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Assessment of Energy Use Patterns and Sustainable Interventions in a Commercial Broiler Hatchery in Luzon Using Energy Audit and ISO 50001-Based Evaluation

GIRON RODIEL[1], JONATHAN DOCOT.[2], MICHAEL JOHN VILLAR, Ph.D.[3], LORINDA PASCUAL, Ph.D.[4]

[12] Graduate Student, Master of Engineering Management, Nueva Ecija University of Science and Technology, Cabanatuan City, Nueva Ecija, Philippines, [2]Associate Professor V, Engineering Management Department, Nueva Ecija University of Science and Technology,
[4]Chair, Graduate School Mathematics Department, Nueva Ecija University of Science and Technology,

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***Abstract*:** Commercial broiler hatcheries are among the most energy-intensive facilities in the poultry production chain due to continuous operation and stringent environmental control requirements. This study assessed energy consumption patterns in a commercial broiler hatchery in Luzon using a combined energy audit and ISO 50001–based energy management evaluation over a 30-day monitoring period. Data were collected through sub-metering, equipment inspection, electricity billing analysis, and structured operational observations. Findings indicate that incubation systems accounted for 33.1% (42,000 kWh/month) of total energy consumption, followed by hatcher machines (24.5%) and HVAC and ventilation systems (22.1%), confirming that environmental control processes dominate energy demand. Identified inefficiencies included outdated equipment, inadequate insulation, and absence of system-level energy monitoring. The study proposes sustainable interventions such as high-efficiency incubators, LED lighting, improved insulation, solar photovoltaic systems, and ISO 50001-aligned energy management practices. These interventions are projected to reduce total energy consumption by 15–30%, resulting in significant cost savings and reduced environmental impact. The findings provide a practical basis for improving energy efficiency and sustainability in commercial hatchery operations in the Philippine context.

***Indexed Terms*:** Broiler Hatchery, Energy Audit, Energy Efficiency, HVAC Systems, Poultry Industry, Renewable Energy, Sustainable Energy

I. INTRODUCTION

1.1 Background of the Study

The poultry industry plays a critical role in global food security and economic development by providing a reliable and affordable source of animal protein [1]. Within the broiler production system, commercial hatcheries serve as the foundational link, converting fertile eggs into healthy day-old chicks through carefully controlled biological and mechanical processes [2]. These facilities operate on a continuous, 24-hour production cycle and rely heavily on energy-intensive incubation and hatching technologies that require precise regulation of temperature, humidity, ventilation, and lighting to achieve optimal hatchability and chick quality.

Energy consumption in commercial broiler hatcheries represents a substantial portion of overall production costs and is a significant contributor to operational greenhouse gas emissions. This challenge is particularly pronounced in developing and emerging economies, where hatchery operations remain largely dependent on conventional grid-based energy sources, often characterized by rising tariffs and supply instability. Moreover, the limited adoption of energy-efficient technologies and the absence of structured energy management systems further exacerbate operational inefficiencies and sustainability concerns [3].

While numerous studies have examined energy use in poultry grow-out and processing facilities [4], there remains a notable lack of empirical, system-level analyses focusing specifically on energy consumption patterns and energy management practices in commercial broiler hatcheries in the Philippine context [5]. In particular, limited empirical studies exist on the distribution of energy use among major hatchery systems and the effectiveness of current energy management practices in Philippine commercial broiler hatcheries. This gap constrains the ability of hatchery operators, energy planners, and policymakers to make informed, data-driven decisions aimed at improving energy efficiency and sustainability.

The present study systematically assesses energy use patterns in selected commercial broiler hatcheries in the Luzon Region, identifies major energy-consuming systems and operational inefficiencies, and proposes sustainable energy interventions to enhance operational efficiency, reduce environmental impacts, and support the long-term economic and ecological resilience of hatchery operations.

1.2 Objective of the Study

General Objective:

To assess and quantify energy use patterns (in kWh/month and percentage share) in a commercial broiler hatchery and evaluate energy management practices to identify sustainable interventions for improving energy efficiency and operational performance.
Specific Objectives:
1. To identify and quantify major energy-consuming systems in terms of kWh/month and percentage share.
2. To analyze energy use patterns, including base load and peak demand, and identify operational inefficiencies.
3. To assess existing energy management practices using an ISO 50001-based evaluation framework.
4. To propose technically feasible and economically viable sustainable energy interventions.

