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Energy Efficiency Assessment in Small Manufacturing Processes in Mongolia

Bachelor Thesis

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Statutory Declaration

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I hereby affirm in lieu of an oath that I provided the submitted bachelor thesis

Energy Efficiency Assessment in Small Manufacturing Processes in Mongolia

I did not use any sources other than those stated. In case that the work is additionally submitted on a data medium, I declare that the written and the electronic form are completely identical. The work was not submitted in the same or similar form to any examination authority.

Ulaanbaatar, 05/01/2026	Tsogzolmaa E.
Place, Date	Signature

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Abstract

Energy efficiency is an important issue for small manufacturing enterprises because it affects production cost, electricity use, and overall operational performance. In Mongolia, this issue is becoming more important due to rising electricity costs, supply reliability concerns, and limited use of energy management practices in small and medium-sized enterprises. This thesis examines the energy efficiency of a chips factory in Mongolia through a case study approach.

The study uses one year of factory data from 2025, including electricity consumption, production output, raw material input, and equipment information. Interviews with factory staff were also conducted to better understand factory operations and possible improvement opportunities. The analysis focused on electricity consumption, energy intensity, electricity cost per package, and the distribution of electricity use across different processes. A time-of-use tariff scenario was also evaluated to examine possible cost savings.

The results show that electricity consumption increased in high-production months, indicating a strong production–energy relationship; however, changes in energy intensity reveal whether efficiency improved or deteriorated. while energy intensity became less efficient during low-production periods. The study also found that most electricity was used in the main production processes and supporting systems. In addition, the time-of-use tariff analysis suggests that some cost savings may be possible with better production scheduling.

Overall, the study concludes that energy efficiency in the selected factory can be improved not only through technical changes, but also through practical actions such as better monitoring, maintenance, and scheduling. The findings may also be useful for other small manufacturing enterprises in Mongolia.

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Chapter 1: Introduction

1.1 Background of the Study

Energy efficiency has become an important issue for industrial development because energy directly affects production cost, productivity, competitiveness, and environmental performance. In manufacturing, energy is not only a supporting resource but also an essential input for operating machines, maintaining production flow, and ensuring stable output. Therefore, improving energy efficiency is increasingly viewed as a way to reduce unnecessary energy use while maintaining or improving production performance.

Small and Medium-sized Enterprises (SMEs) are important contributors to employment, local production, and economic development. However, SMEs often face limitations such as restricted financial resources, limited technical expertise, weak monitoring systems, and low adoption of formal energy management practices. Because of these constraints, energy efficiency opportunities in SMEs are often not fully identified or implemented.

In Mongolia, energy efficiency is especially relevant due to the country's energy-system challenges, including coal-based electricity generation, aging infrastructure, increasing demand, electricity import dependence, and supply reliability concerns. These conditions make efficient energy use important not only for reducing costs, but also for improving operational stability in manufacturing enterprises.

Food processing is one manufacturing area where energy use is closely connected to production activities. In a chips production factory, electricity is consumed by core processes such as mixing, drying, frying, packaging, and auxiliary systems such as compressors, lighting, and ventilation. Therefore, assessing energy efficiency requires more than reviewing electricity bills; it requires linking energy consumption with production output, equipment operation, and cost.

This thesis focuses on the energy efficiency assessment of a chips production factory in Mongolia. Using a case study approach, it analyzes current energy use, identifies key inefficiencies, and develops energy efficiency improvement strategies based on technical, economic, and operational considerations.

1.2 Problem Statement

Although energy efficiency is important for manufacturing enterprises, many SMEs do not have a structured approach for monitoring and improving energy use. Energy consumption is often

recorded only at the total bill level, while detailed information about equipment-level consumption, production-related energy use, and energy performance indicators is limited. As a result, it becomes difficult to identify where energy is wasted and which improvement strategies should be prioritized.

This problem is relevant to the selected chips production factory. The factory uses several energy-consuming processes and auxiliary systems, but without a structured energy assessment, it is difficult to determine which machines or activities contribute most to electricity consumption. In addition, production volume can vary from month to month, meaning that total electricity consumption alone cannot show whether the factory is operating efficiently. For this reason, indicators such as electricity consumption per unit of production are needed.

Another problem is that electricity cost and supply reliability are becoming more important issues in Mongolia. Rising tariffs, time-of-use pricing options, and electricity supply constraints create pressure for manufacturers to manage energy use more carefully. However, without proper analysis, SMEs may miss opportunities to reduce electricity costs, improve scheduling, and strengthen energy performance.

Therefore, the main problem addressed in this thesis is the lack of a structured energy efficiency assessment for a small manufacturing process. This study aims to fill that gap by evaluating current energy use in the selected chips factory and developing data-driven energy efficiency improvement strategies. This study therefore moves beyond descriptive energy reporting by applying production-based energy indicators to identify inefficiencies and evaluate operational improvement opportunities.

1.3 Motivation of the Study

The motivation for this study comes from the need to make energy use in small manufacturing processes more measurable, understandable, and efficient. For SMEs, even moderate improvements in energy performance can reduce operating costs and support more stable production. This is especially important in Mongolia, where electricity prices and supply reliability are important concerns for industrial enterprises.

From an academic perspective, this study is motivated by the limited number of case-based energy efficiency studies focused on Mongolian SMEs. Most existing research discusses energy efficiency in broader international or industrial contexts, while fewer studies examine how these concepts can be applied to a specific small manufacturing process in Mongolia. Therefore, a localized case study can contribute useful insights for both academic and practical understanding.

This study is also motivated by its connection to industrial engineering. It applies concepts such as process analysis, energy performance indicators, cost evaluation, and improvement strategy development to a real production environment. By using actual factory data, the thesis aims to produce energy efficiency improvement strategies that are relevant to the selected chips factory and potentially useful for similar small manufacturing enterprises.

1.4 Objectives of the Study

The primary objective of this thesis is to evaluate the energy efficiency of a small manufacturing process and develop data-driven energy efficiency improvement strategies.
Specific Objectives:

- To analyze the current energy consumption patterns of the selected factory
- To identify key energy-consuming processes and equipment
- To measure energy performance using appropriate indicators (e.g., kWh per unit of production)
- To evaluate the feasibility of implementing a time-of-use (three-tariff) electricity system
- To develop technically and economically feasible energy efficiency improvement strategies.

1.5 Research Questions

This study seeks to answer the following research questions:

1. How is energy currently consumed and managed in the selected manufacturing process?
2. How can energy efficiency be measured and evaluated in the case study?
3. What are the main sources of energy inefficiency in the factory?
4. What technically and economically feasible energy efficiency improvement strategies can be developed for the selected factory?
5. To what extent can the proposed energy efficiency measures be realistically implemented under SME operational constraints?

1.6 Scope and Limitations of the Study

Scope of the Study
This study focuses on the energy efficiency assessment of a single manufacturing facility in Mongolia, specifically a chips production factory, treated as a case study.

The scope includes:

- Analysis of electricity consumption across production processes and auxiliary systems
- Evaluation of energy performance over a defined period (approximately one year)
- Identification of energy-intensive equipment and operational inefficiencies
- Assessment of both direct (production-related) and indirect (lighting, compressors, etc.) energy consumption
- Development of energy efficiency improvement strategies based on technical, economic, and operational considerations.

Limitations of the Study

- The study is based on a single case study; therefore, findings may not be fully generalizable to all SMEs in Mongolia
- Data availability may be limited, and some values may rely on estimates or assumptions
- The analysis focuses primarily on electrical energy and may not fully account for thermal energy usage
- Financial analysis is simplified and may not include all indirect costs or long-term investments
- Recommendations such as ISO 50001 implementation are evaluated conceptually and not implemented in practice
- External factors, such as policy changes or market conditions, are not fully considered
- These limitations are acknowledged to ensure that findings are interpreted as context-specific rather than universally generalizable.

Chapter 2. Literature Review

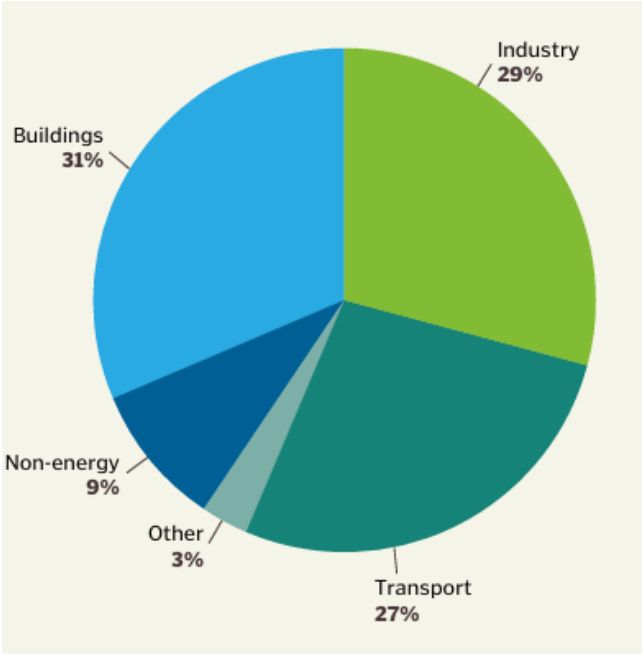
2.1 Energy Efficiency

Energy efficiency is generally understood as obtaining the same or a greater useful output with less energy input. In industrial terms, this means reducing the electricity, fuel, heat, or other energy required to maintain production without lowering product quality, process reliability, or output level. In current energy policy discussions, energy efficiency is increasingly treated as a strategic resource because it can lower energy bills, reduce demand growth, and improve energy security at the same time.

In manufacturing analysis, however, the concept needs to be interpreted carefully. A narrow technical definition based only on the efficiency of an individual machine is often insufficient because factory energy consumption is distributed across several connected processes and

support systems. Industrial energy literature therefore treats energy efficiency more broadly as energy performance across a process or system, not just at the level of one device. This broader view is especially important for small manufacturing firms, where overall performance is often shaped by the combined effect of machinery, support equipment, runtime, maintenance quality, and operating practices rather than by one dominant unit alone.

Figure 1. Final energy consumption by sector



As shown in Figure 1, industry accounts for a substantial share of total final energy consumption, which reinforces the relevance of energy efficiency assessment in manufacturing processes.

For the present thesis, energy efficiency is best understood at the level of the production process and the factory as a whole. In a chips factory, energy is used not only in core manufacturing stages but also in auxiliary systems such as compressors, conveyors, lighting, packaging, ventilation, and other indirect loads. As a result, a meaningful energy efficiency assessment must look beyond absolute electricity consumption and ask how effectively energy is converted into useful production. This is why the present study will later rely on indicators such as kWh per kilogram of product rather than on electricity bills alone.

Another important distinction is between energy reduction and energy efficiency improvement. A factory may consume less electricity in one month simply because production was lower, not because operations became more efficient. Therefore, energy efficiency in this thesis is treated as a relationship between energy input and production output, and not as a simple decline in

total energy use. This distinction is central to later analysis because the objective of the thesis is to assess performance and identify practical recommendations, not only to report consumption figures.

2.2 Energy Efficiency in SMEs

SMEs occupy a central place in the energy efficiency discussion because, although each individual enterprise may be small, their combined economic and energy significance is substantial. Recent review literature shows that SMEs represent the overwhelming majority of businesses and still hold considerable unrealized potential for cost-effective energy savings. At the same time, the same literature argues that SME energy efficiency cannot be addressed effectively through the same assumptions used for large firms, because SMEs face different structural conditions, decision processes, and implementation barriers.

This distinction is highly relevant to the present thesis. The selected case is not a large industrial plant, but a small manufacturing operation in Mongolia. SMEs usually have fewer specialized staff, more limited technical expertise, lower access to capital, and weaker monitoring systems. These characteristics influence not only how energy is used, but also how efficiency opportunities are perceived and adopted. In many SMEs, energy is not neglected because it is irrelevant; rather, it is often overshadowed by production pressures, quality control, delivery deadlines, staffing constraints, and day-to-day business survival. This makes practical assessment especially important, because improvements need to be understandable and realistically applicable within a constrained operating environment.

The SME literature also makes clear that the sector is not homogeneous. Energy use patterns differ significantly by industry, process, and output type. A recent review on energy efficiency in SMEs notes that sectors such as food, beverage, and tobacco have a distinct profile in which production energy use is meaningful but often closely tied to process organization, support systems, and repetitive operational routines. This is particularly useful for the present study because a chips factory belongs to exactly this type of production environment. In such a setting, energy performance is likely to depend not only on machine efficiency, but also on scheduling, maintenance, process control, and the management of auxiliary loads.

Figure 2 Final energy consumption levels for various SME sectors per number of enterprises

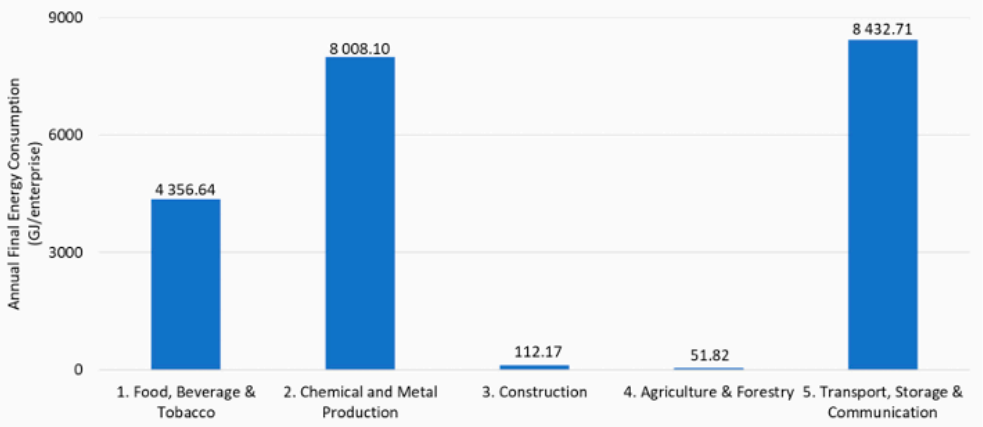


Table 1 Relative energy characteristics of selected SME sectors

Sector	Energy consumption level per enterprise	Relative efficiency level	Improvement potential
Food, beverage and tobacco	Medium	High	Medium
Chemical and metal production	High	High	High
Agriculture and forestry	Low	Low	High
Construction	Low	Medium	High
Transport and storage	High	Low	High

Figure 2 and Table 1 help show that the food-processing SME context is energy-relevant, but also operationally distinct from more energy-intensive sectors, which justifies a tailored case-study approach.

For this reason, the literature review in this chapter does not discuss SMEs in general only as an abstract category. Instead, it focuses on those aspects of SME energy efficiency that are most relevant to small manufacturing processes, especially where practical energy assessment can later support recommendations in a food-processing case study. This orientation is important because the value of the thesis lies not in broad generalization, but in developing a well-grounded and realistic assessment framework for one specific factory context.

