows at 11.97%, primarily used for process heating, while fuel represents a minimal share of 7.57%, suggesting limited application or potential inefficiencies in its use.

Table 1. Energy Use Breakdown and Significant Consumption Areas by Production Stage.

Energy Uses for the Company « CNP »							
Energy Type	Fuel			Electricity		Natural Gas	
Ratio	7.57%			80.46%		11.97%	
Distribution of Energy Uses in the Company Across Production Stages							
Energy Type	Extrusion	Printing	Regeneration	Injection			
Electricity %	83.83%	13.09%	2.2%	0.88%			
Natural Gas %	86%	14%					
Energy Objectives for the Company and Performance Indicators							
Energy Type	Objective			Target Indicator			
Electricity %	Electricity consumption reduction			10%			
Natural Gas %	Natural gas consumption reduction			5%			
Energy Performance Indicators for the Company							
Indicators	**Targeted Indicator**						
Specific Electricity Consumption	0.339 kilowatt-hours per kg of extrusion production						
Specific Gas Consumption	0.95 NM3 per 100 kg of extrusion production						
Energy Management Team Action Plan for the Company							
Type of Action	Gaz naturel			Électricité			
Operational/Technical Optimization	Equip critical areas with gas detectors to prevent energy loss due to leaks.			Optimize the preventive maintenance program to ensure equipment operates at peak efficiency.			
Energy Efficiency/Technical	Insulate boilers, particularly the combustion chamber, with insulation (thermal socks) to reduce excessive heat loss.			Insulate extruders and other machinery to reduce heat loss.			
Process Optimization/Energy Saving	Adjust temperature settings for drying and heating processes to minimize natural gas consumption while maintaining product quality.			Adjust temperature, speed, and pressure settings to minimize energy consumption without compromising product quality.			
Digital Integration/Automation				Effectively leverage existing energy management systems and integrate them with Sage X3 software.			
Capacity Building/Training	Train operators on best practices for efficient equipment operation.			Train operators on best practices for efficient equipment use.			
Process Standardization/Efficiency				Improve processes to minimize production waste, thereby reducing energy consumption related to material reprocessing (standardization across the team).			
Study and Analysis of Energy Performance for CNP							
Energy Consumption Rationalization for the Company							
Energy Type				**2020**	**2021**	**2022**	**2023**
Electricity (%)				3.81	3.78	3.75	3.81
Natural Gas (Nm^3/100 kg of finished product)				1.02	1.04	1.03	1.02

Source: Authors' compilation based on company data.

Moreover, **Table 1** breaks down energy consumption across the various production stages, offering insight into where energy is most intensively used. A key takeaway is the uneven distribution of energy use across different processes:

Extrusion emerges as the most electricity-intensive stage, consuming 83.83% of total electricity, followed by Printing at 13.09%, and Regeneration at 2.2%.

In terms of natural gas, only the Extrusion and Printing stages require this energy source, accounting for 86% and 14% of its total usage, respectively.

These observations suggest that extrusion is the most energy-critical stage of production, warranting focused energy-saving interventions due to its substantial reliance on both electricity and natural gas. This also highlights potential technical or operational inefficiencies that could be addressed to improve energy performance.

Building on the identification of SEUs, the company established specific Energy Performance Indicators (EPIs) and reduction targets to guide its energy management efforts. The set objectives include a 10% reduction in electricity consumption and a 5% reduction in natural gas consumption, as reflected in **Table 1**. Progress toward these goals is tracked by comparing estimated (baseline) consumption with actual usage, enabling continuous performance monitoring. To quantify energy efficiency, the company introduced one key metric:

The Energy Performance Indicator (EnPI), which measures the energy required to produce 1 kg of extrusion for electricity and 100 kg of extrusion for natural gas. This indicator focuses exclusively on process-related energy use, excluding non-productive consumption such as lighting or distribution losses.

To support the achievement of these objectives, a comprehensive Energy Management Action Plan was implemented. This plan includes both technical upgrades (e.g., equipment insulation, leak detection systems) and organizational measures (e.g., staff training, digital monitoring via ERP systems), ensuring that improvements are sustainable and systematically integrated into operations.