1.3 Significance of the Study

This study provides valuable insights for hatchery operation managers, poultry integrators/investors, and energy planners by highlighting areas of high energy demand and potential efficiency improvements. It supports decision-making for cost reduction, sustainability compliance, and modernization of hatchery facilities. Academically, it contributes to limited literature on energy management within poultry hatcheries and supports further research on sustainable agricultural energy systems.

II. METHODOLOGY

2.1 Research Design

A descriptive-analytical research design was employed to systematically evaluate energy consumption patterns without altering operational conditions. This design is appropriate for energy audit studies, as it allows accurate characterization of real-world energy use and identification of inefficiencies.

2.2 Population and Sample of the Study

The population of the study consisted of commercial broiler hatcheries operating within the Luzon Region of the Philippines. These facilities are typically characterized by continuous, large-scale incubation and hatching operations, mechanized environmental control systems, and heavy reliance on grid-based electrical energy to maintain optimal conditions for embryo development and chick quality.
The study utilized a purposive sampling technique, selecting a single commercial broiler hatchery as the study sample. This hatchery operates at a commercial production capacity of approximately 500,000 day-old chicks (DOCs) per production cycle, representing a medium-to-large scale hatchery operation typical of the Luzon poultry industry. The name and exact location of the hatchery were deliberately withheld to preserve confidentiality and comply with management and ethical research considerations.

The basis for selection of the broiler hatchery included the following criteria:

1. The hatchery operates on a continuous, commercial-scale production system with high-capacity incubation and hatching units.
2. The facility utilizes electrically powered incubation, hatching, ventilation, lighting, and environmental control systems, making it suitable for detailed energy assessment.
3. The hatchery maintains complete and accessible energy-related records, including electricity billing data and equipment specifications.
4. The operation is representative of typical commercial broiler hatchery practices in the Luzon Region in terms of scale, technology, and operational processes.
5. Energy consumption data were collected from key operational systems, including incubators or setter machines, hatcher machines, HVAC and ventilation systems, lighting, and auxiliary equipment. Although the study focused on a single hatchery, the selected facility's scale and operational characteristics allowed for an in-depth and representative analysis of energy use patterns and management practices relevant to commercial broiler hatcheries in the region.

2.3 Research Instruments & Monitoring

The study employed a combination of technical measurement instruments and management-focused assessment tools to comprehensively evaluate both energy consumption patterns and energy management practices in commercial broiler hatchery operations.

Category	Instrument / Tool	Purpose and Application
Measurement Tools	Digital Energy Meters and Sub-meters	Directly measure total and system-specific electrical energy consumption (kWh) across major hatchery systems.
	Temperature and Humidity Data Loggers	Continuously monitor environmental conditions in incubation, hatching, and service areas that influence hatchability and energy demand.
Estimation Tools	Equipment Nameplate Ratings	Provide rated power, voltage, and capacity data used to estimate system-level energy demand when direct measurement is unavailable.
	Operating Hour Logs	Record actual daily and weekly operating hours of major hatchery equipment to support accurate energy load estimation.
	Modeled System Load Calculations	Estimate monthly energy consumption using rated equipment power combined with actual operating time.
	Electricity Billing Records	Validate measured and estimated energy consumption and analyze historical electricity use and cost trends.
Management Assessment Tools	Energy Audit Checklist	Systematically evaluate energy-consuming equipment, operational efficiency, maintenance practices, and compliance with energy efficiency principles.
	Observation and Operational Records	Document routine operational practices, equipment usage behavior, and system management during normal hatchery operations.
	Energy Policy and Management Survey Checklist	Assess the existence of energy policies, performance targets, documentation practices, assigned responsibilities, and management commitment.
	ISO 50001–Based Energy Management Evaluation Tool	Evaluate hatchery energy management practices against key ISO 50001 elements, including energy planning, monitoring, review, and continuous improvement.

Table 1. Research Instruments and Monitoring Tools

Note: All instruments were verified for accuracy and calibrated prior to deployment to ensure reliability of measurements.

