Tran Le Phong; Nguyen Dat Minh

Article

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Integration of Lean Methodology and Energy Management in Wooden Industry

Tran Le Phong[1], Nguyen Dat Minh[2]*

[1]University of Economics-Technology for Industries, Vietnam, [2]Electric Power University, Hanoi, Vietnam.
*Email: minhndm@epu.edu.vn

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ABSTRACT

The application of Lean thinking to energy management is the methodology based on the application of the Lean values and the principles of wastes elimination of Lean system. One is then challenging and questioning why a process is using the amount of energy that it does and why it is using energy during non-production hours. One strives to continuously improve and reduce the energy used by implementing improvement ideas. Todays, the pressure of competition in the energy sector is very high. A enterprise that wants to make a difference should continuously run optimization from the production lines. The objective of this study is to measure the impact of Lean tools on energy consumption and energy efficiency improvement. Through a case study, authors point out changes in production and energy efficiency before and after implementing improvement (Kaizen) projects. Besides, this paper illustrate the framework of Lean tools application into energy sector as a guideline for energy efficiency management in industrial enterprises.

Keywords: Energy Saving, Energy Efficiency, Lean Production, Industrial Enterprise, Wooden Industry
JEL Classifications: E23, L23, L6, M11, Q01, Q4

1. INTRODUCTION

Lean term firstly known in 1990 by Womack and Jones in the book "The Machine That Changed The World" when they were talking about the success of Toyota with the Toyota Production System (TPS) which is developed in the 1950s (Pascal, 2015; Womack et al., 1990). The most significant theory of Lean is the non-value-added perspective via eliminating wastes, operational enhancement, and continuous improvement (Dey et al., 2019; Ohno, 1988; Saini and Singh, 2020). The strength of Lean is reduce manufacturing cost through elimination all types of waste and guide a company to become a world-class organization. In reality, Lean is now being applied widely in various areas to optimize cost, reduce waste and irrationalities in business operation so that the enterprise can achieve lower production costs and improve competitiveness for enterprises (Caiado et al., 2018; Fercoq et al., 2013). Lean has played an important role in enterprises in terms of improving the processes and increasing customers' satisfaction and organizational performance (Salah et al., 2010). Besides, Lean principles and tools are believed to contribute to sustainable achievement in its economic dimension by reducing resources and cost within enterprises' operation, social dimension through enhancing working environment conditions for employees, and finally environmental dimension by reducing eliminating wastes and pollution (Caiado et al., 2018).

The energy sector and energy efficiency (EE), which is one of the pillars of national strategy to improve economic competitiveness and sustainability of the economy. The increase in energy consumption depending on the increase of the world population and innovative technological developments require closer attention to the changes in energy sources (Apak et al., 2012). Energy management will contribute to protecting the environment by using less energy or at least improve EE and hence combat climate change by reducing CO_2 emissions (Thollander, 2020). The environmental improvement factor is a particularly strong factor due to the urgency to reduce global warming and high awareness in the public and hence also among the employees. This high awareness among employees can be important when communicating about the energy management initiative and in trying to get improvement suggestions coming in (Mkhaimer et al., 2017). EE is the core dimensions of the energy union, next to energy security, solidarity and trust; the internal energy market; decarbonization of the economy; and research, innovation and competitiveness. Co-benefits of energy efficiency like the reduction of emissions, enhanced competitiveness, health and economic benefits can be significantly higher than the cost of production measures (Zhang et al., 2016).

Energy-saving is a key element to achieve decarbonization at a global level. Indeed, existing evidence suggests that strong energy efficiency policies are key to attaining the 1.5°C objective and reducing energy and climate mitigation costs as increased energy efficiency can provide up to 50% of the emission reduction required to meet the objectives of the Paris Agreement (Allen et al., 2019). Within the framework of the Paris Agreement, different countries commit to reducing emissions in this area through the objectives and actions collected in their Nationally Determined Contributions (Labandeira et al., 2020). During the last three decades, many countries have introduced policies to reduce energy demand and improve energy efficiency (Bertoldi and Mosconi, 2020). However, achieve large savings can be very difficult as the actual implementation of energy efficiency actions has been consistently below the optimal level (Labandeira et al., 2020; Linares and Labandeira, 2010).