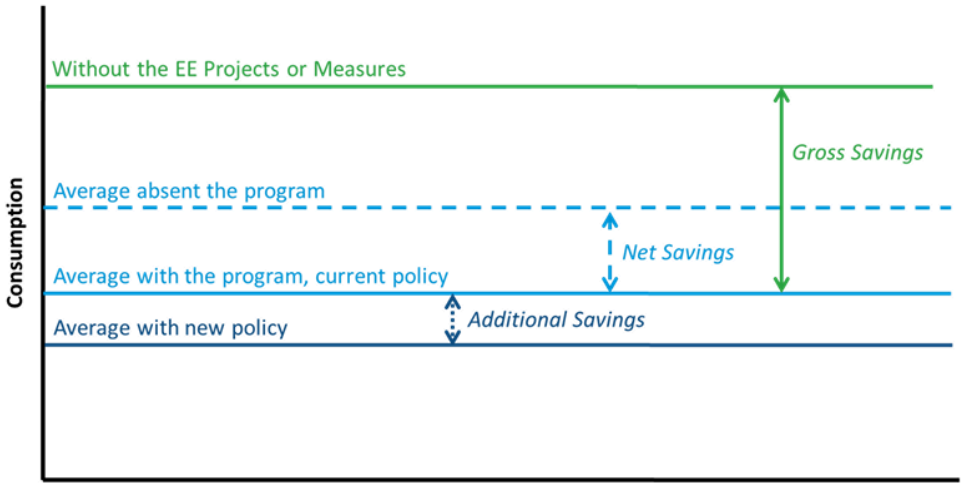
A further point that emerges from the SME literature is that small firms should not be described only in terms of weakness. SMEs often have simpler internal structures, shorter communication paths, and greater operational flexibility than larger organizations. This means that, if the right

opportunities are identified and communicated effectively, implementation can sometimes be faster than in more bureaucratic settings. For a recommendation-based case study, this is important because it supports the argument that meaningful energy efficiency improvement is possible even without large-scale technological transformation.

2.3 Methods and Metrics for Measuring Energy Efficiency

A credible energy efficiency assessment depends on appropriate measurement. It is not enough to report how much electricity a factory consumes. Evaluation, measurement, and verification guidance emphasizes that energy performance must be interpreted relative to a baseline and with consideration of the operating conditions that shape energy use, such as production volume, operating hours, weather, and other independent variables. Without such normalization, an apparent change in energy use may reflect a change in activity rather than a true improvement in efficiency.

Figure 3 Illustration of gross, net, and additional energy efficiency savings



As illustrated in Figure 3, meaningful energy efficiency analysis requires comparison against a baseline rather than simple observation of electricity use in isolation.

This principle is essential for the present thesis. A chips factory may use more electricity in a month simply because it produced more output. Therefore, total kWh is not a sufficient indicator on its own. Measurement in this study must connect energy use to production results in order to distinguish between simple scale effects and actual efficiency performance. This is why process-level and production-linked indicators are more meaningful than absolute monthly consumption alone.

2.3.1 Energy intensity (kWh/kg product)

Energy intensity is commonly understood as the amount of energy required to generate a unit of output. At the national level, it is often expressed as energy use per unit of GDP, but at the level of a factory it becomes more useful when linked to physical production. Energy indicator literature from the IEA shows that industry-level efficiency analysis increasingly relies on end-use activity data and associated indicators precisely because aggregate consumption alone cannot adequately explain performance trends or identify operational improvements.

For the present case study, the most relevant form of energy intensity is electricity consumption per kilogram of finished product. This indicator directly links electricity use to output and is therefore appropriate for a chips factory, where product can be measured physically. Its value lies in allowing fairer comparison across different production periods. If output rises but kWh/kg falls, then the process has become more energy efficient even if total electricity consumption has increased. This makes energy intensity a much stronger analytical tool than monthly electricity use considered in isolation.

Table 2 Core measurement metrics for the present case study

Indicator	Formula / basis	Unit	Relevance to thesis
Total electricity consumption	Metered or billed electricity use	kWh	Shows overall energy demand
Energy intensity	Electricity use / production output	kWh/kg	Core performance measure
Specific energy consumption	Energy per product unit	kWh/kg or kWh/unit	Allows comparison over time
Electricity cost per unit	Electricity cost / production output	MNT/kg	Links performance with economics
Peak-period share	Peak-hour electricity / total electricity	%	Links performance with economics
Indirect electricity share	Lighting, office, auxiliary load / total electricity	%	Links performance with economics

Table 2 summarizes the most relevant indicators for the present study and shows why production-linked metrics are more meaningful than total consumption alone.

Energy intensity is also valuable because it supports later benchmarking and recommendation development. Practical recommendations are easier to evaluate when the factory's current performance can be expressed in a normalized form. For example, maintenance or scheduling

improvements can later be discussed in terms of their likely effect on kWh/kg rather than only on total cost.

2.3.2 Specific energy consumption

Specific energy consumption is closely related to energy intensity and is one of the most practical indicators for manufacturing assessment. SME energy guidance emphasizes the importance of relating energy use to production, turnover, or another meaningful activity measure where consumption changes with output. It also recommends simple and regular monitoring tools such as meter readings, energy trend graphs, and the identification of base load and out-of-hours consumption patterns.

In the present thesis, specific energy consumption is especially relevant because it translates technical analysis into a form that is practical for both research and management. A value such as kWh/kg of chips is easier to interpret and communicate than a general statement that “the factory uses significant electricity consumption” It can also reveal whether process changes actually improve performance over time. In this respect, specific energy consumption is not only a metric; it is also a bridge between analysis and decision-making.

2.3.3 Energy performance indicators (EnPI)

Energy performance indicators, or EnPIs, provide a broader framework for monitoring and interpreting energy use. In a small manufacturing case, useful indicators may include total monthly electricity use, electricity per kilogram of output, electricity cost per kilogram, the share of electricity used by major equipment, and the share of indirect electricity use such as lighting or office-related loads. Their value lies in creating a structured way to observe performance rather than treating electricity use as one undifferentiated total.

For this thesis, EnPIs are important because the study is recommendation-oriented. The factory needs more than a description of current energy consumption; it needs indicators that can support later monitoring and improvement. In this sense, EnPIs connect the literature review with the later methodology and case-study chapters. They also fit well with energy management thinking because they make energy visible at the operational level.

Figure 4 Hierarchy of energy efficiency indicators

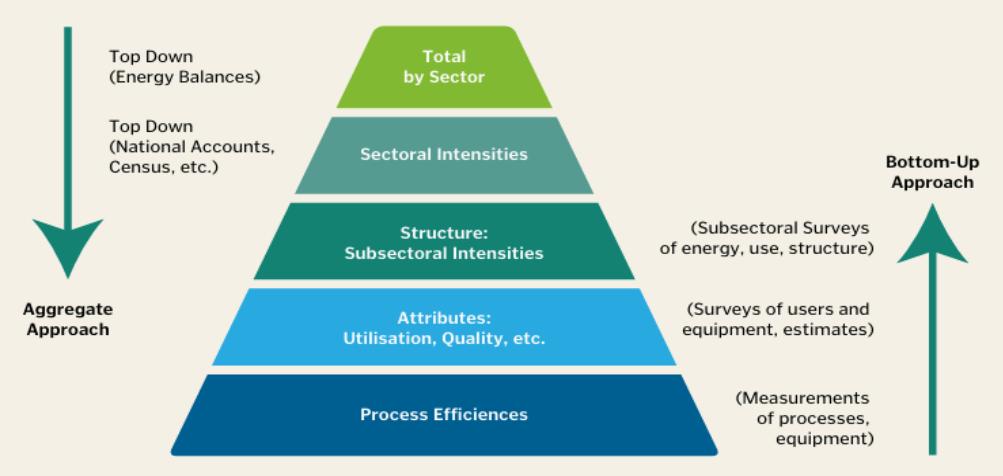


Figure 4 helps clarify why the present study focuses on operational and production-linked indicators rather than only on broad aggregate measures.

A critical point, however, is that SMEs often lack the internal data systems needed to support highly sophisticated indicators. Therefore, indicator selection in this thesis must remain practical. The aim is not to create a complex monitoring model that the case factory cannot realistically use, but to identify simple indicators that are technically meaningful and operationally adoptable. This is one reason why the literature review emphasizes production-based and management-useful indicators rather than advanced optimization metrics.

2.4 Barriers to Energy Efficiency in SMEs

The literature on industrial SMEs consistently shows that energy efficiency opportunities are not implemented automatically, even when they appear economically attractive. A major contribution to this topic argues that barriers differ by type of efficiency measure and by enterprise context, and that firms often face several obstacles simultaneously rather than one single limiting factor. These barriers include economic, organizational, behavioral, informational, and competence-related constraints, all of which shape implementation in different ways.

For the present thesis, this finding is important because it prevents the analysis from treating inefficient energy use as only a technical problem. In a chips factory, inefficiencies may exist not because solutions are unknown, but because there are competing priorities, limited capital, insufficient internal attention, unclear data, or concern about operational disruption. This means that the literature review must explain not only which measures are possible, but also why small firms frequently fail to adopt them.

A separate barrier-and-driver study of SMEs provides further support for this interpretation. It found that cost savings were widely recognized by firms as a motivation for action, yet

implementation rates remained low even for opportunities with substantial financial benefits. The same study also found that many missed opportunities required little or no capital investment, showing that financial barriers alone do not explain the energy efficiency gap in SMEs. Instead, other business considerations such as timing, management attention, and the perceived “hassle cost” of change are often decisive.

Research focused on Chinese SMEs adds another useful dimension by showing that informational barriers can be the core bottleneck even where financial and organizational issues are also present. That study found that only a minority of SMEs engaged actively in significant energy-saving activity, and that lack of awareness of relevant technologies and practices remained a major obstacle. It also highlighted weak government support, low technical skill, and limited access to appropriately structured finance as additional barriers, suggesting that SMEs may require combined informational, financial, and policy support rather than isolated technical advice.

An especially important contribution for the present thesis is the argument that communication itself can operate as a barrier. A study on SME energy programmes found that technical audits often fail to generate strong outcomes when firms receive information passively but do not have the opportunity to discuss, interpret, and connect it to their own operational context. In contrast, programmes that involve active dialogue, peer exchange, and shared interpretation produce stronger energy-efficiency outcomes. This is highly relevant to the current case study because it supports the inclusion of interviews and practical explanation, not only technical calculation.

Taken together, the literature suggests that barriers in SMEs are multidimensional and mutually reinforcing. This matters directly for the present study because any later recommendation for the chips factory must be realistic not only in technical terms, but also in organizational, financial, and communicative terms. A recommendation that is technically sound but difficult to understand, finance, or implement may have little practical value in a small manufacturing setting.

2.5 Industrial Energy Efficiency Best Practices (Global Perspective)

Best-practice literature on industrial energy efficiency shows that meaningful improvement often begins with practical management and operational measures rather than with large capital projects. Recent IEA industry analysis confirms that industry remains the largest final energy-consuming sector and highlights that efficiency improvement in industry depends not only on equipment replacement, but also on how energy is managed across processes, operating schedules, and system integration. The same analysis reinforces the idea that

industrial efficiency improvement must be viewed as a strategic opportunity, especially where demand growth, competitiveness, and energy-system stress intersect.

For a small manufacturing case, this broader international perspective is useful because it shows that energy efficiency should not be reduced to “buying new machines.” Best practices typically include preventive maintenance, reduction of unnecessary runtime, optimization of motors and support systems, lighting control, better housekeeping, improved process settings, and more systematic operational discipline. These categories are especially relevant for a chips factory, where the energy profile is likely to be shaped by repetitive operation, support loads, and process coordination rather than by one single large energy-intensive unit.

Figure 5 Energy maturity model

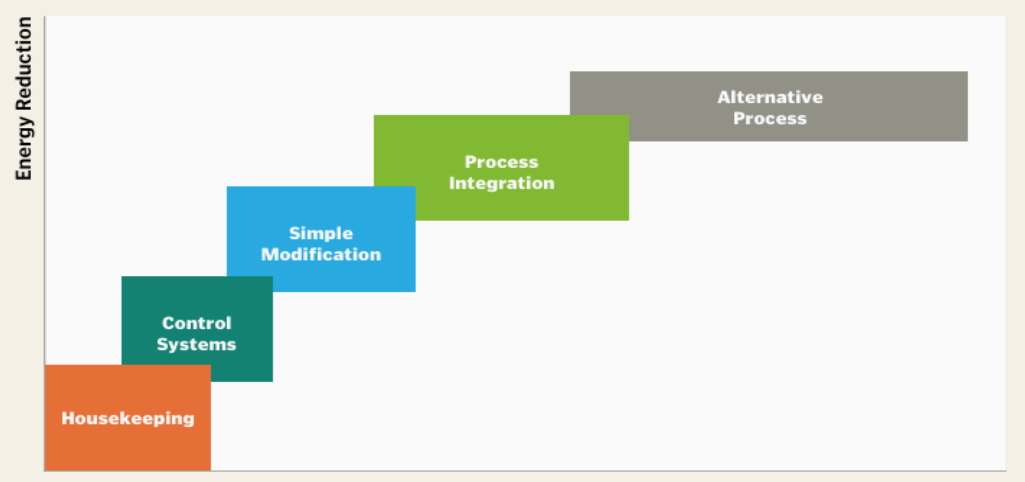


Table 3 Global best-practice categories relevant to small manufacturing firms

Practice area	Example measures	Typical expected benefit	Relevance to a chips factory
Good housekeeping	Switching off idle equipment, reducing leaks	Low-cost savings	High
Maintenance	Calibration, cleaning, preventive service	Reduced waste and downtime	High
Lighting efficiency	LED replacement, sensors, daylight use	Lower indirect load	Medium
Support-system optimization	Compressors, motors, ventilation control	Reduced auxiliary demand	High
Scheduling and runtime control	Production timing, minimizing idle time	Better operational efficiency	High
Staff awareness	Training and internal	More stable long-term	Medium

	communication	performance	

Figure 5 and Table 3 together show that energy efficiency improvement is often a staged process, beginning with practical operational changes before moving toward more advanced interventions.

The practical significance of this literature is that it supports a stepwise logic of improvement. Small firms often benefit first from clearer monitoring, improved maintenance, and low-cost control measures before considering larger capital interventions. This is important for the present thesis because a bachelor-level case study should produce realistic and implementable recommendations. Global best-practice literature helps structure these recommendations into categories that are easier to assess later: operational improvements, maintenance-based improvements, indirect electricity reduction, and scheduling-related improvements.