Performance data for the years 2021, 2022, and 2023 show that the company consistently exceeded its 1% annual electricity savings target, reflecting the success of its energy efficiency initiatives. Although natural gas consumption was reduced, the target threshold of 2 kg per unit was not fully achieved, indicating room for further optimization, particularly in process heating and gas system maintenance.

The company's strategic focus on energy-intensive processes, particularly extrusion and printing, has allowed it to improve efficiency, reduce production costs, and strengthen its competitive position. Since electricity powers all stages of production, maintaining the technical integrity and operational efficiency of equipment and machinery remains essential to sustaining these energy performance gains.

Building on the assessment of energy performance, we now turn our focus to the financial performance of CNP. This transition allows us to examine how the company's efforts in optimizing energy use translate into cost savings, operational efficiency, and overall financial health. Analyzing financial indicators alongside energy metrics provides a comprehensive view of the company's performance and sustainability strategy.

In fact, Fuchs et al. identify several key motivations that drive the adoption of ISO 50001 across industries [8]. These include the desire to obtain formal certification, the drive to improve energy management practices, the need to reduce energy-related costs, alignment with overarching corporate goals, and the opportunity to access financial incentives and government subsidies. Numerous case studies highlight the significant benefits of ISO 50001 implementation across a variety of sectors. For example, a cement plant achieved a 25% reduction in energy consumption [15], while a study on social building stock observed a 15% decrease in energy use [16]. Similarly, energy consumption in administrative buildings dropped by 20% [17], and the dairy sector saw a dramatic 50% reduction in CO_2 emissions. In the automotive industry, a car manufacturing facility reduced its energy consumption by 15% [18, 19]. The hotel industry benefited with a 20.6% decrease in energy consumption and a 30% reduction in CO_2 emissions, while cloud service providers realized a 15% reduction in energy use [20]. Additionally, the foundry sector achieved an 8.7% reduction in energy consumption. Public buildings also saw considerable savings, with one university reducing its energy use by 613,188 kWh, another public building cutting consumption by 31.36%, and yet another reducing energy consumption by 12% [21–23]. The water industry, after implementing ISO 50001, observed a 3.2% decrease in energy consumption [24, 25].

Figure 2 illustrates CNP's monthly production trends, comparing actual production per kilogram in 2022 and 2023 with forecasted production targets. It reveals that production in 2022 consistently lagged behind both the 2023 levels and planned forecasts, indicating earlier operational inefficiencies. However, in 2023, CNP demonstrated a marked improvement in aligning actual production with its targets, reflecting enhanced performance and more accurate planning. Notably, during August, September, and October, actual production not only approached but, in some cases, exceeded forecasted values, suggesting increased operational efficiency and better resource management. Conversely, months like January, July, and December saw actual production fall short of projections in both years, likely due to seasonal slowdowns or capacity limitations. Overall, the data points to a positive trajectory in CNP's production performance, with a significant narrowing of the gap between actual and forecasted output, underscoring the company's progress in operational planning and execution.

The variance measures the degree of fluctuation in monthly production, quantifying how much production levels deviate from the average. It is calculated using

$$v = \frac{\sum_{i=1}^{n}(X_i - \bar{X})^2}{n} \tag{1}$$

Where:
X_i is the production in month i
$\bar{X}$ is the average monthly production
n is the number of months