In recent decades, Vietnam has been one of the active and fastest growing economics in the region and the world. Economic growth is still a high priority by the government of Vietnam, however governmental strategies emphasize that fast development has to go side by side with sustainable development. The energy sector plays a significant role in promoting economy development. Economic growth requires secure and affordable supply of energy to all of the society participants and economic sectors. At the same time, in order to be sustainable, the energy sector must be able to attract the capital required to expand infrastructure, securing the needed supply of energy sources in the long term, and reducing negative environmental impacts as well as controlling green-house gas emissions (Danish Energy Agency, 2017; Hoang, 2021).

Thus, the purpose of this paper is to review the Lean concepts, principles, and tools that are integrated into the energy management goals of enterprises. Additionally, Lean practices result of the previous research will be shown as pieces of evidence to indicate the positive influences of Lean application on the sustainable improvement of enterprises.

2. VIETNAM'S ENERGY EFFICIENCY TARGET

Vietnam government has strengthened the policy framework on EE improvement of various end-users in the economy. A number of legal documents covering the planning and implementation of EE policy and the program has been approved and enforced by the government. In this regard, the Vietnam government has also strengthened the institution for EE improvement by creating a special agency named Energy Efficiency and Conservation Office (EE&CO) under the Ministry of Industry and Trade (MOIT). This agency is tasked to formulate, develop and implement EE&C policies and programs. As the part of EE improvement strategy, the government of Vietnam developed and launched a comprehensive national EE&C program called the Vietnam National Energy Efficiency Program (VNEEP). The VNEEP layouts EE programs for the period 2006-2015, which was approved and enforced on 14 April 2006 by the Prime Minister - Decision No.79/2006/QD-TTG (The Government of Vietnam, 2006) (Minh, 2021).

The national program on EE&C is an important target of the national energy development strategy, which the Ministry of Industry and Trade (MoIT) was assigned by the Government to develop. So far, the industry and trade sector has made concerted efforts to adopt many energy-saving solutions, with initial positive results.

The energy security and sustainable have always been one of the top concerns of the Vietnamese Government, and the MoIT is tasked with administering sufficient energy supplies for the country, EE&C is one of the most effective solutions to reduce pressure in the exploitation, processing and supplies of different kinds of energies. It also helps preserve national energy resources, protect the environment and reduce greenhouse gas emissions, contributing to mitigating the impacts of global climate change.

The Vietnam National Energy Efficiency Program (VNEEP) was approved in 13th March 2019 in Decision No. 280/2019/QD-TTg by the Prime Minister to set up the energy efficiency goals as well as activities, and outcomes for period 2019-2025 and 2026-2030 (Prime Minister of Vietnam, 2019). In accordance with the VNEEP program, all city/provincial governments have been developing their own action plans of EE to achieve the goals of 5%-7% of energy consumption. Through case study, the main purpose of this study is to develop the action plan of EE implementation (EEAP) at provincial level of Vietnam. Besides, the energy consumption in the industrial sector accounts for more than 47% of the country's total energy consumption. Therefore, the potential for energy saving in the industrial sector in Vietnam is estimated at 20-30%, even up to 40* in some industries.

In summary, the purpose of this study is to introduce the application of Lean in the industrial energy consumption sector to contribute the achievable of energy-saving by 2025, vision to 2030 of Vietnam.

3. LEAN PRODUCTION MANAGEMENT AND ITS IMPACT ON ENERGY CONSUMPTION

3.1. Lean Introduction

Lean is a combination of principles, tools, and techniques designed to deal with the root problems of ineffective activities in manufacturing. Lean aims to optimize the values of Productivity, Quality, Cost, and Ability to meet customer's requirements (Delivery) while still ensuring the safety conditions of production. As to meet these goals, Lean tries to get rid of three main sources leading to damages from the production management system: waste, volatility, and inflexibility.