At the same time, international literature must be used critically. Many best-practice examples come from environments with more stable power systems, stronger incentives, or more accessible technical support than Mongolia. Therefore, the purpose of using global literature in this chapter is not to copy foreign practices directly, but to identify types of intervention that can be adapted to the local SME context. This critical adaptation is necessary if the literature review is to remain relevant to the case study rather than becoming a general discussion of industrial energy management.

2.6 Time-of-Use (TOU) Tariff and Load Shifting

TOU tariff systems make electricity cost depend on the timing of use rather than on total consumption alone. From an energy management perspective, this makes the timing of demand a key analytical issue. ISO's official explanation of ISO 50001 stresses that effective energy management requires organizations to use data to understand energy use, set objectives, measure results, and continually improve decisions related to energy performance. Although ISO 50001 is not a tariff-specific framework, its emphasis on data-driven understanding of energy use strongly supports the logic of TOU analysis and load-aware scheduling.

For the present thesis, TOU tariffs are especially relevant because one of the proposed contributions is to compare the factory's current electricity cost with a three-tariff scenario. In such a system, the economic result depends not only on how much electricity is consumed, but also on whether significant loads occur during daytime, evening peak, or night periods. This shifts part of the analysis from energy volume to energy timing.

Table 4 Illustrative TOU tariff structure and load-shifting logic

Time period	Relative tariff level	Potential operational implication
Daytime	Standard / high	Core production should be optimized
Evening peak	Highest	Avoid non-essential energy-intensive activities
Night / off-peak	Lowest	Potential for load shifting if feasible

As shown in Table 4, the economic value of electricity management depends not only on the quantity of energy consumed, but also on the timing of demand.

The concept of load shifting is therefore important. In a manufacturing context, load shifting means moving selected energy-intensive operations to lower-cost periods where possible. For the chips factory case, this could potentially create electricity cost savings even if total electricity use remains similar. However, this is not automatically beneficial. A shift in operating hours may introduce higher labor costs, transport costs, supervision requirements, and worker-related constraints. As a result, TOU tariff analysis in this thesis must be treated as an operational and economic feasibility issue, not simply as a theoretical pricing advantage.

Including this topic in the literature review strengthens the relevance of the chapter to the case study. It shows that practical energy assessment in SMEs should not focus only on reducing consumption, but also on understanding how the structure of electricity pricing influences operating decisions.

2.7 Energy Risk and Energy Resilience

Industrial energy efficiency is often justified in terms of cost and environmental performance, but in unstable or capacity-constrained systems it also has a resilience value. Energy resilience literature in the Mongolian context explains that resilience concerns the ability of the energy system to withstand external and internal shocks, maintain essential functions, and recover quickly when disruptions occur. It also emphasizes that preparedness, reserves, contingency planning, and learning from failures are central to building resilience in the energy sector.

This perspective is highly important for the present thesis because the chips factory operates in a broader setting where energy risk is not only a matter of price. It also includes supply reliability, infrastructure weakness, import dependence, and power interruptions. In such a context, energy efficiency can contribute to resilience by reducing unnecessary demand, improving operational control, and making factory energy use more predictable and manageable.

For a small manufacturing enterprise, the relevance of this concept is practical. Power instability or outages can interrupt production, damage workflow, increase downtime, and complicate maintenance. Therefore, the study of energy risk is not separate from energy efficiency; it provides part of the reason why energy management matters. A factory that improves maintenance, manages load more carefully, and reduces avoidable electricity demand may also become less vulnerable to external system stress. This broader interpretation helps connect the case study not only to cost-saving logic, but also to continuity of operations.

2.8 ISO 50001 Energy Management System

One of the persistent weaknesses of SMEs is that energy improvements are often informal and fragmented rather than systematic. ISO 50001 is relevant in this context because it provides an internationally recognized framework for establishing, implementing, maintaining, and continually improving an energy management system. ISO explains that the standard is applicable to organizations of all sizes and is intended to improve energy performance, including energy efficiency, energy use, and energy consumption, through a structured and data-based approach.

For the present thesis, ISO 50001 is useful because one of the proposed recommendations is to assess how its principles could improve the factory's energy management. However, the literature and practical SME experience suggest that full formal certification may be difficult for small firms because of limited resources, staff capacity, and administrative burden. This means that the value of ISO 50001 in the current case lies less in certification itself than in the structured logic it provides.

Figure 6 ISO 50001 and the Plan–Do–Check–Act cycle

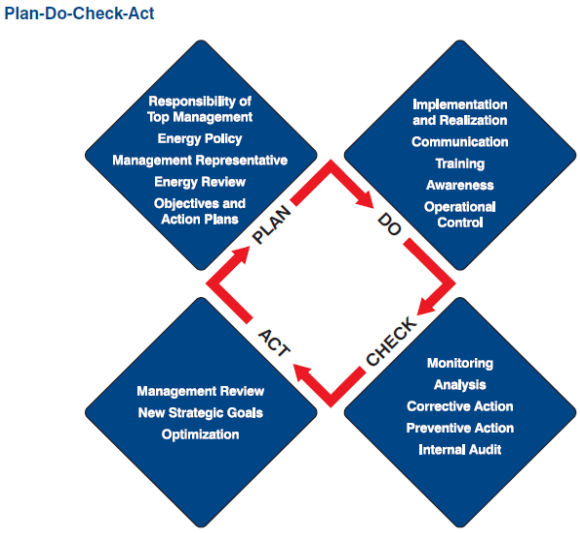


Figure 6 is especially relevant because it shows how a small factory can adopt the logic of structured improvement even without immediately seeking formal certification.

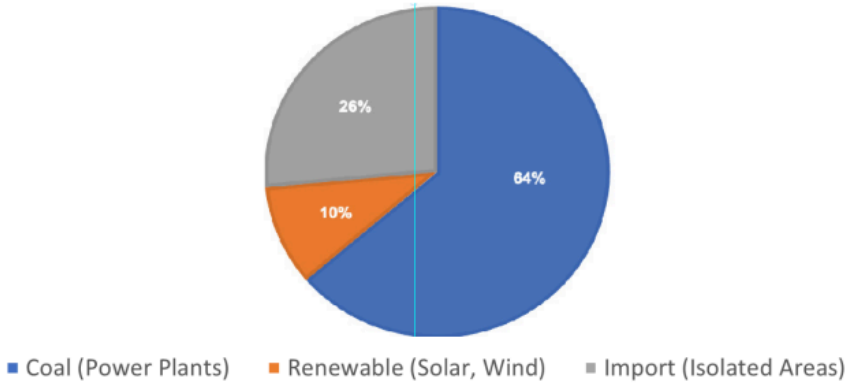
The most relevant principles for the chips factory are likely to be the identification of significant energy uses, the selection of practical performance indicators, the assignment of responsibilities, the use of data for decision-making, and regular review of progress. In that sense, ISO 50001 can serve as a practical framework for making energy improvement more systematic over time. This interpretation is especially appropriate for a bachelor thesis because it allows the discussion to remain realistic and connected to SME conditions rather than treating the standard as an abstract corporate ideal.

2.9 Energy Situation in Mongolia

2.9.1 Current conditions

Mongolia's current energy situation is shaped by import dependence, centralized infrastructure, and structural vulnerability in the electricity system. According to a recent national resilience assessment, Mongolia's total electricity consumption in 2024 was 10.7 TWh, of which 74.3% was met by domestic production and 25.7% by imports . The same report states that coal-fired power plants account for 90.5% of Mongolia's domestic electricity production, showing that the country remains highly dependent on thermal generation . In infrastructure terms, Mongolia's total installed capacity is 1,808 MW, and the Central Energy System accounts for 78.2% of national electricity consumption, far exceeding the shares of the Southern, Eastern, Western, and Altai–Uliastai systems . These figures show that Mongolia's energy system is both centralized and exposed to structural risk.

Figure 7 Mongolia's Energy Source



2.9.2 Challenges

These current conditions create several challenges for industrial SMEs. First, energy efficiency must be understood in a setting where supply reliability is a concern. Second, import dependence and infrastructure weaknesses mean that electricity cost and stability are shaped not only by internal factory performance but also by broader system conditions. Third, the aging nature of the system increases the importance of operational flexibility and resilience at firm level. For a chips factory, this means that internal efficiency improvements should be viewed not only as cost-saving actions, but also as part of adapting to a more constrained energy environment.

Import dependence is especially important in quantitative terms. The same 2025 report states that Mongolia's total electricity imports in 2024 reached 2,863.4 million kWh, with total payments of 671.5 billion MNT . It further reports that imports from the Russian Federation increased from 312.1 million kWh in 2020 to 1,319.2 million kWh in 2024 . Since total imports in 2024 were 2,863.4 million kWh and imports from Russia were 1,319.2 million kWh, the remaining imported electricity—approximately 1,544.2 million kWh—can be understood as coming mainly from China. This means that Mongolia depends on both Russia and China for electricity supply, with Russia remaining the major explicitly reported source in the available data and China accounting for the remaining imported share by difference from the reported total .

2.9.3 Power outages

Power outages and electricity restrictions are especially relevant to this thesis because they directly affect production continuity, scheduling reliability, and the operational stability of manufacturing enterprises. In a small manufacturing process, an outage or forced restriction

may interrupt production flow, increase downtime, reduce planning certainty, and create additional operational risks. Therefore, electricity supply reliability should not be treated as separate from energy efficiency. In the Mongolian context, it forms an important part of the broader energy risk environment within which SMEs operate. Recent events in Ulaanbaatar indicate that electricity-related disruptions were not limited to isolated technical incidents. On 16 October 2025, a large-scale outage affected Ulaanbaatar around 13:30 after a fault occurred on the 220 kV electricity import line from the Russian side. Official information reported that domestic stations covered approximately 85% of demand while around 15% of consumption was temporarily restricted until the line was restored. Later, on 20 January 2026, electricity restrictions were introduced again after a failure occurred on a boiler surface at CHP-4, creating a shortage in available power capacity. Reports from 23 January 2026 further noted that Ulaanbaatar had already been under 1–2 hour electricity restrictions for four consecutive days following that incident. In the same period, the Ministry of Energy also published planned two-hour restriction schedules for specific locations on 27, 28, and 30 January 2026 in order to prevent emergency conditions in the integrated energy system.

Table 5 Selected major electricity outages and power restrictions in Ulaanbaatar (2025–2026)

Date	Event type	Main cause	Scope / implication
2025.10.16	Major outage	Fault on the 220 kV imported electricity line from Russia	A large-scale outage affected Ulaanbaatar around 13:30; about 15% of consumption was temporarily restricted
2026.01.20	Power restriction	Failure at CHP-4, resulting in power capacity shortage	Restriction schedule announced for selected locations in Ulaanbaatar
2026.01.23	Continued restriction period	Ongoing consequences of the 2026.01.20 CHP-4 failure	Reports indicated that the city had experienced 1–2 hour restrictions for four consecutive days
2026.01.27	Planned restriction	Preventive action to avoid emergency conditions in the integrated system	Night-time restriction schedule announced for specific areas
2026.01.28	Planned restriction	Preventive action to avoid emergency conditions in the integrated system	Two-hour restrictions announced for specific locations
2026.01.30	Planned restriction	Continued preventive load restriction in the integrated system	Two-hour restrictions announced for specific locations

As shown in Table 5, Ulaanbaatar experienced both large-scale outages and scheduled electricity restrictions during 2025–2026. These events suggest that electricity-related risk in Mongolia should be understood not only in terms of tariff cost, but also in terms of operational reliability. For small manufacturing enterprises, such conditions may increase downtime risk, complicate production planning, and strengthen the importance of energy management and resilience-oriented operating strategies. In this sense, energy efficiency in the present study is not discussed only as a way to reduce electricity consumption and cost, but also as part of a broader effort to improve production stability under uncertain energy system conditions.

2.9.4 Regulations and policies

Mongolia's policy environment has recognized energy efficiency as an important issue for many years. An earlier policy document from the Asian Development Bank linked energy efficiency, renewable energy support, energy security, sustainable development, and sector reform in Mongolia and the wider Asian context. While this document is not recent enough to describe the current system in detail, it remains useful as evidence that energy efficiency has long been treated as a strategic development issue rather than only as a narrow technical topic.

Taken together, these conditions show why a factory-level energy efficiency study in Mongolia matters. The chips factory case is not only about one enterprise reducing its bill. It also reflects a wider national need for more efficient, resilient, and better-managed energy use in small manufacturing processes.

In addition to the broader policy orientation, recent tariff reform has made energy efficiency more urgent for industrial enterprises in practical economic terms. In November 2024, electricity tariffs were revised, and the average electricity tariff increased from 216 MNT/kWh to 280 MNT/kWh, which is equivalent to an increase of approximately 29.6%, or about 30% on average. This adjustment is highly relevant to the present study because it strengthens the financial importance of reducing unnecessary electricity consumption, improving operational control, and evaluating alternative electricity-use strategies such as time-of-use tariff application and load shifting. Thus, recent tariff increases further reinforce the importance of energy efficiency assessment for SMEs operating under rising electricity costs and an increasingly constrained energy environment.

2.10 Research Gap

While existing literature provides strong conceptual and methodological foundations for energy efficiency assessment, several gaps remain. First, limited empirical research applies

production-based energy indicators within small-scale manufacturing contexts in Mongolia. Second, many studies focus on either technical or policy-level analysis, with fewer integrating operational, economic, and scheduling dimensions within a single framework. Third, SME-specific implementation constraints are often underrepresented. This study addresses these gaps by developing a data-driven, case-based assessment integrating energy intensity, cost analysis, and operational feasibility.

Chapter 3 Methodology

3.1 Research Approach: Case Study Method

This thesis uses a case study method to assess energy efficiency in a small manufacturing process. A case study is suitable when a study focuses on one real-life case and examines it in its actual context. In this thesis, the case is one chips production factory in Ulaanbaatar, Mongolia.

This approach is appropriate because energy efficiency in manufacturing depends on actual operating conditions. In the selected factory, electricity use is influenced by production volume, working hours, equipment operation, maintenance practices, and production scheduling. These factors cannot be understood well through general industry data alone. For this reason, the study examines one factory in detail instead of comparing many companies at a broad level.

The study uses one full year of data from January to December 2025. This period includes both normal production months and peak production months, which makes it possible to compare changes in output, electricity use, and operating conditions across the year. The company name is not disclosed for confidentiality reasons, so it is referred to as the selected chips factory throughout the thesis.

Both quantitative and qualitative data were used. Quantitative data include monthly electricity consumption, production quantity, raw material input, equipment information, machine-level electricity data, and electricity cost. These data were used to calculate energy intensity, electricity cost per package, equipment-level electricity use, and TOU tariff scenarios. Qualitative data were collected through interviews with three employees: the factory manager, the chief engineer, and one production worker. These interviews were used to support the interpretation of the numerical results.