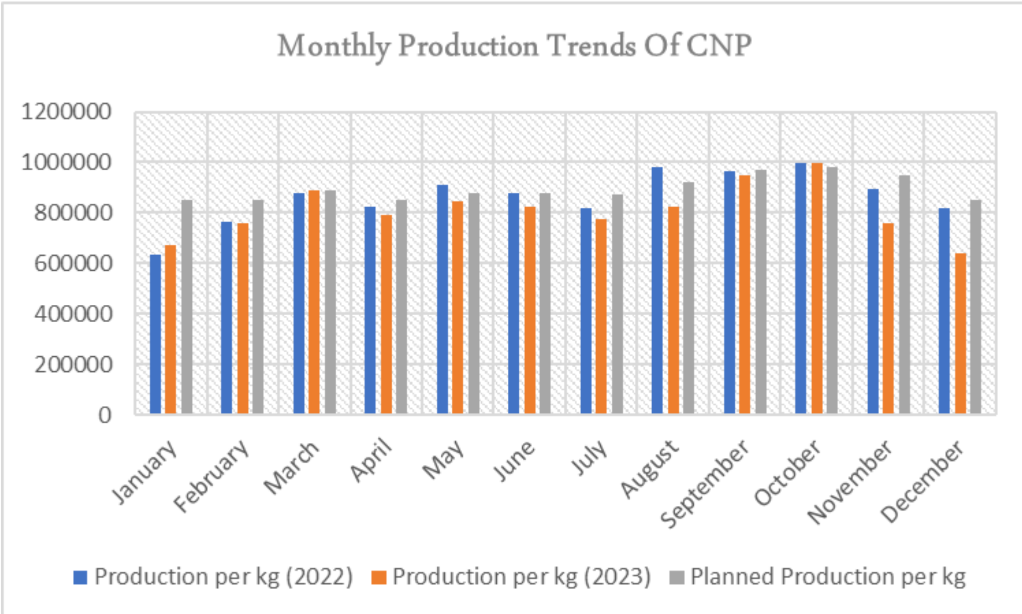

Figure 2. Monthly Production Trends of CNP.

Source: Authors' compilation.

An initial production variance of 8,473,272,844.39 indicates significant monthly fluctuations, pointing to inconsistent operational performance and potentially inefficient use of energy and other resources. In contrast, the target variance of 2,141,666,667 represents a desired state of stability and predictability in production processes. The substantial gap between these two values underscores the need for improved production planning, tighter process control, and strategies to mitigate the impact of fluctuating variables such as equipment inefficiencies or environmental conditions.

One of the most notable outcomes of implementing ISO 50001 at CNP is the sharp reduction in production variance from 8.47 billion, to 2.14 billion, highlighting a marked improvement in operational consistency. This stabilization reflects more efficient energy management and better control over production processes. Enhanced stability not only allows for more accurate demand forecasting and budget planning but also ensures better cost control throughout the production cycle. By reducing susceptibility to external disruptions, particularly during critical months like January, July, and December ISO 50001 supports uninterrupted operations. Ultimately, this improvement contributes to lower energy costs, reduced waste, and increased profitability, reinforcing the strategic value of energy performance management.

Table 2 presents a comparative analysis of monthly energy consumption (in kWh/kg) and energy cost (in DT/kg) for CNP over the years 2022 and 2023. On average, the company slightly reduced its energy consumption per unit of production from 0.378 kWh/kg in 2022 to 0.375 kWh/kg in 2023, reflecting a modest improvement in energy efficiency. Similarly, energy cost per kilogram of production decreased from 0.123 DT/kg to 0.122 DT/kg, indicating enhanced cost control despite possible variations in energy prices. Notably, in November 2023, there is a significant drop in both energy consumption (from 0.382 to 0.332 kWh/kg) and cost (from 0.125 to 0.108 DT/kg), suggesting an operational improvement or optimization measure that had a tangible impact during that month. Throughout most of the year, the differences between 2022 and 2023 figures are subtle, yet the overall trend suggests increased energy management efficiency. This data supports the conclusion that CNP's ongoing energy performance efforts potentially linked to ISO 50001 implementation are gradually yielding measurable benefits in both consumption and cost efficiency.

Table 2. Monthly Energy Consumption (kWh/kg) and Energy Cost (DT/kg) per kg of Production (2022–2023).

Monthly	Energy Consumption (kwh/kg) 2022	Energy Consumption (kwh/kg) 2023	Energy cost (DT/kg) 2022	Energy Cost (DT/kg) 2023
January	0.410	0.401	0.134	0.131
February	0.390	0.388	0.127	0.126
March	0.376	0.377	0.123	0.123
April	0.370	0.368	0.121	0.120
May	0.376	0.383	0.123	0.125
June	0.379	0.380	0.124	0.124
July	0.382	0.384	0.125	0.125
August	0.364	0.379	0.119	0.124
September	0.359	0.367	0.117	0.120
October	0.373	0.374	0.122	0.122
November	0.382	0.332	0.125	0.108
December	0.391	0.375	0.127	0.122
TOTAL/average	0.378	0.375	0.123	0.122

Source: Authors' compilation.