One of the other goals of Lean is to use fewer resources to generate the same results. This is obviously environmentally friendly: since using fewer materials in production leads to reduced environmental impact. Besides, quality improvement reduces reusing, reconditioning, or remanufacturing, then waste is reduced and pollution costs are diminished, so the environmental benefits are obvious. Lean practices represent the Lean principles in an implementation form. There are many tools and techniques of Lean that vary from one study to another.

The basic system of tools and techniques in different levels build up "Lean house" with the foundation and pillars illustrated in Figure 1 as below.

The foundation of the Lean house includes 5Ss system, Visual management (VM), Waste/Muda elimination, Total productive maintenance (TPM), Standardized work (SW) and Continuous improvement (Kaizen). These platforms of tools and techniques play a role in creating the stability of production systems and build up the Lean culture in the entreprise (Liker, 2006; Ohno, 1988; Womack and Jones, 2003).

The first pillar of the Lean house is Just in time (JIT). JIT means producing the right item at the right time in the right quantity, anything else is wasted, it means JIT just only producing what is necessary at that time with a necessary quantity (Pascal, 2015). Therefore, all of the activities providing more or earlier than planned are considered as waste (Womack and Jones, 2003). Performing JIT in manufacturing is such an important activity to obtain the inventory reduction objection and eliminate overproduction (Achanga, 2007). The few main principles of JIT is do not supply anything unless the customer has ordered it; level demand so that work may proceed smoothly throughout the plant; link all processes to customer demand through simple visual tools; maximize the flexibility of people and machinery. Therefore, to meet JIT rules, we need to utilize tools, techniques, and principles to build up the continuous flow, synchronized production and achieve a "pull" production system. There are several tools are produced including Kanban, cell layout, takt time, leveling production, Value stream mapping (VSM), one-piece flow, SMED, etc… that illustrated in Figure 1 (Pascal, 2007; Womack and Jones, 2003).

The second pillar of the Lean house is Jidoka. The Japanese word Ji-do-ka comprises three Chinese characters. The first "Ji" refers to the worker himself, if he feels "something is wrong" he must stop the production line. "Do" refers to motion or work, and "ka" refers to the suffix or action. Therefore, taken together Jidoka has been defined by Toyota as "Automation with a human mind" and intelligent production and taking quick countermeasures (Ohno, 1988; Pascal, 2007). In this way, automation prevents low-quality products from being sent to the next steps and does not create uncommon mistakes (Pascal, 2015). The goal of Jidoka is to prevent the risk of malfunction in production or to recognize the problems before it occurs. Jidoka also helps to identify errors, to prevent and control mistakes (Liker, 2004). Implementing Jidoka ensures standard quality and also preventing faults of machines, equipment and reducing the human-related activities in the production process. Some tools performing Jidoka are error prevention system (Poka-Joke) and Work control system, production introductions (Andon).

3.2. Waste of Energy Consumption from Perspective of Lean Production

Substantial energy savings typically ride the coattails of lean. By eliminating manufacturing wastes such as unnecessary processing and transportation, business also reduce the energy needed to power equipment, lighting, and cooling." Without explicit consideration of energy wastes, however, Lean may overlook significant opportunities to improve performance and reduce costs. Energy is a vital input to most production processes and value streams. By thinking explicitly about unnecessary energy use as another "deadly waste", Lean implementers can significantly reduce costs and enhance competitiveness, while also achieving environmental performance goals. Energy wastes increase the costs of business. The energy use hidden in lean wastes is shown in Table 1.

In summary, energy waste should also be linked and controlled by the enterprises. All the enterprises management system are in tremendous pressure to increase productivity and reduce energy waste. Top managers should view energy waste as an obstacle in achieving profits, so they are encouraging to improve energy performance of their factories.