The main purpose of the methodology is to connect electricity use with production activity. Total electricity consumption alone does not show whether the factory is operating efficiently, because electricity use may increase when production output increases. Therefore, this study uses

production-based indicators, especially electricity consumption per package and electricity cost per package, to evaluate energy performance more clearly.

Overall, the case study method is suitable for this thesis because it allows the analysis to reflect the actual conditions of the selected chips factory and supports the development of practical energy efficiency improvement strategies. This methodological approach directly responds to the research gap by combining quantitative indicators with qualitative operational insights."

3.2 Description of the Case Company: Confidential Chips Factory

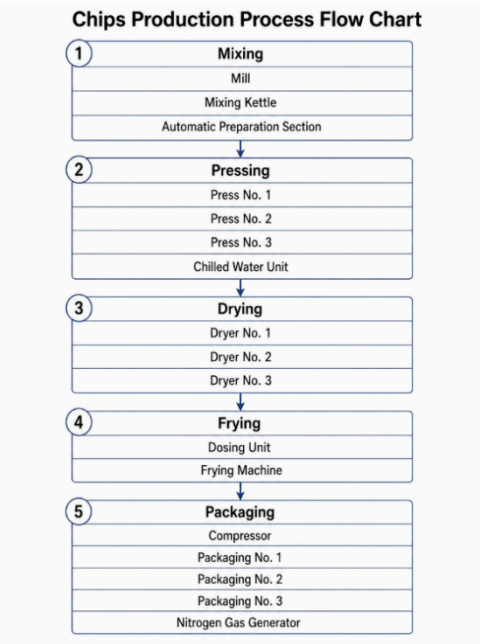
The case company in this thesis is a chips production factory located in Ulaanbaatar, Mongolia. Because of confidentiality requirements, the company name is not disclosed. In this thesis, it is referred to as the selected chips factory.

The factory is treated as an SME-scale manufacturing case in the food-processing sector. It produces only chips, and the analysis focuses on one production facility, its electricity use, operating conditions, and energy efficiency improvement opportunities.

The selected chips factory has about 27 employees, divided into two shifts of approximately 13 and 14 workers. In normal months, the factory usually operates for around 12 hours per day. In peak months, production may continue for 24 hours per day using a 12-hour/12-hour shift system. Depending on demand, the factory operates for about 18 to 28 days per month.

The main production stages are raw material preparation, mixing, forming or extrusion, drying, frying, seasoning, weighing, and nitrogen packaging. However, for the equipment-level electricity analysis in this thesis, the main electricity-related process groups are presented as mixing, pressing, drying, frying, and packaging, based on the factory equipment data.

Figure 8 Chips production process flow chart of the selected factory



As shown in Figure 3.1, the production process begins with mixing and continues through pressing, drying, frying, and packaging. The figure presents the main process groups and equipment used in the later electricity analysis. Some detailed production steps, such as seasoning and weighing, are not shown separately because separate equipment-level electricity records for these steps were not available in the factory data.

In this thesis, electricity use is considered in two categories: direct factory electricity use and indirect/support electricity use. Direct electricity use includes production-area equipment and factory-related loads that support production. Indirect/support electricity use includes office equipment, office lighting, and other non-production electrical devices. This distinction is important because the factory's electricity cost is not created only by production machines.

The selected chips factory is suitable for this study because data were available for production, electricity consumption, equipment operation, and interviews for the year 2025. These data make it possible to examine how electricity use changes with production activity and to develop practical energy efficiency improvement strategies for the factory.

3.3 Data Collection Methods

This study uses data collected from the selected chips factory for the period from January to December 2025. The data were gathered to analyze electricity consumption, production output, equipment operation, electricity cost, and current energy management practices.

The main data sources are electricity bills, production records, raw material records, equipment data, machine-level electricity meter data, auxiliary and support load information, and interviews with factory employees. Using these data together makes it possible to compare monthly electricity use with production output, machine operation, and staff explanations for the same study period. Where direct measurements were unavailable, estimates based on rated power and operating hours were used, which may introduce minor uncertainty.

3.3.1 Electricity Bill Data

Monthly electricity bill data were collected for the full year of 2025. The data include monthly electricity consumption in kilowatt-hours (kWh) and monthly electricity cost in Mongolian tugrik (MNT). These data are used to identify the factory's total electricity demand and monthly electricity cost.

Electricity bill data provide the main baseline for the energy assessment. However, bill data alone do not show which machines or processes consume the most electricity. Therefore, electricity bills are analyzed together with production data, equipment data, and machine-level electricity information.

3.3.2 Production Data

Production data were collected for the same 12-month period. The main production data used in this thesis are monthly chips production quantity and monthly raw material input. Production quantity is measured by the number of chips packages produced.

Production data are necessary because electricity consumption must be compared with factory output. If production increases, electricity use may also increase. Therefore, production-based indicators are used to evaluate whether electricity is used efficiently relative to the number of chips packages produced.

3.3.3 Raw Material Data

Raw material data were collected to understand the relationship between input material and production output. The data include monthly raw material input in kilograms. This information is used to calculate raw material input per package and to support the interpretation of production efficiency.

Although raw material input is not a direct electricity indicator, it helps explain production changes across months. For example, changes in raw material input and production quantity can affect equipment use, operating hours, and electricity consumption.

3.3.4 Equipment and Machine-Level Data

Equipment data were collected to identify the main electricity-consuming machines in the factory. The data include machine type, function in the production process, rated power in kilowatts (kW), number of machines, operating hours, and machine-level electricity meter data where available.

Machine-level electricity meter data are important because they provide more accurate information about the electricity consumption of major production equipment. These data help identify which machines or production stages contribute most to total electricity use. For equipment or support loads without detailed meter data, electricity consumption may be estimated using rated power and operating hours.

The equipment data cover the main production stages, including raw material preparation, mixing, forming or extrusion, drying, frying, seasoning, weighing, and nitrogen packaging.

3.3.5 Auxiliary and Support Electricity Data

Auxiliary and support electricity data were collected to consider electricity uses that are not directly part of chips production but still contribute to the factory's total electricity consumption. These include lighting, office computers, printers, ventilation, compressors, and other small electrical devices.

This category is included because the supervisor specifically highlighted the need to consider electricity use from office equipment, lighting, and other indirect loads. These loads may be smaller than the main production machines, but they can still create unnecessary electricity cost if they are used inefficiently. Therefore, this thesis includes both production-related and support-related electricity use.

3.3.6 Interview Data

Interview data were collected from three employees of the selected chips factory: the factory manager, the chief engineer, and one production worker. These participants were selected because they represent different perspectives within the factory.

The factory manager provided information about production planning, working schedules, staffing, and cost-related concerns. The chief engineer provided technical information about machines, maintenance, electricity use, and equipment operation. The production worker provided information about daily production activities, machine use, and actual working conditions on the production floor.

The interview data were used to support the interpretation of the numerical data. For example, if a certain month had high electricity use, interview answers helped explain whether this was related to longer working hours, peak demand, machine operation, maintenance issues, or production schedule changes.

3.3.7 Summary of Collected Data

Table 6 Summary of data collected for the energy efficiency assessment

Data type	Data collected	Source	Purpose
Electricity bill data	Monthly kWh consumption and monthly electricity cost	Factory electricity bills	To analyze total electricity use and electricity cost
Production data	Monthly production quantity and raw material input	Factory production records	To calculate energy use per unit of production
Raw material data	Monthly raw material input in kg	Factory production records	To analyze material input per package and support production analysis
Equipment data	Machine type, function, power rating, quantity, operating hours	Chief engineer / equipment list	To identify major energy-consuming equipment
Machine-level electricity data	Electricity consumption of major machines	Machine-level meter data	To analyze equipment-level electricity consumption
Auxiliary electricity data	Lighting, office equipment, printers, compressors, ventilation	Factory observation / equipment records	To assess indirect and support electricity use
Interview data	Operational, technical, and production information	Factory manager, chief engineer, production worker	To explain data trends and identify improvement opportunities

The combination of these data sources allows the study to evaluate energy performance from both numerical and operational perspectives. Electricity bills show total consumption, production data show output, machine-level data identify major electricity users, and interviews explain how the factory actually operates.

3.4 Interview Design

Interviews were conducted to collect qualitative information to support the interpretation of the quantitative data. They helped explain production practices, equipment operation, maintenance routines, and possible energy efficiency improvement opportunities.

Three employees were interviewed: the factory manager, the chief engineer, and one production worker. These participants were selected to provide management, technical, and operational

perspectives. A semi-structured interview format was used, based on the same main themes for all participants. The interviews were conducted in Mongolian, written notes were taken, and the notes were later summarized in English.

3.5 Energy Efficiency Calculation Methods

This section explains the calculation methods used to evaluate the energy efficiency of the selected chips factory. The calculations are based on electricity bill data, production quantity, raw material input, equipment information, machine-level electricity meter data, and operating hours from 2025.

In this thesis, energy efficiency is evaluated by connecting electricity consumption with production output. This is important because total electricity consumption alone may increase or decrease depending on production volume. For this reason, the main production-based indicator used in this study is electricity consumption per chips package. Energy performance should therefore be interpreted in relation to production activity rather than total consumption alone. In addition, cross-checks were conducted to ensure consistency between total electricity consumption and aggregated equipment-level estimates.

3.5.1 Monthly Electricity Consumption

Monthly electricity consumption is taken from the factory's electricity bills. It represents the total electricity consumed by the factory in one month.

Equation 1 Monthly electricity consumption

$$E_m = Total\ electricity\ consumption\ in\ month\ m$$

Where:

$$E_m = monthly\ electricity\ consumption\ (kWh)$$

This value is used as the main input for calculating energy intensity and electricity cost indicators.

3.5.2 Energy Intensity per Package

Energy intensity per package shows how much electricity is used to produce one chips package.

Equation 2 Energy intensity per package

$$EI_m = \frac{E_m}{Q_m}$$

Where:

$$EI_m = energy\ intensity\ in\ month\ m\ (kWh/package)$$

$$E_m = monthly\ electricity\ consumption\ (kWh)$$

$$Q_m = monthly\ production\ quantity\ (packages)$$

A lower energy intensity value means that less electricity is used to produce one package of chips. A higher value may indicate inefficient operation, low equipment utilization, longer idle time, or other energy losses.

3.5.3 Raw Material Input per Package

Raw material input per package is calculated as a supporting production indicator. It helps understand how raw material input relates to the number of chips packages produced.

Equation 3 Raw material input per package

$$RM_m = \frac{R_m}{Q_m}$$

Where:

$$RM_m = raw\ material\ input\ per\ package\ in\ month\ m\ (kg/package)$$

$$R_m = monthly\ raw\ material\ input\ (kg)$$

$$Q_m = monthly\ production\ quantity\ (packages)$$

This indicator supports the interpretation of production performance. If raw material input per package changes significantly, it may indicate changes in product weight, production loss, moisture loss, or process conditions.

3.5.4 Equipment Electricity Consumption

Equipment electricity consumption is analyzed using machine-level meter data where available. For equipment without detailed meter data, electricity consumption can be estimated using rated power, operating hours, and number of machines.

Equation 4 Equipment electricity consumption

$$E_i = P_i \times H_i \times N_i$$

Where:

$$E_i = electricity\ consumption\ of\ equipment\ i\ (kWh)$$

$$P_i = rated\ power\ of\ equipment\ i\ (kW)$$

$$H_i = operating\ hours\ of\ equipment\ i\ (hours)$$

$$N_i = number\ of\ equipment\ units$$

This calculation helps identify the major electricity-consuming machines and production stages. It is also used to compare electricity consumption across mixing, forming, drying, frying, seasoning, weighing, packaging, and support systems.

3.5.5 Direct and Indirect Electricity Use

Electricity consumption is classified into direct production electricity use and indirect/support electricity use.

Direct production electricity use includes electricity consumed by machines directly involved in chips production, such as raw material preparation, mixing, forming or extrusion, drying, frying, seasoning, weighing, and nitrogen packaging.

Indirect or support electricity use includes electricity consumed by systems that support factory operation but are not directly part of the production process. This includes lighting, office computers, printers, compressors, ventilation, and other auxiliary loads.

Equation 5 Total estimated electricity use

$$E_{total} = E_{direct} + E_{direct}$$

Where:

$$E_{total} = total\ estimated\ electricity\ use\ (kWh)$$

$$E_{direct} = direct\ production\ electricity\ use\ (kWh)$$

$$E_{indirect} = indirect/support\ electricity\ use\ (kWh)$$

This classification is used to identify whether energy efficiency improvement strategies should focus mainly on production machines, support systems, or both.

3.5.6 Share of Direct and Indirect Electricity Use

The share of direct and indirect electricity use is calculated to understand the contribution of each category to total electricity consumption.

Equation 6 Direct electricity share

$$S_{direct} = \frac{Edirect}{Etotal} \times 100$$

Where:

$$S_{direct} = share\ of\ direct\ production\ electricity\ use\ (\%)$$

$$E_{direct} = direct\ production\ electricity\ use\ (kWh)$$

$$E_{total} = total\ estimated\ electricity\ use\ (kWh)$$

Equation 7 Indirect electricity share

$$S_{indirect} = \frac{E_{indirect}}{E_{total}} \times 100$$

Where:

$$S_{indirect} = share\ of\ indirect/support\ electricity\ use\ (\%)$$

$$E_{total} = indirect/support\ electricity\ use\ (kWh)$$

$$E_{total} = total\ estimated\ electricity\ use\ (kWh)$$

These calculations are important because support systems such as lighting, office equipment, ventilation, and compressors may also create avoidable electricity consumption.

3.5.7 Electricity Cost per Package

Electricity cost per package is calculated to connect energy performance with production cost.

Equation 8 Electricity cost per package

$$C_{p,m} = \frac{C_m}{Q_m}$$

Where:

$$C_{p,m} = electricity\ cost\ per\ package\ in\ month\ m\ (MNT/package)$$

$$C_m = monthly\ electricity\ cost\ (MNT)$$

$$Q_m = monthly\ production\ output\ (packages)$$

This indicator shows how much electricity cost is associated with producing one package of chips. It is useful because total electricity cost may be higher in high-production months, but the cost per package may be lower if equipment is used efficiently.

3.5.8 Interpretation of Energy Efficiency Indicators

The calculated indicators are used to evaluate the factory's energy performance. Monthly electricity consumption shows total electricity demand. Energy intensity per package shows electricity use relative to production output. Raw material input per package supports production analysis. Equipment electricity consumption identifies major electricity-consuming machines. Direct and indirect electricity shares show whether electricity use is mainly related to production or support systems. Electricity cost per package connects electricity use with production cost.

These indicators provide the basis for developing energy efficiency improvement strategies. The strategies are developed by identifying high-consumption equipment, unnecessary support electricity use, inefficient operating patterns, and possible cost-reduction opportunities.