Monitoring and Management Assessment Approach

Continuous and periodic technical monitoring was conducted to capture daily and weekly energy consumption patterns under normal operating conditions. In parallel, energy management practices were assessed using structured survey checklists and an ISO 50001–based evaluation framework to determine the level of institutionalization of energy efficiency within the hatchery [6]. This dual approach ensured that both physical energy performance and organizational energy management maturity were systematically evaluated.

2.4 Data Collection Procedure

Data for the study were collected using **a** multi-method approach that combined on-site energy audits, detailed equipment inspections, analysis of historical electricity billing records, and direct observation of day-to-day hatchery operations. This approach enabled a comprehensive assessment of electrical energy utilization across critical hatchery systems under normal operating conditions, without interfering with routine production activities.

Energy monitoring instruments were strategically installed in key energy-intensive areas, including incubation rooms, hatching units, HVAC and ventilation systems, lighting circuits, and auxiliary service areas. These locations were selected to capture both process-related and support-system energy demands within the hatchery.

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Energy consumption and environmental data were collected continuously over a 30-day monitoring period, covering at least **one** complete incubation–hatching cycle. Measurements were recorded at hourly intervals, allowing the study to capture variations in operational load associated with different production stages, equipment loading conditions, and daily and weekly operating schedules. This monitoring resolution ensured accurate representation of fluctuations in energy demand during incubation, hatching, and support activities.

The selected monitoring duration provided sufficient data to reliably characterize baseline energy use patterns while minimizing disruption to regular hatchery operations. This ensured that the collected data were both valid and representative of typical commercial broiler hatchery energy performance.

2.5 Statistical Treatment

The collected data were analyzed using descriptive statistical methods to systematically characterize energy consumption patterns within the hatchery facility. These methods included frequency distributions, measures of central tendency (primarily mean values), percentage share analysis, and graphical representations to clearly illustrate the distribution and relative contribution of energy use across major hatchery systems.

In addition to descriptive statistics, the study employed several energy-specific analytical techniques to strengthen interpretation and support decision-oriented findings. These included:

1. Energy Intensity Analysis, expressed as kilowatt-hours per day-old chick (kWh/DOC) produced, to evaluate the efficiency of energy use relative to production output.
2. Percentage Share Distribution, used to quantify the proportional contribution of each hatchery system (e.g., incubation, hatching, HVAC, lighting, and auxiliary services) to total electrical energy consumption.
3. Load Pattern Analysis, distinguishing between base load and peak demand periods, to assess daily and cyclical variations in energy use and identify opportunities for load optimization.

Comparative analysis was conducted to evaluate differences in energy consumption among major operational systems and across distinct operational phases, including incubation, hatching, and auxiliary support activities. This analytical framework enabled the identification of dominant energy loads, operational inefficiencies, and critical periods of high demand, providing a basis for recommending targeted energy efficiency and sustainability interventions.

III. RESULTS AND DISCUSSION

The findings revealed that energy consumption in the commercial broiler hatchery is predominantly concentrated in environmental control systems, with incubators (33.1%), hatchers (24.5%), and HVAC systems (22.1%) accounting for 79.7% of total electricity use. This confirms that hatchery operations are inherently energy-intensive due to the strict environmental requirements necessary for embryo development. Supporting this finding, Okonkwo et al. [7] emphasized that artificial incubation systems rely heavily on continuous energy input, particularly for heat generation and environmental regulation, making them one of the most energy-demanding processes in poultry production.

The observed energy use pattern shows a continuous base load with peak demand occurring during simultaneous setter–hatcher operations. This reflects the biological constraint that incubation processes require uninterrupted environmental stability. Similarly, Cheepati and Balal [8] highlighted that maintaining stable temperature conditions in poultry incubators requires continuous operation of cooling and heating systems, further reinforcing the high and constant energy demand of such facilities.

Operational inefficiencies identified in the study—including outdated incubation equipment, lack of preventive maintenance, inadequate insulation, and continuous non-zoned lighting—were found to significantly increase energy consumption. These inefficiencies result in higher thermal losses and increased HVAC load. Ferreira et al. [9] demonstrated that poorly optimized environmental control systems in poultry facilities lead to increased energy consumption due to inefficiencies in maintaining thermal stability and airflow distribution.