Figure 1: A simple view of main elements in the house of lean

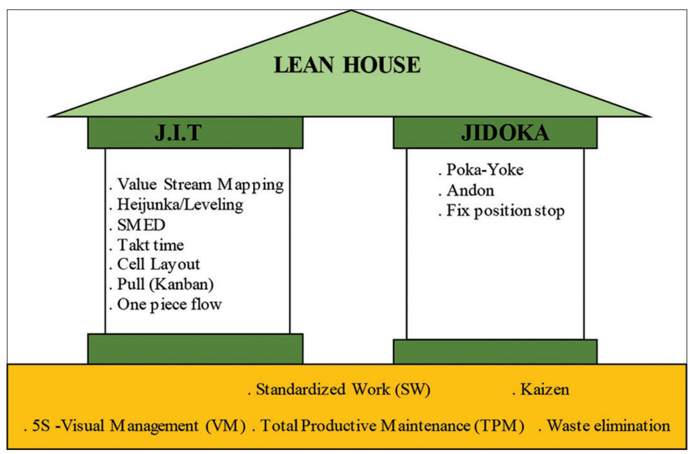


Table 1: Energy used hidden in Lean waste

Waste type	Energy use
Overproduction	Energy consumed in operating equipment to make unnecessary products
Inventory	Energy used to heat, cool, and light inventory storage and warehousing space
Transportation and Motion	More energy used for transportation and delivery More space required for work in process (WIP) movement, increasing lighting, heating, and cooling demand and energy consumption
Defects	Energy consumed for making defective products; space required for rework and repair; increasing energy use for heating, cooling, and lighting
Over processing	Energy consumed in operating equipment related to unnecessary processing
Waiting	Wasted energy from heating, cooling, and lighting during production downtime.

Source: The author conducted from (Gogula et al., 2011)

3.3. Lean Tools Application for Energy Consumption Reduction

Although, all the Lean tools are not energy saving tools, there are a great deal of lean tools, six tools that are frequently used to implement lean and can be used to greatly reduce energy consumption have be identified. These tools are: Standard Work, Visual Workplace, Error Proofing/Poka-yoke, TPM, Quick Changeover/SMED, Value stream mapping, and Right-Sized Equipment. In the following paragraphs we show how the different tools mentioned above can play a significant role in the reduction of energy consumption:

- 5S and Visualize: Visual Workplace provides visual indicators so that goals and current status of the workplace can be easily identified. These indicators can include energy usage goals, which can help workers and managers to be conscious of energy use and opportunities for energy reduction.
- Standardized work: Standard work is a set of work procedures that establish the best and most reliable method of performing a task or operation. Work procedures maintained at each work station incorporating energy reduction best practices can reduce the energy waste. For instance:
  - Building energy reduction best practices into training materials, standard work for equipment operation and maintenance.
  - Adding energy reduction practices into 5S checklists.
- Poka-yoke (Mistake-proofing): Mistake proofing refers to procedures that are used to prevent defects and processing errors. Reducing the errors or completely eliminating the errors or defective parts reduces the energy consumption per unit of good parts.
- Total Productive Maintenance (TPM): Systematic care and maintenance of the equipment increases the life of machines and reduces machining downtime. With proper equipment and system maintenance, facilities can reduce manufacturing process defects and save an estimated more than 20% in energy cost. Different strategies that can be adopted for integrating Energy-Reduction Efforts into TPM are:
  - Integrate energy reduction opportunities into autonomous maintenance activities.
  - Train employees on how to identify energy wastes and how to increase equipment efficiency through maintenance and operations.
  - Conduct energy kaizen events to make equipment more efficient.
  - Build EE best practices into systems for management of safety, health, and environmental issue.
- SMED/Quick Change-over: Quick Change-over is a procedure to reduce the setup and changeover time for a process. This tool reduces the time the line is down. It also reduces the energy used to make the changeover and provide light and heat during non-productive time.
- Value stream mapping - VSM: VSM is one way to understand the overall of energy consumption in shop floor. The information of energy consumption added into the VSM makes everyone to be able to easily understand the complete impact that the value stream has on the operational performance, energy efficiency.
- Right-Sized Equipment: It is a method that ensures that the appropriate machines and equipment are used to complete a process step. Selecting equipment that has just enough capability and speed to satisfy the flow of a production cell can provide energy savings over an outdated machine that has much more capacity than it is required.