3.6 Cost Analysis Method

The cost analysis in this thesis compares the factory's electricity cost under the current fixed tariff and two time-of-use tariff scenarios. The purpose is to understand how electricity cost changes depending on tariff structure and operating schedule. This section does not conduct a full investment feasibility study.

The current electricity tariff used by the factory is 265 MNT/kWh. Under this tariff, monthly electricity cost is calculated by multiplying monthly electricity consumption by the electricity price.

Equation 9 Monthly electricity cost under the current tariff

$$C_m = E_m \times T_c$$

Where:

$$C_m = monthly\ electricity\ cost\ (MNT)$$

$$E_m = monthly\ electricity\ consumption\ (kWh)$$

$$T_c = current\ electricity\ tariff\ (MNT/kWh)$$

In this study:

$$T_c = 265\ MNT/kWh$$

The study also compares the current tariff with a time-of-use tariff. Under the TOU tariff, electricity cost depends on the time of consumption. The tariff periods used in this thesis are:

- Day period: 06:00–17:00 = 265 MNT/kWh
- Evening period: 17:00–22:00 = 397 MNT/kWh
- Night period: 22:00–06:00 = 160 MNT/kWh

The general TOU electricity cost is calculated by separating electricity consumption into day, evening, and night periods.

Equation 10 Electricity cost under TOU tariff

$$C_{TOU} = (E_d \times T_d) + (E_e \times T_e) + (E_n \times T_n)$$

Where:

$$C_{TOU} = electricity\ cost\ under\ TOU\ tariff\ (MNT)$$

$$E_d = electricity\ consumption\ during\ day\ period\ (kWh)$$

$$E_e = electricity\ consumption\ during\ evening\ period\ (kWh)$$

$$E_n = electricity\ consumption\ during\ night\ period\ (kWh)$$

$$T_d = day\ tariff\ (265\ MNT/kWh)$$

$$T_e = evening\ tariff\ (397\ MNT/kWh)$$

$$T_n = night\ tariff\ (160\ MNT/kWh)$$

For the selected chips factory, two TOU operating schedules are considered because the factory normally operates approximately 12 hours per day.

The first TOU scenario is 05:00–17:00. This schedule includes 1 hour of night tariff and 11 hours of day tariff. It is considered the more feasible TOU scenario because it avoids the expensive evening peak tariff and stays closer to normal daytime operation.

The second TOU scenario is 22:00–10:00. This schedule includes 8 hours of night tariff and 4 hours of day tariff. It is the lowest-cost TOU scenario from an electricity-cost perspective. However, it may be difficult to apply in practice because night work can create challenges related to labor rules, worker fatigue, transportation, supervision, safety, and production management.

These two TOU schedules are used as cost-comparison scenarios. They do not represent confirmed implemented schedules.

The average tariff for each 12-hour schedule is calculated as follows.

Equation 11 Average tariff for a 12-hour TOU schedule

$$T_{avg} = \frac{(H_d \times T_d) + (H_e \times T_e) + (H_n \times T_n)}{H_{total}}$$

Where:

$$T_{avg} = average\ electricity\ tariff\ for\ the\ schedule\ (MNT/kWh)$$

$$H_d = number\ of\ day\ tariff\ hours$$

$$H_e = number\ of\ evening\ tariff\ hours$$

$$H_n = number\ of\ night\ tariff\ hours$$

$$H_{total} = total\ working\ hours\ per\ day$$

For the 05:00–17:00 schedule:

$$T_{avg} = \frac{(11\times265)+(1\times160)}{12}$$

$$T_{avg} = 256.25\ MNT/kWh$$

For the 22:00–10:00 schedule:

$$T_{avg} = \frac{(4\times265)+(8\times160)}{12}$$

$$T_{avg} = 195\ MNT/kWh$$

After calculating the average tariff, the estimated electricity cost under each schedule is calculated by multiplying monthly electricity consumption by the average tariff.

Equation 12 Estimated electricity cost under selected TOU schedule

$$C_{schedule} = E_m \times T_{avg}$$

Where:

$$C_{schedule} = estimated\ electricity\ cost\ under\ selected\ TOU\ schedule\ (MNT)$$

$$E_m = monthly\ electricity\ consumption\ (kWh)$$

$$T_{avg} = average\ tariff\ of\ the\ selected\ schedule\ (MNT/kWh)$$

The possible electricity cost saving is calculated by comparing the current electricity cost with the estimated cost under each TOU schedule.

Equation 13 Electricity cost saving

$$S = C_{current} - C_{schedule}$$

Where:

$$S = electricity\ cost\ saving\ (MNT)$$

$$C_{current} = electricity\ cost\ under\ current\ tariff\ (MNT)$$

$$C_{schedule} = electricity\ cost\ under\ selected\ TOU\ schedule\ (MNT)$$

The percentage saving is calculated as follows.

Equation 14 Electricity cost saving percentage

$$S_{\%} = \frac{S}{C_{current}} \times 100$$

Where:

$$S\% = electricity\ cost\ saving\ percentage\ (\%)$$

The cost analysis therefore compares three electricity cost conditions:

1. current tariff: 265 MNT/kWh;
2. TOU Schedule 1: 05:00–17:00, with an average tariff of 256.25 MNT/kWh;
3. TOU Schedule 2: 22:00–10:00, with an average tariff of 195 MNT/kWh.

The results of this comparison are presented later in Chapter 4. The comparison helps evaluate whether changing the production schedule could reduce electricity cost. However, the lowest-cost option is not automatically the best option for the factory. The final interpretation must also consider operational feasibility, especially the difficulties related to night-shift production.

3.7 Limitations of Methodology

This methodology has several limitations related to data accuracy, calculation assumptions, interview interpretation, and cost comparison.

First, although machine-level electricity meter data were available for the main production equipment, some auxiliary and support electricity uses may not be measured with the same level of detail. Loads such as office computers, printers, lighting, ventilation, and other small electrical devices may require estimation based on power rating, operating hours, or operational assumptions. Therefore, the calculated share of indirect electricity use may include some uncertainty.

Second, equipment electricity consumption may vary depending on actual operating conditions. Rated power values and operating-hour data provide a useful basis for estimation, but actual consumption can change due to machine loading, idle operation, start-up periods, maintenance condition, and production intensity. Therefore, estimated equipment-level consumption should be interpreted carefully unless it is directly supported by meter data.

Third, interview data were collected from three employees and recorded through written notes rather than audio recording. Although the participants represented management, technical, and production perspectives, their responses may include personal judgment or subjective interpretation. In addition, the interviews were conducted in Mongolian and summarized in English, so some details may have been simplified during translation and summarization.

Fourth, the time-of-use tariff comparison is based on electricity cost only. The calculation compares the current fixed tariff with two possible TOU operating schedules, but it does not include additional costs related to night operation, such as extra labor cost, transportation difficulty, worker fatigue, supervision, safety, or management requirements. Therefore, the TOU

result should be understood as an electricity-cost comparison, not a complete financial feasibility analysis.

Fifth, the proposed energy efficiency improvement strategies are not implemented and tested during the thesis period. The expected benefits are developed from data analysis, equipment information, cost comparison, and interview findings. Therefore, the results represent estimated improvement opportunities rather than verified post-implementation savings.

Despite these methodological limitations, the selected approach is suitable for this thesis. It combines electricity bills, production data, raw material data, machine-level electricity information, auxiliary load assessment, and interview findings. This allows the study to evaluate energy performance and develop data-driven energy efficiency improvement strategies based on the actual operating conditions of the selected chips factory.

Chapter 4 Results and Analysis

4.1 Overview of Collected Data

This chapter presents the results of the energy efficiency assessment of the selected chips factory. The analysis uses one year of data from January to December 2025. The main data include monthly production quantity, raw material input, electricity consumption, equipment-level electricity use, office/support electricity use, electricity cost, TOU tariff scenarios, and interview findings.

The purpose of this chapter is to understand how electricity is used in the factory and how energy performance changes across different production months. Since production volume changes during the year, total electricity consumption alone is not enough to evaluate energy efficiency. Therefore, this chapter also uses production-based indicators such as electricity consumption per package and electricity cost per package.

Table 7 Overview of data used for Chapter 4 analysis

Data category	Data used in analysis	Purpose in Chapter 4
Production data	Monthly chips production quantity	To compare electricity use with output
Raw material data	Monthly raw material input in kg	To understand production input and output relationship
Electricity data	Monthly electricity consumption and cost	To analyze electricity demand and cost
Equipment data	Equipment groups and machine-level electricity use	To identify major electricity-consuming processes

Office/support data	Office equipment, office lights, small support loads	To assess indirect/support electricity use
TOU tariff data	Current tariff and two TOU scenarios	To compare electricity cost under different schedules
Interview data	Answers from three factory employees	To explain operational reasons behind the data
Data category	Data used in analysis	Purpose in Chapter 4

4.2 Monthly Production and Raw Material Analysis

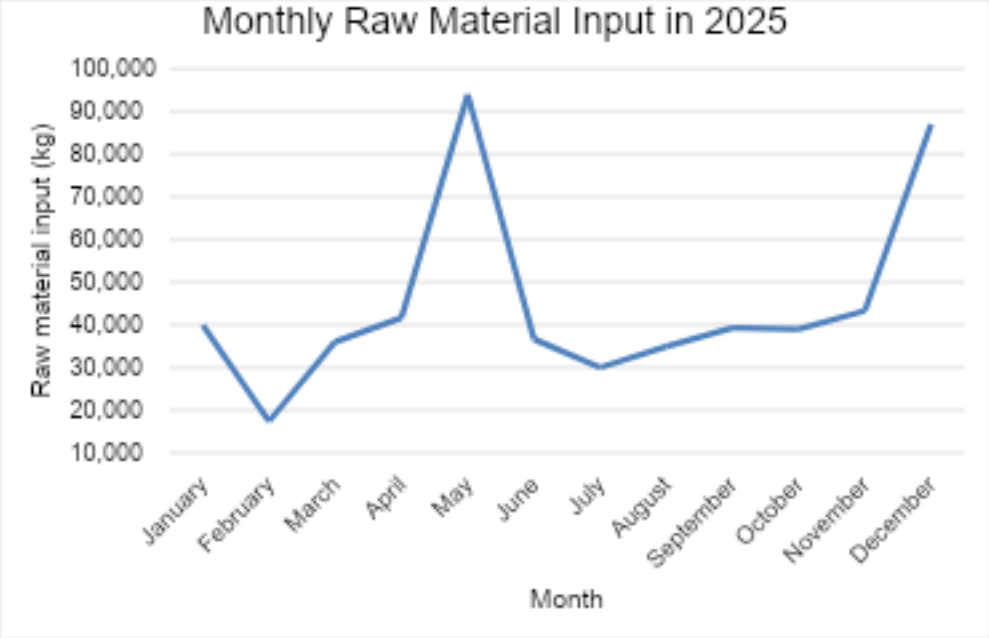
The selected chips factory produced 15,497,000 packages in 2025. The total raw material input was 539,027 kg. Production was not constant throughout the year. May and December were the peak production months, while February had the lowest production quantity.

May had the highest production, with 2,700,000 packages, followed by December, with 2,500,000 packages. These two months reflect peak demand and longer operating hours. February had the lowest production, with only 500,000 packages. The detailed monthly production quantity and raw material input values used in this analysis are shown in Appendix B.

Figure 9 Monthly chips production quantity in 2025



Figure 10 Monthly raw material input in 2025



Figures 9 and 10 show the same general pattern: raw material input increases when production quantity increases. This confirms that electricity use in later sections must be interpreted together with production output.

4.3 Monthly Electricity Consumption Analysis

The factory consumed 894,392.43 kWh of electricity in 2025. This value represents factory electricity consumption used for production-area equipment and factory-related systems. Office/support electricity is analyzed separately in Section 4.6.

The highest electricity consumption occurred in May and December, which were also the highest production months. The lowest electricity consumption occurred in February, which also had the lowest production quantity. The detailed monthly electricity consumption values used in this section are presented in Appendix C.

Figure 11 Monthly electricity consumption in 2025

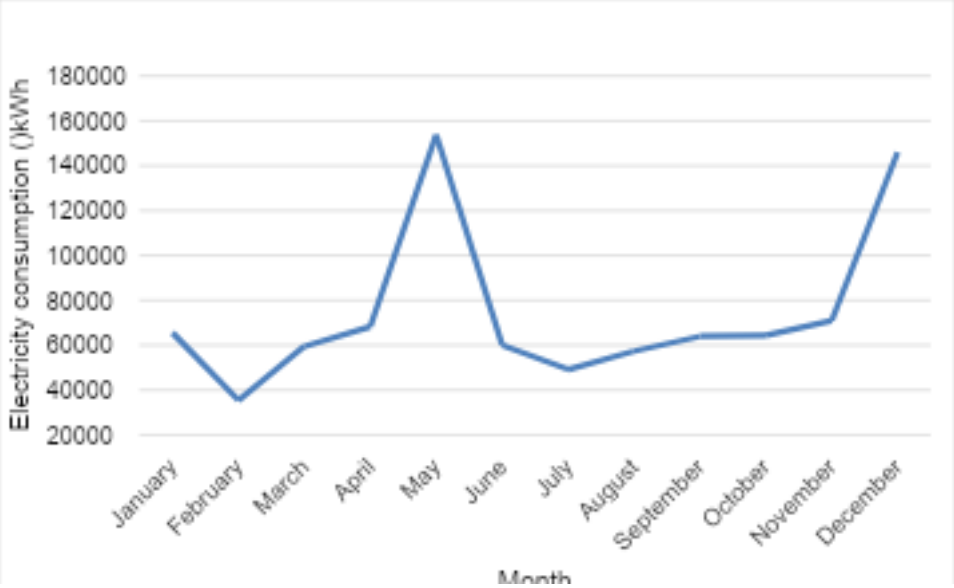


Figure 11 shows clear peaks in May and December. This is mainly because the factory operates longer during peak months, sometimes up to 24 hours per day using a 12-hour/12-hour shift system.

However, high electricity consumption does not automatically mean poor energy efficiency. May and December used the most electricity, but they also produced the most packages. For this reason, the next section analyzes energy intensity per package.

4.4 Energy Intensity Analysis: kWh per Package

Energy intensity was calculated using Equation 3.2 in Section 3.5.2. This indicator shows how much electricity was used to produce one package of chips.

Table 8 Monthly energy intensity of the selected chips factory in 2025

Month	Electricity consumption, kWh	Production quantity, packages	Energy intensity, kWh/package	Energy intensity, Wh/package
January	65,548.78	1,149,000	0.0570	57.05
February	35,415.12	500,000	0.0708	70.83
March	59,431.38	1,036,000	0.0574	57.37
April	68,285.02	1,197,000	0.0570	57.05
May	153,669.34	2,700,000	0.0569	56.91
June	60,076.79	1,053,000	0.0571	57.05

July	49,171.62	862,000	0.0570	57.04
August	57,341.64	1,005,000	0.0571	57.06
September	63,914.69	1,130,000	0.0566	56.56
October	64,447.56	1,120,000	0.0575	57.54
November	71,020.31	1,245,000	0.0570	57.04
December	146,070.18	2,500,000	0.0584	58.43
Average	**—**	**—**	**0.0577**	**57.71**

The average energy intensity was 57.71 Wh/package. Most months were close to 57 Wh/package, which shows that electricity consumption generally followed production output.