In terms of energy management practices, the study revealed the absence of formal energy policies, lack of system-level monitoring, and reliance on monthly electricity billing data. This indicates a reactive rather than performance-based approach to energy management. This finding is strongly supported by the study of Pascual et al. [10], which demonstrated that implementing energy monitoring and forecasting techniques significantly improves energy management efficiency by enabling better load prediction, reducing wastage, and supporting data-driven decision-making in institutional energy systems.

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Furthermore, the hatchery's reliance on grid electricity without renewable energy integration increases vulnerability to rising energy costs and supply instability [11]. Okonkwo et al. (2024) also noted that dependence on grid electricity in poultry incubation systems poses challenges, particularly in regions with unstable energy supply, highlighting the need for alternative energy solutions such as solar power.

The proposed interventions including high-efficiency incubators, LED lighting systems, improved insulation, solar photovoltaic systems, and ISO 50001-aligned energy management are therefore both technically and practically justified. Cheepati and Balal [8] demonstrated that integrating energy-efficient and renewable-based systems in incubators significantly improves energy performance while reducing operational costs.

The results imply that energy inefficiencies in commercial broiler hatcheries are primarily due to technical, infrastructural, and managerial limitations rather than the production process itself**.** From a technical perspective, prioritizing improvements in incubators, hatchers, and HVAC systems can yield the highest energy savings. Operationally, implementing preventive maintenance and upgrading outdated equipment can significantly reduce unnecessary energy losses.

From a management standpoint, the absence of structured energy monitoring systems highlights the need for adopting data-driven energy management frameworks, as supported by Pascual et al. [10]. Economically, the integration of energy-efficient technologies and renewable energy sources can reduce operating costs and mitigate risks associated with fluctuating electricity prices. Environmentally, these interventions contribute to reduced carbon emissions and improved sustainability performance.

System	Energy Consumption (kWh/month)	Percentage (%)
Incubators (Setter Machine)	42,000	33.1
Hatcher Machine	31,000	24.5
HVAC & Ventilation	28,000	22.1
Lighting	9,500	7.5
Auxiliary Equipment	11,500	9.1
Total	122,000	100

Table 2. Monthly Energy Consumption by System (Illustrative Data)
Source: Computed from field data (2026)

Aspect	**Summary of Findings**
Objective	To identify and quantify the major energy-consuming systems in the hatchery
Key Systems Identified	Incubators (setter machines), hatcher machines, HVAC and ventilation, lighting, auxiliary equipment
Dominant Energy Consumer	Incubators accounted for the highest energy use at 33.1% (42,000 kWh/month)
Supporting Observation	Environmental control systems (incubation, hatching, HVAC) collectively represented 79.7% of total electricity consumption
Interpretation	Hatchery energy demand is primarily driven by biological and environmental control requirements

Table 3. Major Energy-Consuming Systems

Aspect	**Summary of Findings**
Objective	To analyze energy use patterns and identify operational inefficiencies
Energy Use Pattern	Continuous base load with peak demand occurring during full setter–hatcher operation
Identified Inefficiencies	Outdated incubation equipment, lack of preventive maintenance, inadequate room insulation, non-zoned continuous lighting
Operational Impact	Increased electricity demand and reduced system efficiency
Interpretation	Energy inefficiencies are primarily operational and equipment-related rather than process-related

Table 4. Energy Use Patterns and Operational Inefficiencies

International Journal of Engineering, Management and Humanities (IJEMH)
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Aspect	Summary of Findings
Objective	To assess existing energy management and conservation practices
Energy Policy Status	No formal energy policy or documented energy performance targets
Monitoring Practices	Reliance on monthly electricity bills; absence of system-level sub-metering
Management Approach	Reactive and cost-driven rather than performance-based
Interpretation	Lack of structured energy management limits the hatchery's ability to optimize energy performance

Table 5. Energy Management and Conservation Practices

Aspect	Summary of Findings
Objective	To propose sustainable energy interventions suitable for commercial hatchery operations
Recommended Interventions	High-efficiency incubators, LED lighting, improved insulation, rooftop solar PV, ISO 50001-aligned energy management
Expected Benefits	Reduced electricity consumption, lower operating costs, decreased carbon emissions
Technical Feasibility	Interventions are compatible with existing hatchery operations
Interpretation	Sustainable energy solutions are both technically viable and economically beneficial for hatchery systems