4. METHODOLOGY

This study focuses on the potential in combining Lean principles and EE through a case study from wooden manufacturer in Vietnam. Accordingly, primary evidence was collected through multiple sources of evidence including interview of energy and production managers that followed and deployed Lean energy projects, and a participants observation by the author.

The data was collected over period of time from Jan, 2022 to June, 2022, allowing participants to have an in-depth reflection upon their experience from the projects as well as and impact of their experience on the factories. All interviewees participated with EE improvements projects in their plants. The interviews focused on the interviewees' experiences with and perceived impact of the Lean application to the EE improvement. The interview questions were structured around the following themes that also served as the foundation for data analysis: personal influence; knowledge and lessons learned… Besides, the authors also participated into Energy Audit and EE improvement (called project KZ) from Mar, 2022 to June 2022 provide insights and understanding about the problems and answer "how" and "why" Lean can success applied and achieved EE improvement in the case company. A leading manufacturer in wooden industry in Vietnam are selected to conduct this study because of high rate of energy consumption and its impacts to production total cost. The case study is the most common research approach that is generally used in Lean research. This is probably because this approach is valuable in terms of providing explanations of linkages among events, and it is suitable when a real-world event is being examined as in the case of Lean implementation for EE improvement at the empirical level.

Participation observing through joining EE improvement projects in case company to get more data and compared to interview

Table 2: Data Collection Sources and Information Gathered

Sources	Description	Information gathered
Document review	Energy audit reports; Lean implementation reports.	Data on Energy consumption and Lean operation; Data on before-after Lean/QCC implemented.
Interviews	Managers of Electromechanical department; Managers of production department; Supervisors from shop floors	General aspects of the company on EE improvement and Lean targets; Mechanism of EE projects was implemented and its results;
Observation	On site survey; Participated one Lean Energy project	How the Lean tools solved the problems occurred during the project and achieved the targets on EE improvement

results on project implementation. After receiving the interview and observe results, the authors recorded and took notes on all the related documents including EE outcomes (Table 2).

The findings are presented in the next section, starting with an individual description of the company Lean energy practices.

5. RESEARCH RESULTS

5.1. Case Study Profile

The Case company is one of the biggest wooden furniture manufacturers in the Northern of Vietnam (Called WL). WL is introducing furniture products from wood including indoor and outdoor furniture, tableware and decoration, vanity and kitchen cabinet, doors, plywood, and film-faced plywood. The yearly turnover in 2020 is more than two million US dollars from six factories and more than 3,000 employees. The company's mission is to create the best products by constant innovation and optimizing resources in a productive sustainable way.

The company has faced the pressure of cost reduction in the context of Covid-19 and force from their customers in requirement of energy use reduction for export products. Then, the KZ project is deployed in WL from Mar 2022 to June 2022 to reduce total production cost, improve production efficiency, and improve energy consumption through Lean tools implementation. This project is led by the company president and the author of this study participated as a consultant. The Thuan Hung factory is selected to implement as a model process of the project. There are 33 steps in the production line from five main processes including raw material sorting and insulation, drying and handling, machining, assembly, and finishing. The overall production process of the model line is showed in Figure 2.

5.2. Energy Consumption Situation

5.2.1. Energy management system

To evaluate the status of energy management system in Thuan Hung, the auditor team used the Energy Management Matrix EMM to consider the factors impact to energy management and verifying which factors should to be improved to achieve EE improvement. The EMM evaluation results as shown in Table 3. Currently, investment for high performance machines and equipments are received the highest points from EMM evaluation at level 4. There are also many projects are deployed for energy saving, EE improvement in recent years. However, the company does not have a clear and systematic of EE policy. Top manager has assigned a full-time energy manager to setup and operate energy management system but did not setup an organization for EE improvement. The measurement system is focused on power system only.