February had the highest energy intensity, at 70.83 Wh/package. This happened because production was very low, while some electricity use continued even during lower output. This may include machine preparation, lighting, idle operation, ventilation, or other support loads.

The lowest energy intensity occurred in September, at 56.56 Wh/package. May also had a low value of 56.91 Wh/package, even though it had the highest total electricity consumption. This shows why energy intensity is more useful than total kWh alone.

Figure 12 Monthly energy intensity in 2025

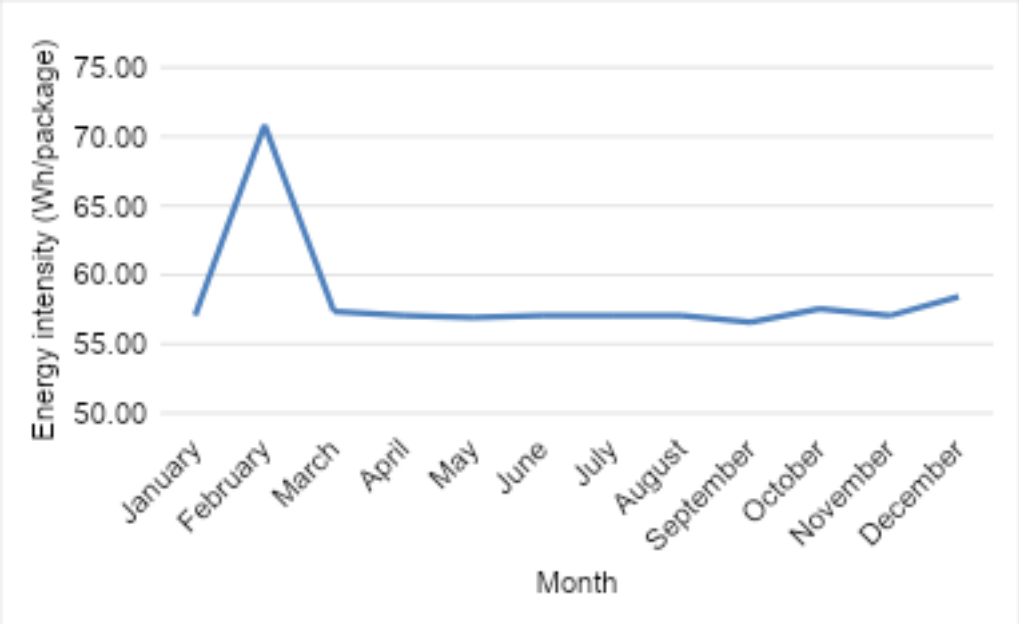


Figure 12 shows that February was clearly higher than the other months. This suggests that low-output months create a higher unit energy burden. Therefore, reducing idle operation during low-production periods is an important improvement opportunity.

4.5 Equipment-Level Electricity Consumption Analysis

This section identifies the main electricity-consuming process groups in the factory. The equipment groups follow the order used in the factory data. The compressor is included in the packaging group because it supports gas production and packaging operation.

Although seasoning is part of the general chips production process, there was no separate seasoning machine or separate seasoning electricity record in the factory data. Therefore, seasoning is not analyzed as an independent electricity-consuming process.

Table 9 Annual electricity consumption by main production equipment group in 2025

Production equipment group	Equipment included	Annual electricity consumption, kWh	Share of production equipment electricity, %
Mixing	Mill, Mixing Kettle, Automatic Preparation Section	55,699.46	6.23
Pressing / Extrusion	Press No. 1, Press No. 2, Press No. 3, Chilled Water Unit	396,803.90	44.37
Drying	Dryer No. 1, Dryer No. 2, Dryer No. 3	18,391.60	2.06
Frying	Dosing Unit / Automatic Weighing Machine, Frying Machine	216,599.02	24.22
Packaging	Compressor, Packaging No. 1, Packaging No. 2, Packaging No. 3, Nitrogen Gas Generator	206,898.46	23.13
Total	—	894,392.44	100

The largest electricity-consuming group was pressing/extrusion, with 396,803.90 kWh, or 44.37% of total equipment/process electricity use. This makes pressing/extrusion the main priority area for energy efficiency improvement.

The second-largest group was frying, with 216,599.02 kWh, or 24.22%. Since frying is directly related to product quality, improvement should focus on stable operation, maintenance, and avoiding unnecessary idle time rather than reducing necessary process energy.

The packaging group consumed 206,898.46 kWh, or 23.13%. This group includes the compressor and nitrogen gas generator, so packaging-related systems are also important for electricity control.

Table 10 Annual electricity consumption by production equipment group in 2025

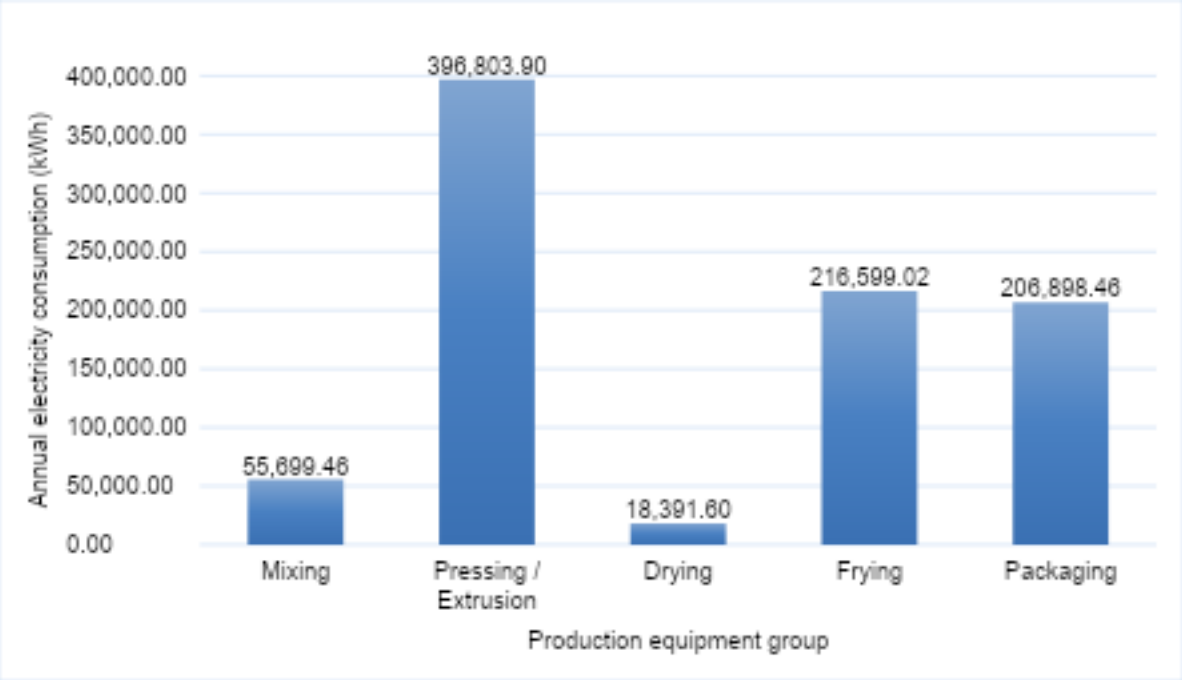


Figure 10 shows that electricity use is concentrated mainly in pressing/extrusion, frying, and packaging. Together, these three groups consumed:

$$396,803.90 + 216,599.02 + 206,898.46 = 820,301.38\ kWh/year$$

This represents 91.72% of total factory equipment/process electricity use. Therefore, Chapter 5 should focus mainly on these three areas.

4.6 Direct and Indirect Electricity Use Analysis

This section separates electricity use into direct factory electricity and indirect/support electricity. To avoid double counting, direct factory electricity refers to production-area electricity, while office/support electricity is added separately from the office electricity calculation.

Direct factory electricity includes production equipment, compressor, nitrogen gas generator, packaging systems, and factory LED lighting. Factory LED lighting is included in direct use because it is part of the factory TOU calculation. Indirect/support electricity includes office computers, monitors, printer/scanner, router, office air conditioner, office LED lights, exhaust fan, security camera, smoke detectors, refrigerator, coffee machine, microwave oven, and water dispenser.

The office/support cost is calculated using the fixed tariff of 265 MNT/kWh. TOU tariff is not applied to office/support electricity because the TOU schedule is considered only for factory production operation.

Table 11 Monthly office/support electricity consumption and cost in 2025

Month	Office/support electricity consumption, kWh	Office/support electricity cost, MNT
January	1,609.90	426,623.50
February	1,257.90	333,343.50
March	1,593.00	422,145.00
April	1,626.60	431,049.00
May	2,095.90	555,413.50
June	1,643.40	435,501.00
July	1,660.20	439,953.00
August	1,677.20	444,458.00
September	1,609.90	426,623.50
October	1,576.40	417,746.00
November	1,593.00	422,145.00
December	2,179.60	577,594.00
Total	20,123.00	5,332,595.00

Office/support electricity use was 20,123 kWh/year, with an annual cost of 5,332,595 MNT. December and May had the highest office/support electricity use. February had the lowest value.

Table 12 Direct and indirect electricity use in 2025

Electricity use category	Included loads	Annual electricity consumption, kWh	Annual electricity cost, MNT	Share of total electricity use, %
Direct factory electricity use	Production equipment, compressor, nitrogen gas generator, factory LED lighting, and other factory production-related loads	894,392.44	237,013,496.60	97.8
Indirect/support electricity use	Office computers, monitors, printer/scanner, router, office air conditioner, office LED lights, exhaust fan, security camera, smoke detectors, refrigerator, coffee	20,123.00	5,332,595.00	2.2

	machine, microwave oven, water dispenser			
Total	—	914,515.44	242,346,091.60	100

Direct factory electricity represents 97.80% of total electricity use, while office/support electricity represents 2.20%. This shows that the main saving potential is in production-area equipment and operation. However, office/support electricity still costs more than 5.3 million MNT/year, so simple actions such as turning off office equipment, controlling office air conditioning, and reducing unnecessary lighting use should also be considered.

4.7 Electricity Cost Analysis

This section analyzes factory electricity cost under the current fixed tariff of 265 MNT/kWh. Office/support electricity cost was already analyzed in Section 4.6, so this section focuses only on factory production-area electricity.

Table 13 Monthly electricity cost and electricity cost per package in 2025

Month	Electricity consumption, kWh	Production quantity, packages	Monthly electricity cost, MNT	Electricity cost per package, MNT/package
January	65,548.78	1,149,000	17,370,426.70	15.12
February	35,415.12	500,000	9,385,006.80	18.77
March	59,431.38	1,036,000	15,749,315.70	15.2
April	68,285.02	1,197,000	18,095,530.30	15.12
May	153,669.34	2,700,000	40,722,375.10	15.08
June	60,076.79	1,053,000	15,920,349.35	15.12
July	49,171.62	862,000	13,030,479.30	15.12
August	57,341.64	1,005,000	15,195,534.60	15.12
September	63,914.69	1,130,000	16,937,392.85	14.99
October	64,447.56	1,120,000	17,078,603.40	15.25
November	71,020.31	1,245,000	18,820,382.15	15.12
December	146,070.18	2,500,000	38,708,597.70	15.48
Total / Average	894,392.43	15,497,000	237,013,993.95	15.29

The annual factory electricity cost under the current tariff was 237,014,099.95 MNT. May had the highest monthly electricity cost, followed by December. This is expected because these were the peak production months.

February had the lowest total electricity cost, but it had the highest electricity cost per package at 18.77 MNT/package. This happened because production volume was low, so the electricity cost was divided across fewer packages.

Figure 13 Monthly electricity cost under the current fixed tariff in 2025

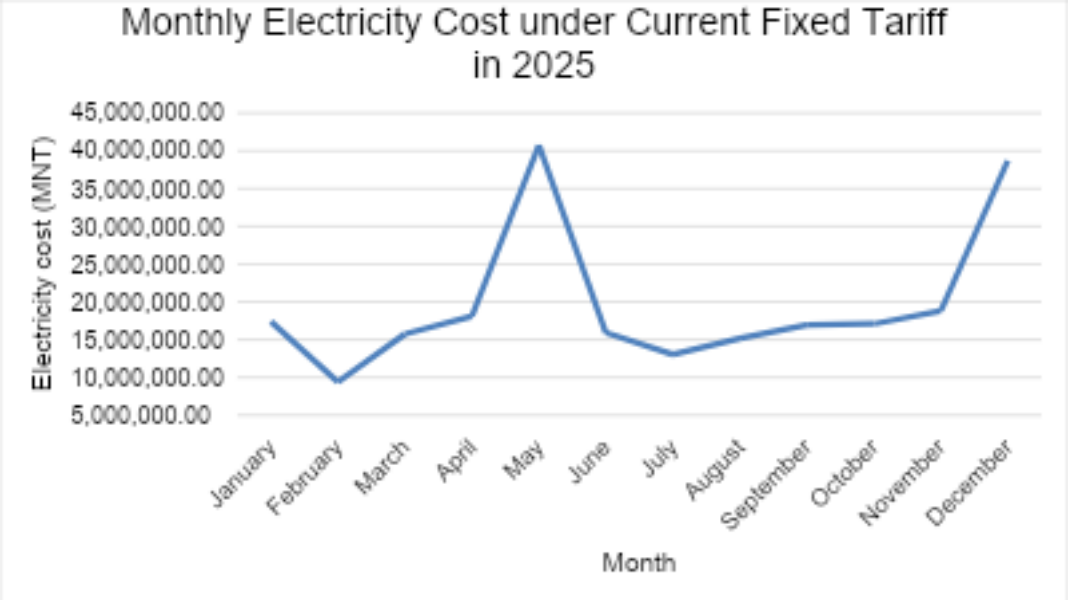
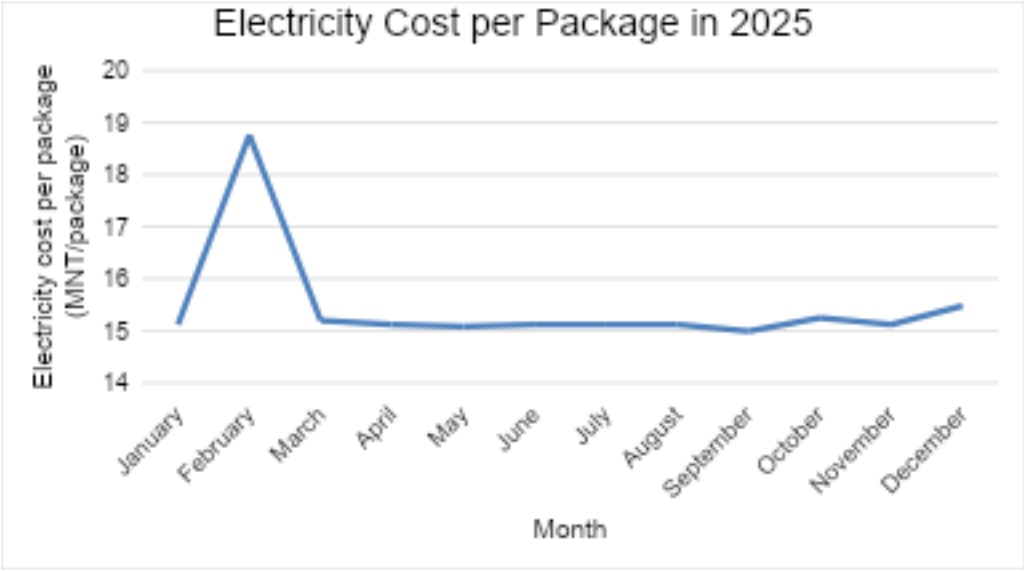


Figure 14 Electricity cost per package in 2025



Figures 13 and 14 show two different points. May and December had the highest total electricity cost, but February had the highest cost per package. This confirms that unit cost is more useful than total cost when evaluating energy performance.