An analysis of monthly performance data reveals that certain months, particularly January, July, and December, exhibited higher production variance and, in some cases, increased energy consumption per kilogram. These patterns can be explained by both operational and seasonal factors. For example, January and December are traditionally affected by year-end shutdowns, national holidays, and reduced workforce availability, which contribute to lower production volumes and greater variance. In addition, during these periods, equipment may not operate at optimal load levels, causing temporary declines in energy efficiency. Similarly, July coincides with scheduled preventive maintenance and higher ambient temperatures during the summer season. Elevated cooling demands and occasional disruptions in production planning during this month can temporarily increase energy intensity and variance. Recognizing these seasonal patterns allows CNP to further refine its energy management planning, by anticipating such variations and enhancing operational resilience during known periods of underperformance.

Table 3 illustrates CNP's monthly regeneration figures for 2022 and 2023, quantifies the reduction in waste (in kg), and estimates the resulting cost savings (in Tunisian dinars). Overall, waste regeneration increased from 312,825 kg in 2022 to 384,364 kg in 2023, indicating a significant improvement in waste recovery practices. The total waste reduction amounts to 72,844.9 kg, generating a corresponding cost saving of 114,439.337 DT. These savings are a direct outcome of enhanced regeneration efficiency and better waste management. For instance, months like December and November show the highest waste reductions and savings, reflecting intensified efforts or operational upgrades during those periods. A notable disruption occurred in September 2022, where no regeneration was recorded due to operational issues; in contrast, 2023 showed strong recovery that month with over 31,000 kg regenerated and savings of nearly 9,821 DT. This data underscores the positive impact of improved waste management strategies in 2023, which not only boosted regeneration volumes but also led to significant financial gains demonstrating the dual benefits of environmental and economic performance improvements.

Figure 3 presents a visual comparison of key performance indicators at the National Plastics Company (CNP) over the period 2022–2023 and following ISO 50001 implementation. It displays four metrics: energy cost (DT/kg), total energy consumption (kWh), waste cost (DT/kg), and waste reduction (tonnes). The data show consistent improvements in operational efficiency post-certification, including reductions in energy consumption and energy cost, more effective waste management, and substantial gains in waste reduction. These results highlight the positive financial and environmental impact of ISO 50001 adoption and its alignment with CNP's strategic objectives for sustainability and enhanced competitiveness.

This study has several limitations that should be acknowledged. First, it focuses on a single case study (the National Plastics Company), which may restrict the generalizability of the findings across Tunisia's broader industrial landscape. Second, the analysis is primarily descriptive, lacking econometric modeling to establish causal relationships between ISO 50001 implementation and financial outcomes. Third, external factors such as energy price fluctuations, government incentives, and macroeconomic trends were not fully explored, though they likely influenced the results. Future research should address these limitations by adopting a comparative approach involving multiple industrial firms across various sectors and extending the analysis beyond three years to capture long-term effects. Incorporating advanced econometric techniques, such as difference-in-differences (DiD) or panel data analysis, would improve analytical rigor. Additionally, future studies should examine the role of organizational culture, employee engagement, and digital maturity in supporting effective energy management, and should include detailed financial cost-benefit analyses to quantify the return on investment (ROI) and payback periods for specific interventions.

Table 3. Monthly Waste Regeneration (kg) and Cost Savings (DT) (2022–2023).

Month	Waste Regeneration (kg) 2022	Waste Regeneration (kg) 2023	Reduction in Waste (kg)	Cost Savings (DT) 2023
January	40,279	26,735	6,701.4	10,527.899
February	37,229	26,831	6406	10,063.826
March	29413	28,970	5,838.3	9,171.969
April	19,980	19,551	3,953.1	6,210.320
May	24,709	33,380	5,808.9	9,125.782
June	39,752	31,660	7,141.2	11,218.825
July	26,427	17,866	4,429.3	6,958.430
August	17,716	38,371	5,608.7	8,811.268
September	0 (Operational disruption)	31,257	6,251.4 (2023)	9,820.949
October	20,267	28,765	4,903.2	7,702.927
November	26,040	49,498	7,553.8	11,867.020
December	31,016	51,480	8,249.6	12,960.122
Total	312,825	384,364	72,844.9	114,439.337

Source: Authors' compilation.