5.2.2. Specific energy consumption

SEC is a commonly used as EE performance indicators is the ratio between amount of energy consumption and production volume during the baseline period, which the amount of energy consumption requirement to complete a product. The purpose of SEC is to identify potential of energy improvements. This is an important tool of energy management. SEC is used as an energy performance indicator to measure the performance of EE in both literature and practices. Besides, SEC can be used indirectly to calculate the value of energy efficiency index (EEI). The deviation between the actual value of SEC and the standard value of SEC is a guide to explore the improvement chances when the best available EE practices are established (Minh et al., 2021). The unit used for the SEC in Thuan Hung factory is kWh/m3 of product as shown in formula 1.

$$SEC = \frac{Energy\ used}{Product's\ amount} \quad (1)$$

The total of energy consumption in the Thuan Hung factory in 2019 is 1,397.5 TOE; in 2020 is 1,224 TOE; 2021 is 1068 TOE. Besides, the fuel consumption from 2018 to 2020 also more than 49,000 litre per year. The average specific energy consumption (SEC) in the factory in 2021 is 21.52 kWh/m3. The detailed SEC in 2021 as shown in Figure 3.

5.2.3. Lean implementation for EE improvement results

With the aim of evaluating changes in terms of EE improvement, the evaluation criteria for WL project is carried out during the whole time of the project from the beginning to the end. The

Figure 2: Main processes of furniture production line in the KZ project

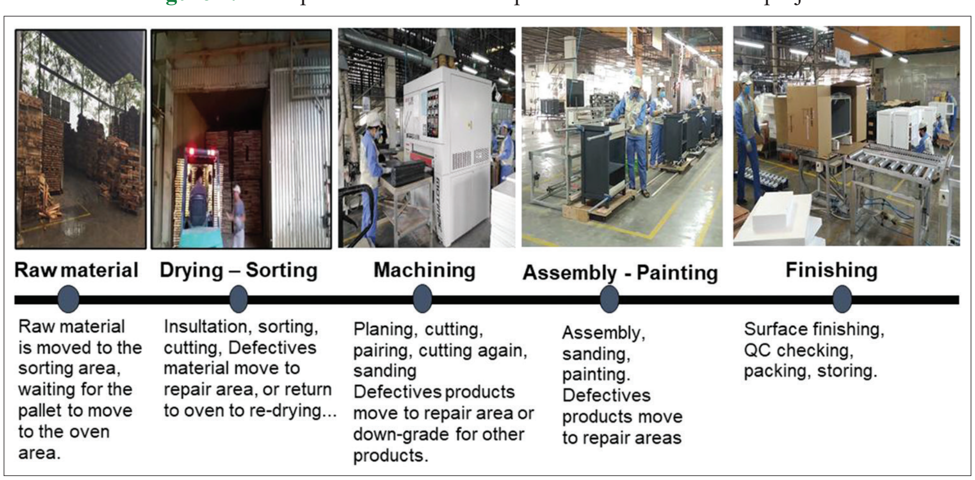
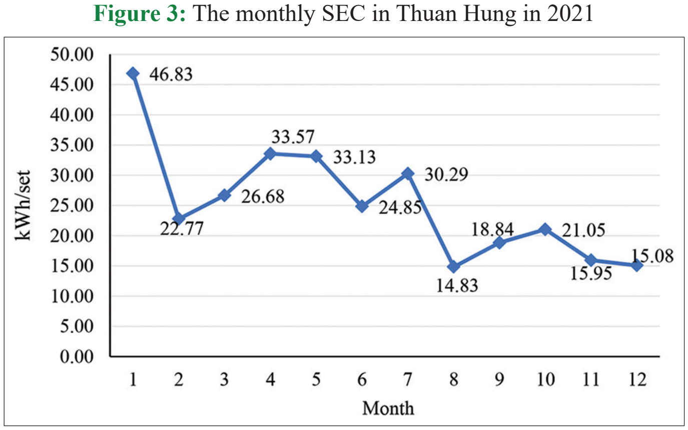