4.8 TOU Tariff Scenario Comparison

This section compares the current fixed tariff with two time-of-use tariff scenarios. The calculation follows the method explained in Section 3.6. Only factory electricity consumption is included because TOU scheduling is considered for production operation, not office/support electricity.

Table 14 Tariff scenarios used for TOU comparison

Scenario	Working time	Tariff composition	Average tariff, MNT/kWh	Interpretation
Current fixed tariff	Existing condition	Fixed tariff	265	Current operating condition
TOU Scenario 1	05:00–17:00	1 hour night + 11 hours day	256.25	More feasible TOU option
TOU Scenario 2	22:00–10:00	8 hours night + 4 hours day	195	Lowest-cost TOU option

Scenario 1 is more realistic because it avoids the expensive evening tariff and remains close to daytime work. Scenario 2 gives the lowest electricity cost, but it requires more night work and may create problems related to workers, transport, supervision, and safety.

Table 15 Monthly electricity cost comparison under current tariff and TOU scenarios in

Month	Current tariff cost, MNT	TOU Scenario 1 cost, MNT	Saving under Scenario 1, MNT	TOU Scenario 2 cost, MNT	Saving under Scenario 2, MNT
January	17,370,426.70	16,796,874.88	573,551.83	12,782,012.10	4,588,414.60
February	9,385,006.80	9,075,124.50	309,882.30	6,905,948.40	2,479,058.40
March	15,749,315.70	15,229,291.13	520,024.58	11,589,119.10	4,160,196.60
April	18,095,530.30	17,498,036.38	597,493.93	13,315,578.90	4,779,951.40
May	40,722,375.10	39,377,768.38	1,344,606.73	29,965,521.30	10,756,853.80
June	15,920,349.35	15,394,677.44	525,671.91	11,714,974.05	4,205,375.30
July	13,030,479.30	12,600,227.63	430,251.68	9,588,465.90	3,442,013.40
August	15,195,534.60	14,693,795.25	501,739.35	11,181,619.80	4,013,914.80

September	16,937,392.85	16,378,139.31	559,253.54	12,463,364.55	4,474,028.30
October	17,078,603.40	16,514,687.25	563,916.15	12,567,274.20	4,511,329.20
November	18,820,382.15	18,198,954.44	621,427.71	13,848,960.45	4,971,421.70
December	38,708,597.70	37,430,483.63	1,278,114.08	28,483,685.10	10,224,912.60
Total	237,014,099.95	229,188,162.69	7,825,937.26	174,406,601.85	62,607,498.10

Under Scenario 1, annual electricity cost would decrease from 237,014,099.95 MNT to 229,188,162.69 MNT. The annual saving would be:

$$\frac{7{,}825{,}937.26}{237{,}014{,}099.95} \times 100 = 3.30\%$$

Under Scenario 2, annual electricity cost would decrease to 174,406,601.85 MNT. The annual saving would be:

$$\frac{62{,}607{,}498.10}{237{,}014{,}099.95} \times 100 = 26.42\%$$

Table 16 Annual summary of electricity cost under current tariff and TOU scenarios

Scenario	Annual electricity cost, MNT	Saving compared with current tariff, MNT	Saving, %	Average cost per package, MNT/package
Current fixed tariff	237,014,099.95	—	—	15.29
TOU Scenario 1 (05:00–17:00)	229,188,162.69	7,825,937.26	3.3	14.79
TOU Scenario 2 (22:00–10:00)	174,406,601.85	62,607,498.10	26.42	11.25

The TOU comparison shows that changing the operating schedule can reduce electricity cost even if total electricity consumption does not change. Scenario 2 provides the largest saving, but it is not automatically the best option because it depends heavily on night work. Scenario 1 gives smaller savings, but it is more practical for short-term implementation because it avoids the expensive evening period without fully shifting production to night.

Figure 15 Monthly electricity cost comparison under current tariff and TOU scenarios in 2025

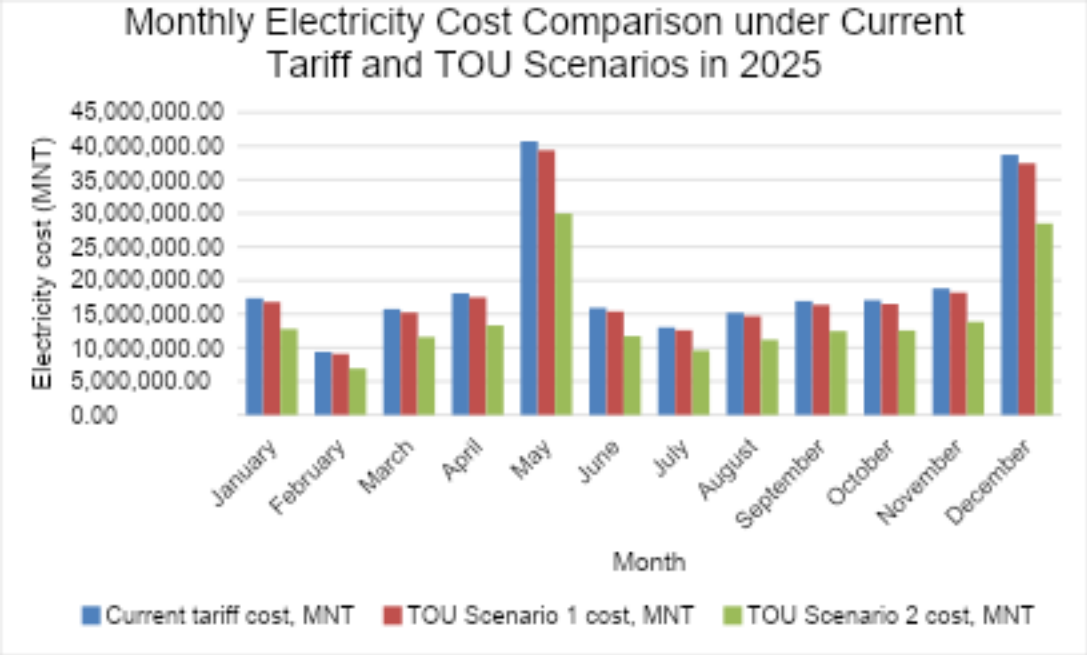
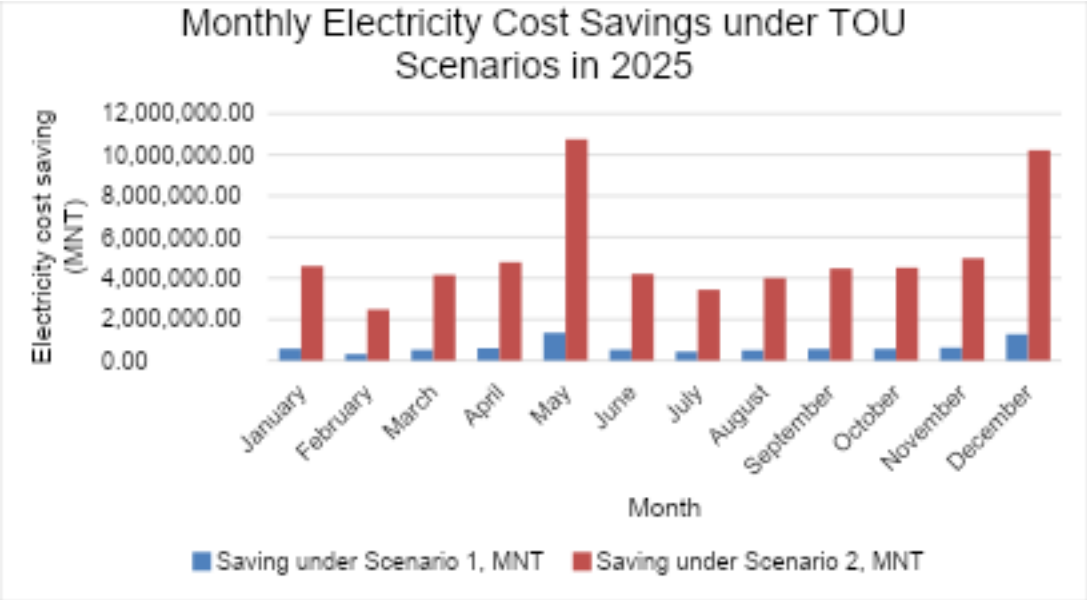


Figure 16 Monthly electricity cost savings under TOU scenarios in 2025



Figures 15 and 16 show that the largest savings occur in May and December because these months have the highest electricity use. From an electricity-cost perspective, Scenario 2 is the best. From an operational perspective, Scenario 1 is more realistic.

4.9 Interview Findings

This section summarizes the main findings from interviews with three employees: the factory/production manager, the chief engineer/maintenance engineer, and one production worker/shift leader. The interviews were note-based and summarized in English, so the findings are presented as themes rather than direct quotations.

All three participants mentioned that electricity cost has become more important, especially during peak production months. They also explained that production pressure often receives more attention than electricity saving, especially when the factory needs to meet output targets.

A common issue was unnecessary machine runtime. Machines, conveyors, lights, or auxiliary equipment may continue operating during short breaks, waiting time, cleaning, or process delays. These delays may come from raw material preparation, machine adjustment, packaging material delays, or imbalance between production stages.

Maintenance was another repeated issue. The chief engineer explained that regular checks are done, but some maintenance is still reactive. This means machines are often repaired after problems appear. The manager and production worker also confirmed that machine problems can cause delays and electricity waste.

The interviews also showed that monitoring should be improved. The manager and chief engineer both mentioned that more detailed electricity measurement would help identify the main consumers more accurately. The chief engineer especially recommended measuring major equipment separately for a period of time.

Regarding the TOU tariff, all participants saw possible benefits, but they also mentioned practical difficulties. The manager noted possible labor and management problems. The engineer suggested that avoiding the expensive evening period may be more realistic than moving all production to night. The production worker mentioned fatigue, rest time, and transportation concerns.

Table 17 Summary of interview findings

Theme	Main interview finding	Relevance to energy efficiency
Electricity cost	Electricity cost is more noticeable during peak production months	Supports cost and TOU analysis
Monitoring	More detailed machine-level measurement is needed	Supports sub-metering and energy monitoring
Idle operation	Machines, conveyors, and lights may run during waiting time	Indicates opportunity to reduce unnecessary electricity use
Maintenance	Some maintenance is reactive	Preventive maintenance may reduce delays

		and inefficient operation
Scheduling	TOU may reduce cost, but night work is difficult	Supports feasible schedule selection
Employee practices	Workers need clearer rules and checklists	Supports simple operational control

Overall, the interviews support the quantitative results. The main issues are limited monitoring, idle operation, reactive maintenance, manual control of equipment, and difficulty in changing working schedules. These findings show that the factory's energy efficiency problems are not only technical. They are also related to planning, maintenance, employee habits, and management decisions.

4.10 Chapter Summary

The results of Chapter 4 show that the factory's energy performance depends not only on how much it produces, but also on how effectively equipment is used, how production is scheduled, and how indirect electricity loads are managed. The analysis suggests that inefficiencies are associated with changes in production intensity and the non-optimized use of support systems. These findings provide the basis for the improvement strategies presented in Chapter 5.

Chapter 5 Energy Efficiency Improvement Strategies

5.1 Basis for Developing Improvement Strategies

The strategies in this chapter are based on the results presented in Chapter 4 and the literature reviewed in Chapter 2. The aim is to recommend actions that are realistic for the selected chips factory and suitable for an SME operating under practical technical and financial limits.

The results of Chapter 4 showed that the main electricity use is concentrated in pressing/extrusion, frying, and packaging. The analysis also showed that energy performance becomes weaker in low-output months, which suggests that idle operation and operational control are important issues. In addition, the TOU tariff comparison showed that production scheduling can reduce electricity cost, while the interviews highlighted limited monitoring, reactive maintenance, and difficulty in changing work schedules.

For these reasons, the improvement strategies in this chapter focus on four main areas: energy monitoring and operational control, maintenance-based improvement, TOU-based production scheduling, and prioritization of recommended actions.

5.2 Energy Monitoring and Operational Control

The strategies in this chapter are based on the results presented in Chapter 4 and the literature reviewed in Chapter 2. The aim is to recommend actions that are realistic for the selected chips factory and suitable for an SME operating under practical technical and financial limits.

The results of Chapter 4 showed that the main electricity use is concentrated in pressing/extrusion, frying, and packaging. The analysis also showed that energy performance becomes weaker in low-output months, which suggests that idle operation and operational control are important issues. In addition, the TOU tariff comparison showed that production scheduling can reduce electricity cost, while the interviews highlighted limited monitoring, reactive maintenance, and difficulty in changing work schedules.

For these reasons, the improvement strategies in this chapter focus on four main areas: energy monitoring and operational control, maintenance-based improvement, TOU-based production scheduling, and prioritization of recommended actions.