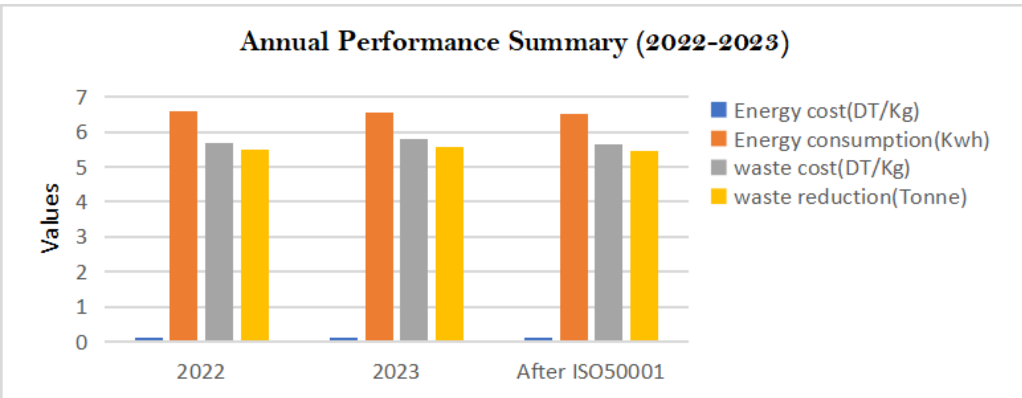

Figure 3. Annual Performance Summary (2022–2023).

Source: Authors' compilation.

4. Conclusions

The study conducted by the National Plastics Company (CNP) highlights the growing importance of energy management for industrial companies, where balancing economic competitiveness and environmental compliance has become essential. ISO 50001 has proven that implementing a structured energy management system is a key strategy for ensuring sustainability while reducing a company's carbon footprint. This approach optimizes energy resources, improves competitiveness, and enhances profitability. The benefits of ISO 50001 certification have been recognized across national, local, and global policy frameworks [26]. Several studies have explored the impact of Energy Management Systems (EnMS) based on ISO 50001 across various industrial sectors, demonstrating improvements in energy performance, reductions in CO_2 emissions [27], and energy savings in industries such as plastics [28], food [29], cement [30], and other energy-intensive sectors [31]. These findings underscore the significant advantages of adopting EnMS, as seen in various industrial applications worldwide.

One of the major conclusions of this study is that ISO 50001 enables CNP to better structure its energy consumption. By identifying energy-intensive items and adopting proactive resource management, the company can significantly reduce energy waste. The impact of ISO 50001 certification is evident: the reduction in energy costs is paired with an improvement in overall profitability. By optimizing production processes and investing in efficient technologies, CNP reduces energy costs while increasing production capacity. Furthermore, committing to an energy transition strengthens the company's competitiveness, providing access to green financing and public subsidies often available to companies meeting ecological standards.

Importantly, the energy savings achieved reflected in the reduction of the energy cost per kilogram from 0.123 DT/kg in 2022 to 0.122 DT/kg in 2023, demonstrate a positive financial impact. Although detailed capital expenditure data were not available, a qualitative assessment suggests that the payback period for several interventions, such as insulation and maintenance upgrades, is likely within one to two years based on typical industry benchmarks. These outcomes reflect a strong return on investment (ROI), particularly when energy cost savings are aggregated with waste reduction gains. Integrating such financial metrics into energy efficiency planning enhances the strategic value of ISO 50001 for industrial firms.

From an environmental perspective, ISO 50001 supports global sustainability efforts by reducing greenhouse gas emissions and encouraging the use of renewable energy sources. This approach also helps CNP comply with new regulatory requirements and enhances its eco-responsible brand image, which is critical for attracting business partners and consumers.

To further strengthen these outcomes, CNP should consider several strategic actions:

Enhance real-time monitoring systems to identify inefficiencies as they occur;

Invest in renewable energy technologies, such as solar panels and cogeneration systems;

Establish continuous employee training to promote a culture of energy responsibility;

Conduct periodic internal energy audits to maintain performance and identify emerging inefficiencies;

Benchmark with industry leaders to adopt best practices and remain internationally competitive;

Explore innovative, energy-efficient manufacturing techniques that align with both economic and environmental goals.