Table 3. The EMM evaluation result

Level	Energy policy	Organization	Staff Motivation	Measurement, supervision	Marketing	Investment
4	Energy policy, action plan and regular review, have commitment of top management as part of an environmental strategy	Energy / environmental management fully integrated into management structure. Clear delegation of responsibility for energy use	Formal and informal channels of communication regularly exploited by energy / environmental manager and staff at all levels	Comprehensive system sets targets, monitors materials and energy consumption and wastes and emissions, identifies faults, quantifies costs and savings and provides budget tracking	Marketing the value of material and energy efficiency and the performance of energy / environmental management both within the organisation and outside it	Positive discrimination in favour of energy / environmental saving schemes with detailed investment appraisal of all new build and plant improvement opportunities
3	Formal energy policy, but no activc commitment from top management	Energy / environmental manager accountable to energy committee, chaired by a member of the management board	Energy / environmental committee used as main channel together with direct contact with major users	Monitoring and targeting reports for individual premises based on sub-metering / monitoring, but savings not reported effectively to users	Programme of staff training, awareness and regular publicity campaigns	Same pay back criteria as for all other investments. Cursory appraisal of new build and plant improvement opportunities
2	Unadopted / informal energy / environmental policy set by energy / environmental manager or senior departmental manager	Energy / environmental manager in post, reporting to ad-hoc committee but line management and authority are unclear	Contact with major users through ad-hoc committee chaired by senior departmental manager	Monitoring and targeting reports based on supply meter / measurement data and invoices. Env. / energy staff have ad-hoc involvement in budget setting.	Some ad hoc staff awareness and training	nvestment using short term pay back criteria mostly
1	An unwritten set of guidelines	Energy / environmental management the part-time responsibility of someone with only limited influence or authority	Informal contacts between engineer and a few users	Cost reporting based on invoice data. Engineer compiles reports for internal use within technical department	Informal contacts used to promote energy efficiency and resource conservation	Only low cost measures taken
0	No explicit policy	No energy / environmental manager or any formal delegation of responsibility for env / energy use	No contact with users	No information system. No accounting for materials and energy consumption and waste	No awareness raisingof energy efficiency and resource conservation	No investment in increasing environmental performance / energy efficiency in premises

Source: Authors

Figure 3: The monthly SEC in Thuan Hung in 2021



authors attended all meetings of the improvement teams and recorded data carefully. The capability assessment results (total energy consumption, SEC, number of Kaizen was implemented).

From the findings in the kaizen implementation in three months, we can see that there are a lot of opportunities in order to decrease the production cost in general and decrease in energy consumption of the shop floor. In the case of KZ project, most of the energy wastages that are related to Lean seven wastes such as over-processing, defective or rework, machine waiting or no-load running… There are 85 Kaizen problems related to EE are identified after three months, 43 Kaizen problems were deployed. The detail of week to week Kaizen follow up as shown in Figure 4.

SW, TPM, Visualize, and Poka-yoke are the most frequency tools of Lean applied to decrease wastes of energy consumption in Thuan Hung. A systematic of job instruction for machine operating and maintenance of the equipment help increase the life-cycle of machine and reduce downtime or stop time.

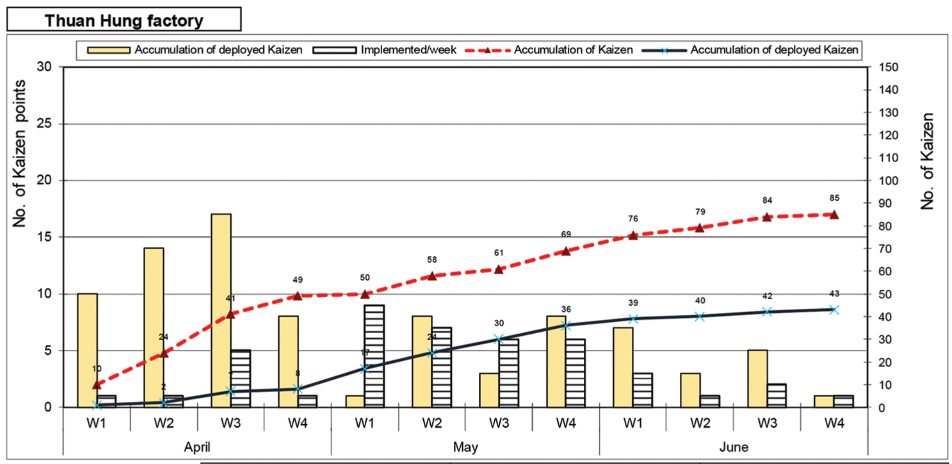
The results showed positive improvements in all of the production lines after the KZ projects ended. The staff's motivation is