Table 6. Sustainable Energy Interventions

IV. SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

4.1 SUMMARY

The results indicate that incubation and hatching systems consume approximately 57.6% of total energy, consistent with documented hatchery benchmarks [2]. HVAC systems represent a significant load due to temperature and humidity control demands. Lighting, while a smaller fraction, operates continuously and presents opportunities for efficiency gains through LED retrofitting.
The absence of sub-metering and automated energy monitoring limits commercial broiler hatchery's ability to detect inefficiencies and optimize operational scheduling.

4.2 CONCLUSION

Commercial broiler hatcheries are highly energy-intensive, with energy demand dominated by environmental control systems. Addressing the top three energy-consuming systems which are incubators, hatchers, and HVAC offers the greatest potential for efficiency improvements.
The study demonstrates that implementing energy-efficient technologies and structured energy management practices can achieve estimated energy savings of 15–30%, leading to reduced costs and improved sustainability [12].

4.3 RECOMMENDATION

The recommendations presented in this section are directly derived from the specific problems and inefficiencies identified in the energy assessment results. Each recommendation is mapped to a corresponding operational or management issue observed during the study to ensure practical relevance and evidence-based applicability [13].

Identified Problem	Recommendation	Description	Expected Outcome
Lack of system-level energy visibility and performance tracking	**Energy Audits and Monitoring**	Conduct annual professional energy audits supported by sub-metering and periodic or continuous energy monitoring systems	Improved visibility of system-specific energy use, early detection of inefficiencies, and informed energy management decisions
High energy consumption due to outdated	**Equipment Modernization**	Replace legacy incubators, hatchers, and associated equipment with modern energy-efficient technologies	Reduced electricity consumption, improved system reliability, and

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incubation and hatching equipment			enhanced hatchery performance
Heavy reliance on grid electricity and exposure to rising energy costs	**Renewable Energy Adoption**	Integrate renewable energy solutions, particularly rooftop solar photovoltaic systems, to supplement grid electricity supply	Lower electricity costs, reduced dependence on grid power, and decreased carbon emissions
Energy inefficiencies linked to operational practices and limited staff awareness	**Personnel Training**	Implement regular training programs on energy-efficient operation, maintenance, monitoring, and leadership-based accountability practices, since effective leadership and employee engagement have been shown to improve operational performance in broiler hatchery businesses [14]	Sustained energy efficiency improvements and improved staff awareness and accountability
Energy efficiency not integrated into facility planning and expansion	**Energy-Efficient Planning**	Incorporate energy efficiency considerations into hatchery expansion and modernization plans	Long-term cost savings and improved sustainability of hatchery facilities

Table 7. Problem–Solution–Outcome Framework for Energy Efficiency Improvement

Proposed Sustainable Energy Interventions

The following technical interventions are recommended to directly address the major energy consumption sources and inefficiencies identified in the study.

Identified Problem	**Intervention**	**Technical Description**	**Energy Efficiency Benefit**
High energy demand from incubation systems (33.1% of total consumption)	High-Efficiency Incubators	Replacement of legacy incubators with modern units featuring improved insulation, optimized airflow, and intelligent control systems	Significant reduction in electricity demand and improved thermal efficiency
Continuous lighting load due to 24-hour operation	LED Lighting Systems	Installation of energy-efficient LED fixtures to replace conventional lighting	Lower power consumption, reduced heat load, and longer lighting service life
Excessive HVAC loads caused by thermal losses	Improved Insulation and Sealing	Enhancement of building envelope performance in incubation and hatching rooms	Reduced heat losses and lower HVAC energy requirements
High dependence on grid electricity	Rooftop Solar Photovoltaic Systems	Installation of grid-tied or hybrid solar PV systems on available roof areas	Offset of grid electricity use and reduction in operating energy costs
Absence of structured energy management practices	ISO 50001–Aligned Energy Management System	Implementation of formal energy management procedures consistent with ISO 50001 standards	Continuous improvement in energy performance and institutionalized energy accountability

Table 8. Problem-Oriented Sustainable Energy Interventions for Broiler Hatcheries

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