However, implementing an effective energy management system is demanding. It requires strong commitment from management, active employee participation, and ongoing training to adopt best practices. ISO 50001 is not merely about streamlining energy consumption but is a strategic lever for enhancing financial performance, competitiveness, and resilience. The reduction in energy costs strengthens competitiveness by lowering operating costs and increasing profitability, all while improving energy resource efficiency. These improvements in waste management and energy efficiency demonstrate ISO 50001's positive impact on reducing operational costs and improving the sustainability of the extrusion process.

Similar findings were reported by Jekabsone et al. [24], whose case study of the Daugavpils municipality in Latvia demonstrated that a well-implemented Energy Management System (EnMS) can lead to substantial energy savings of up to 12% in the public building sector, particularly when supported by strong leadership and active employee engagement. This underscores the critical role of both technical measures and organizational commitment in driving energy efficiency across sectors. Complementing these results, İsçan and Arıkan found that in Turkey, businesses can reduce invoice costs by 2.93% to 3.71% through optimal tariff management, achieving savings without requiring any additional investment [32].

These findings align with international experiences where ISO 50001 has demonstrated its effectiveness across diverse industrial sectors. For example, Pakbin and Taheri emphasizes that ISO 50001 significantly enhances energy efficiency in food manufacturing processes through its structured Plan-Do-Check-Act (PDCA) methodology, also used in ISO 9000 and ISO 14000 standards [33]. Notably, PepsiCo was the first company to implement this protocol, illustrating the global corporate shift toward structured energy management systems. Several studies have also examined the level of EnMS implementation across various countries. For example, in Turkey, Ates and Durakbasa found that 22% of companies in industries like steel, iron, paper, ceramics, and textiles had adopted energy management practices [34]. In Sweden, Thollander and Ottosson reported that 40% of paper manufacturers had implemented EnMS [35]. In Denmark, EnMS adoption ranged from 3% to 14% across different manufacturing sectors [36]. In Serbia, Jovanović et al. reported an average EnMS adoption level of 59.05% [37], with only 5.8% of companies fully implementing EnMS [38]. These studies illustrate the varied levels of EnMS implementation, highlighting both progress and ongoing challenges in achieving widespread adoption.

While this study provides meaningful insights into the impact of ISO 50001 on energy and financial performance, it is not without limitations. Primarily, the analysis is based on a single case study the National Plastics

Company (CNP) which constrains the extent to which the findings can be generalized across Tunisia's broader industrial landscape. Furthermore, although the use of Power BI has enhanced real-time monitoring and visualization of performance metrics, the research remains largely descriptive. It does not incorporate econometric modeling techniques that would allow for a more rigorous examination of causal relationships between ISO 50001 implementation and financial outcomes. Additionally, external variables such as government subsidies, energy pricing frameworks, and broader macroeconomic conditions were not explicitly accounted for, despite their potential influence on energy consumption and cost structures. To build on this work, future research should consider comparative case studies involving multiple firms across various sectors to validate and extend the findings. Applying econometric methods such as panel data analysis or difference-in-differences approaches could significantly improve the analytical strength of such studies. Moreover, exploring organizational dimensions, including corporate culture, employee engagement, and the degree of digital integration, would offer valuable insights into the enablers of successful energy management implementation, particularly in the context of Tunisia's evolving industrial environment. In addition, future studies should incorporate comprehensive financial evaluations, including cost-benefit analyses and estimations of return on investment (ROI) and payback periods for specific interventions. Such financial quantification would provide more practical guidance for industrial decision-makers and policy designers.

Author Contributions

Conceptualization, S.S. and J.K.; methodology, S.S. and J.K.; software, S.S.; investigation, S.S. and J.K.; resources, S.S. and J.K.; data curation, S.S.; formal analysis, S.S.; validation, J.K.; visualization, S.S.; writing—original draft, S.S.; writing—review & editing, J.K.; supervision, J.K. All authors have read and agreed to the published version of the manuscript.

Funding

This work received no external funding.

Institutional Review Board Statement

Not applicable.

Informed Consent Statement

Not applicable.

Data Availability Statement

The data used in this study were extracted from the annual reports of the company under investigation. These reports are publicly available from the company's official website or may be obtained upon request from the corresponding author.

Acknowledgments

The authors extend their sincere gratitude to Professor Mounir Smida, Director of the MOfid Research Laboratory, for his invaluable assistance, insightful guidance, and unwavering encouragement throughout the course of this work.

Conflicts of Interest

The authors declare no conflict of interest.

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