Table 18 Suggested monitoring and operational control actions

Area	Recommended action	Responsible person	Frequency	Expected benefit
Pressing / extrusion	Record electricity use and operating hours	Chief engineer / shift leader	Weekly or monthly	Identify high use and idle time
Frying	Record operating hours, waiting time, and issues	Chief engineer	Weekly	Reduce unnecessary runtime
Packaging	Monitor packaging machines, compressor, and nitrogen system	Chief engineer / operator	Weekly	Improve control of packaging-related electricity use
Production line	Turn off conveyors during long waiting periods	Shift leader / workers	Daily	Reduce idle electricity consumption
Lighting	Turn off unused factory and office lights	Shift leader / office staff	Daily	Reduce unnecessary support electricity use
Office/support loads	Use switch-off checklist for computers, printer, AC, and small devices	Office staff	Daily	Reduce indirect electricity cost
Overall performance	Review kWh/package and cost/package	Manager / chief engineer	Monthly	Track energy performance

This strategy is important because it creates the basis for all later improvement actions. Without monitoring, the factory cannot know whether maintenance or scheduling changes actually improve energy performance. Exact savings from monitoring and operational control are not calculated in this thesis because the strategy was not implemented. Actual savings should be measured later by comparing energy intensity before and after applying the monitoring system

and checklist. This finding is consistent with SME energy efficiency literature, which emphasizes operational practices and scheduling as key determinants of performance.

5.3 Maintenance-Based Energy Improvement Strategy

Maintenance-based energy improvement is recommended for the selected chips factory because it focuses on improving the condition and operation of existing equipment. This is more realistic than replacing machines, especially for an SME with limited resources. Energy efficiency in SMEs can be improved through operational and maintenance-based actions, not only through new technologies.

The results in Chapter 4 showed that pressing/extrusion, frying, and packaging are the main electricity-consuming groups. Together, these groups accounted for 91.72% of total factory equipment/process electricity use. Therefore, maintenance should first focus on these areas.

For pressing/extrusion, the main focus should be the press machines and the chilled water unit. This group consumed 396,803.90 kWh/year, or 44.37% of total factory equipment/process electricity use. The factory should regularly check whether the press machines and cooling system are operating normally and whether technical problems are increasing operating time.

For frying, the focus should be stable fryer operation and reduced waiting time. Frying consumed 216,599.02 kWh/year, or 24.22%. Since frying is directly related to product quality, the aim should not be to reduce necessary process energy. Instead, maintenance should help keep the process stable and avoid unnecessary runtime caused by technical problems or delays.

For packaging, maintenance should focus on the packaging machines, compressor, and nitrogen gas generator. This group consumed 206,898.46 kWh/year, or 23.13%. Because the compressor supports gas production and packaging operation, poor control or technical problems in this system can increase electricity use without increasing useful output.

The interviews also support this strategy. The chief engineer explained that regular checks are done, but some maintenance is still reactive. The production worker also mentioned that machine problems can slow down production while some equipment remains on. This can increase electricity use per package because electricity is consumed even when useful output is delayed.

The factory should gradually move from reactive maintenance to preventive maintenance. This does not require a complex system at the beginning. A simple weekly or monthly checklist for the main equipment groups would already help.

Table 19 Suggested maintenance-based energy improvement actions

Equipment/process group	Main equipment to check	Recommended maintenance action	Expected energy-related benefit
Pressing / extrusion	Press machines and chilled water unit	Check operating condition, cooling performance, abnormal operation, and unnecessary runtime	Lower risk of extended operation and inefficient cooling
Frying	Frying machine and dosing/automatic weighing unit	Check stable operation, cleaning condition, and waiting time	More stable operation and reduced idle electricity use
Packaging	Packaging machines, compressor, nitrogen gas generator	Check compressor operation, gas system, machine condition, and possible air/gas leaks	Reduced unnecessary packaging-related electricity use
Production line	Main process equipment	Record technical delays and repeated problems	Helps identify causes of energy waste
Shift operation	End-of-shift equipment condition	Add maintenance items to shift checklist	Prevents equipment from being left running unnecessarily

Exact savings from maintenance are not calculated in this thesis. To calculate actual savings, the factory would need to measure energy performance before and after applying the maintenance checklist. For example, the factory could compare monthly energy intensity before and after preventive maintenance is introduced. Since this thesis does not implement the strategy, the expected benefit is discussed qualitatively. This finding is consistent with SME energy efficiency literature, which emphasizes operational practices, maintenance quality, and scheduling as key determinants of performance.

5.4 TOU Tariff and Production Scheduling Strategy

The TOU tariff and production scheduling strategy is recommended mainly as a cost-reduction strategy. It does not directly reduce total electricity consumption. Instead, it reduces electricity cost by shifting production to lower-tariff hours where possible.

In Chapter 4, two TOU scenarios were compared with the current fixed tariff. The first scenario was 05:00–17:00, which includes 1 hour of night tariff and 11 hours of day tariff. The second scenario was 22:00–10:00, which includes 8 hours of night tariff and 4 hours of day tariff.

The 05:00–17:00 schedule is recommended as the main short-term option. Under this scenario, the estimated annual electricity cost saving is approximately 7.83 million MNT/year, or 3.30% compared with the current fixed tariff. The saving is smaller than the night-shift option, but it is more realistic because it avoids the expensive evening tariff period and remains close to a daytime working schedule.

The 22:00–10:00 schedule gives the largest electricity-cost saving. Under this scenario, the estimated annual saving is approximately 62.61 million MNT/year, or 26.42%. However, it is not recommended as the first option because it depends heavily on night work. The interviews showed that night operation may create problems related to worker fatigue, transportation, supervision, safety, labor rules, and management control. Therefore, this option should be treated as a long-term or special-case option. While cost savings are possible, implementation depends on labor constraints, operational flexibility, and potential increases in indirect costs.

A practical requirement for TOU application is a compatible smart electricity meter. Based on available market information, a 380V, three-phase, 100A HPLC smart meter is a suitable preliminary option for this thesis because it is designed for three-phase electricity use and remote reading. One listed price is approximately 704,000 MNT. Another similar 380V, three-phase, 100A HPLC smart meter is listed at 679,000 MNT and can calculate electricity under up to 8 tariffs, which is relevant to TOU tariff application.

However, the final meter selection should be confirmed by the electricity distribution company or a licensed electrician. The factory's actual maximum current and connection type may require a CT-connected meter instead of a direct 100A meter. Therefore, the meter price should be treated as an estimated implementation cost, not a final confirmed installation cost.

Compared with the estimated saving of 7.83 million MNT/year under the feasible 05:00–17:00 scenario, the smart meter cost of about 679,000–704,000 MNT appears reasonable. However, installation cost, approval cost, wiring changes, and possible service fees are not included. Therefore, this should be understood as a simple cost indication, not a complete payback analysis.

Table 20 TOU tariff strategy and practical interpretation

Option	Working time	Estimated annual saving	Practical interpretation
Current fixed tariff	Existing condition	—	No schedule change required
TOU Scenario 1	05:00–17:00	7.83 million MNT/year	Recommended short-term option because it is more feasible
TOU Scenario 2	22:00–10:00	62.61 million MNT/year	Lowest-cost option, but difficult because of night-work issues
Smart meter requirement	3-phase TOU-compatible meter	Estimated meter cost: 679,000–704,000 MNT	Required for TOU application, but final type must be confirmed

The factory should test the TOU schedule before applying it for the full year. May and December are suitable test periods because they have the highest electricity consumption and the largest possible savings. During the test period, the factory should compare electricity cost, production output, worker availability, and operational problems.

The recommended steps are to confirm TOU requirements with the electricity provider, confirm the correct smart meter type, test the 05:00–17:00 schedule during selected days or peak months, compare the results, and then decide whether the schedule can be used regularly. The 22:00–10:00 option should only be considered if night-shift operation can be managed safely and legally.

5.5 Prioritization of Recommended Strategies

This section prioritizes the recommended strategies based on Chapter 4 findings, interview results, expected impact, implementation cost, and practical difficulty. Since most strategies were not implemented during the thesis period, their expected impact is evaluated qualitatively.

Table 21 Prioritization of recommended energy efficiency improvement strategies

Priority	Strategy	Main action	Expected impact	Implementation cost	Difficulty	Reason for priority
1	Energy monitoring and operational control	Monitor major equipment groups, use simple Excel tracking, apply checklists, reduce idle operation	High	Low–Medium	Low–Medium	Foundation for all other strategies
2	TOU tariff and production scheduling	Test the 05:00–17:00 schedule and confirm suitable smart meter	Medium–High	Medium	Medium	Gives clear cost-saving potential but needs approval and testing
3	Maintenance-based energy improvement	Improve preventive checks for pressing/extrusion, frying, packaging, compressor, and nitrogen system	Medium	Low–Medium	Medium	Targets the highest electricity-consuming equipment groups
4	Office/support electricity-saving practices	Turn off office equipment, office lights, AC, and small devices when not needed	Low	Low	Low	Small share, but easy to apply

The first priority is energy monitoring and operational control. Without basic monitoring, the factory cannot confirm whether later actions actually improve energy performance. This strategy is also low-cost and directly addresses the problems of limited monitoring and idle operation.

The second priority is the TOU tariff and production scheduling strategy. It has a clear calculated saving, especially under the 05:00–17:00 schedule. However, it requires smart meter confirmation, possible approval from the electricity provider, and schedule testing.

The third priority is maintenance-based energy improvement. This strategy targets the highest electricity-consuming process groups and can support more stable operation. However, exact savings can only be confirmed after before-and-after measurement.

The fourth priority is office/support electricity-saving practices. Office/support electricity represented only 2.20% of total electricity use, so the expected impact is smaller. However, it still cost approximately 5.33 million MNT/year, and many actions are simple to apply.

Overall, the recommended strategies should be implemented step by step. The factory should begin with monitoring and operational control, then test the TOU schedule, strengthen preventive maintenance, and apply simple office/support electricity-saving rules. This order is suitable for an SME because it avoids large immediate investment and focuses first on improving visibility, control, and daily operating discipline.

These prioritized strategies show that energy efficiency improvement does not depend only on buying new equipment. For the selected chips factory, the main improvement potential is in better monitoring, better scheduling, stable maintenance, and more disciplined daily operation. The results suggest that low-cost operational improvements may provide greater immediate benefits than capital-intensive interventions, consistent with SME best practices.

Chapter 6. Conclusion

6.1 Summary of the Study

This thesis examined the energy efficiency of a selected chips factory in Mongolia using a case study approach. The analysis was based on factory data from January to December 2025, including production quantity, raw material input, electricity consumption, equipment-level electricity use, office/support electricity use, and interviews with three employees.

The study was carried out to understand how electricity was used in the factory, where the main inefficiencies appeared, and which improvement strategies would be realistic for this SME case. To do this, the thesis analyzed monthly electricity consumption, energy intensity per package, equipment-level electricity use, electricity cost, and the possible effect of TOU tariff scheduling.

6.2 Main Findings

The analysis showed that the selected chips factory produced 15,497,000 packages in 2025 and consumed 894,392.43 kWh of production-area electricity during the same period. The average energy intensity was 57.71 Wh/package. Electricity use generally followed production volume, with the highest values in May and December, which were also the peak production months.

At the same time, the results showed that lower production months can have weaker energy performance. February had the highest energy intensity, at 70.83 Wh/package, even though it had the lowest total electricity consumption. This suggests that some electricity use continued even when output was low.

The equipment-level analysis showed that electricity use was concentrated mainly in pressing/extrusion, frying, and packaging. Together, these three groups accounted for 91.72% of total factory equipment/process electricity use. This means that the main improvement potential is in these areas, not equally across all equipment.

The TOU tariff comparison showed that changing the production schedule could reduce electricity cost. The 05:00–17:00 schedule was the more realistic short-term option, with an estimated saving of about 7.83 million MNT per year. The 22:00–10:00 schedule gave much larger savings, but it was less practical because of night-shift issues.

The interviews supported these findings. The main problems mentioned by employees were limited monitoring, idle machine operation, reactive maintenance, manual control of lights and equipment, and difficulty in changing working schedules.

6.2 Contribution of the Study

This study contributes by demonstrating how production-based energy indicators can be applied in a real SME context to generate practical energy efficiency improvements. In particular, the study shows how electricity consumption data can be linked with production output and operational information to provide a more meaningful assessment of energy performance than total electricity use alone. It also contributes a practical case from Mongolia, where case-based studies on energy efficiency in small manufacturing enterprises remain limited. In this way, the thesis provides both an analytical approach and practical recommendations that may be useful for similar SMEs facing cost pressure, limited monitoring systems, and operational constraints.

6.3 Limitations of the Study

The reliance on estimated equipment-level data and the single-case design limit generalizability. Some equipment-level electricity values were based on rated power and operating hours where direct measurements were unavailable, which may introduce minor uncertainty into the analysis. In addition, the study focuses on one chips factory only, so the findings should be interpreted as context-specific rather than representative of all SMEs in Mongolia. The analysis also focused mainly on electricity use and did not include a full evaluation of thermal energy use or long-term implementation results. Therefore, the conclusions of this study should be understood as a practical case-based assessment rather than a universally generalizable model.

6.3 Final Recommendations

Based on these findings, the factory should first improve energy monitoring and operational control, especially for pressing/extrusion, frying, and packaging. Second, it should strengthen preventive maintenance for the main electricity-consuming equipment. Third, it should test the 05:00–17:00 TOU schedule during selected production periods to see whether it is workable in practice. Finally, it should also apply simple office and support electricity-saving actions, even though their share of total electricity use is smaller.

Overall, the findings suggest that the factory does not need to begin with large equipment investment. More immediate improvement can come from better monitoring, better maintenance, better scheduling, and more careful daily operation.

Reference List

Appendices:

Appendix A: Interview Questions

1. What are the main stages of the chips production process in the factory?
2. Which machines or processes do you think consume the most electricity?
3. Are there any machines that operate even when production is stopped or not fully active?
4. How is equipment maintenance usually carried out in the factory?
5. What problems most commonly affect production efficiency or energy use?
6. Does the factory monitor electricity consumption by machine or only through the monthly electricity bill?
7. Are lighting, office equipment, compressors, or other support systems switched off when they are not needed?
8. What changes do you think could reduce unnecessary electricity use in the factory?
9. Would it be possible to adjust the production schedule to reduce electricity cost, for example by using lower-tariff hours?
10. What energy efficiency improvement strategies do you think would be realistic for this factory?

Appendix B: Monthly production quantity and raw material input in 2025

Month	**Production quantity, packages**	**Raw material input, kg**

January	1,149,000	39,965
February	500,000	17,391
March	1,036,000	36,035
April	1,197,000	41,635
May	2,700,000	93,913
June	1,053,000	36,626
July	862,000	29,983
August	1,005,000	34,957
September	1,130,000	39,304
October	1,120,000	38,957
November	1,245,000	43,304
December	2,500,000	86,957
Total	15,497,000	539,027

Appendix C: Monthly electricity consumption of the selected chips factory in 2025

Month	Electricity consumption (kWh)
January	65548.78
February	35415.12
March	59431.38
April	68285.02
May	153669.34
June	60076.79
July	49171.62
August	57341.64
September	63914.69
October	64447.56
November	71020.31
December	146070.18
Total	894392.43