Table 4: Percentage of energy reductions by applying different Lean tools for main equipments

Equipment	Quantity	Waste (problems)	Lean tool application	% energy reduction
Conveyor	144	No-load running	Visual, 5S, TPM.	14.9
Drill machine	125	Long cutting journey	SW, Poka- yoke, TPM	13.7
Vacuum machine	49	No-load running	SW, 5S, TPM	18.3
Drying oven	20	Over-heat, over-time drying	SW, right-size equipment, TPM	39.1
Cutting machine	35	No-load running, long cutting journey	SW, Poka- yoke, TPM	9
CNC machine	12	-	TMP	2
Compress machine	4	Defective	SMED, SW, Poka- yoke	3.7
Sanding machine	37	Defect, no-load running	SMED, SW, Poka- yoke	25.2

Source: The author

Figure 4: Number of Kaizen activity of KZ project



	April				May				June			
	W1	W2	W3	W4	W1	W2	W3	W4	W1	W2	W3	W4
No. of KZ/week	10	14	17	8	1	8	3	8	7	3	5	1
Implemented/week	1	1	5	1	9	7	6	6	3	1	2	1
Accumulation of Kaizen	10	24	41	49	50	58	61	69	76	79	84	85
Accumulation of deployed Kaizen	1	2	7	8	17	24	30	36	39	40	42	43

increased from level 2 to level 3, organization and energy policy evaluation are improved to level 3; measurement system for production line No.3 is increased to level 4 while line No.1 and No.2 are still keep at level 2. The OEE (Overall Equipment Effective) increase from 36% to 59% in the production line No.1, while reducing NG (not good) ratio, lead time, delivery time, and energy consumption (Table 4).

5.2.4. SEC improvement

A part of the reporting to describe the improvement of the current SEC value from the previous years. The improvement can be calculated as mentioned in fomula No.2 (Nguyen Dat Minh et al., 2021).

$$\text{Improvement} = \frac{SEC_{Previous\,Year} - SEC_{Present}}{SEC_{Previous\,Year}} \times 100 \qquad (2)$$

Thus, the average present of SEC up to Jun 2022 has measured is 18.3 kWh/m3 of wood product. Therefore, the SEC improvement is 14.9%:

$$\text{Improvement} = \frac{21.52\frac{kWh}{m3} - 18.3kWh/m3}{21.5\,kWh/m3} \times 100\% = 14.9\%$$

6. CONCLUSION

In this study, the concept of the contribution of Lean implementation in energy-saving for achieving a better performance of production systems was carried out. Lean concepts were implemented in the shop floor from the perspective of waste of energy consumption. The energy utilization in the production processes including machinery, conveyors, robots, lights… can be decreased by applied several Lean tools. The energy efficiency improvement can be increase and SEC can be also reduced (through reduce the energy consumption per part index). This study has highlighted the possibility of Lean tools implementation in the enterprises' shop floor and its impact on energy consumption through a case study. This approach can be further applied and confirmed for Vietnam industrial sector to achieve the target of energy-saving and production cost reduction. This result will provide a good guideline about EE improvement via Lean tools application. The result of this study also could be useful guideline for managers of manufacturers and enterprises in developing countries to deploy a productivity, sustainable production, and EE programs.

Although the results of this paper is valuable, this study has some limitations. This study was conducted from a single case of Lean methodology into energy sector from one is limited to generalized to other enterprises. This topic can be further improved by consider and expanse to other sectors.

7. ACKNOWLEDGEMENT

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