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ENERGY CONSERVATION AND MITIGATION USING SIX-SIGMA METHODOLOGY AT ISABELA STATE UNIVERSITY, ANGADANAN, ISABELA, PHILIPPINES

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Abstract

A proposed application of Six Sigma is through the analysis of energy management. The DMAIC method analyzes how to conserve energy. Also, Six Sigma techniques were used in this study. Load inventory was done, classifying potential loads with their demands. Data such as monthly bills gives information needed along the process. The process illustrates activities that were done to satisfy customers' requirements. Six years of energy consumption were recorded. The average energy consumption per year is 83,851.37 kWhr, as compared to the year 2022, which has a significant increase of 164%. Air-conditioning units' account for 68.60% or more than two-thirds of the total demand. This illustrates that other combined loads are just half the demand of ACUs. Energy awareness campaigns were conducted for the group of students and faculty. There is a percentage reduction of 5.59% after the intervention. A test of significance using two independent samples t-tests were done and revealed that the effort had given a sig-value of 0.85 at a confidence interval of 95%, and had no significant effect. However, in terms of monetary consideration, the reduction of 5.59% saved a considerable amount of money and mitigated 0.090 tCO2e of carbon footprint for that particular month. A continuation of the study must be conducted using the same method but consider an automation process or a comprehensive energy audit.

Keywords: Six Sigma, Energy Management, Electrical Loads, Percentage Reduction, SDG 13, SDG 9.

INTRODUCTION

The six sigma method is a project-driven management strategy for enhancing an organization's product, services, and processes by steadily lowering organizational faults. It is a company approach that emphasizes enhancing client needs, output, and services. By combining knowledge with statistics, engineering, and project management, six sigma methodologies have helped many firms maintain their competitive edge.

One application of Six Sigma can be in the analysis of energy management. Several methods have been made to increase the efficient utilization of energy in any type of buildings around the world. The concept of reducing waste energy involves many assumptions on how to start doing it. Technical studies on energy efficiency were seen in the literature works with considerations on the effects of the type of materials used, heating, ventilation, and air conditioning (HVAC), lighting system (Guan et al, 2010), the use of renewable energy, and changing of devices with higher energy efficiency (Escriva, 2011), and electrical system audit (Rashdi 2022, Bosu 2023). The Philippine government spearheaded by the DOE launched the Government Energy Management Program (GEMP). Specifically, the DOE will plan, develop, implement, and monitor management policies, and other related energy efficiency and conservation plans and programs (NEDA, 2022).

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This study proposed the application of the Six Sigma methodology to analyze the electrical system status of Isabela State University, Angadanan, Isabela, and to support government efforts on efficient energy management.

METHODOLOGY

The concept of Six Sigma was introduced by Bill Smith in 1986 at Motorola. It standardized the way defects occur, setting a “Six Sigma goal” of 3.4 defects per million opportunities. During those times, the company was facing the threat of Japanese competition in the electronics industry and needed to make drastic improvements in its quality levels. Motorola set this goal so that process variability is 6 S.D. from the mean (Adams, 1998).

General Electric was an early adopter of Six Sigma. It is one of the key reasons for the spread of Six Sigma. It was announced in 1998 by GE that $350 million in cost savings was recorded as a result of Six Sigma, and this amount later increased to more than $1 billion (Dusharme, 2001). Later, the first international standard outlining the Six Sigma process, ISO 13053:2011, was released by the International Organization for Standardization (ISO) in 2011.

The implied aim of Six Sigma is to enhance all processes, though perhaps not to the 3.4 DPMO level. For each of their most crucial processes, organizations need to choose an appropriate sigma level and work toward achieving it. This objective places a responsibility on the organization's management to rank areas that need improvement.

The methodologies for Six Sigma was inspired by the Deming Wheel introduced by Edwards Deming in 1950’s in Japan – the Plan-DO-Check-Act (PDCA) (De Feo and Barnard, 2005).

The DMAIC and DMADV, each have five phases. DMAIC stands for- Define, Measure, Analyze, Improve and Control. While MADV- is Define, Measure, Analyze, Design, and Verify.

According to Eckes (2003), in the define step, the project team is formed, a charter is created, customers, their needs and requirements are determined and verified, and, finally, a high-level map of the current process is created. The second step of the application of Six Sigma tactics is Measure. It is in this second step that the current Sigma performance is calculated, sometimes at a more detailed level than occurred at the strategic level of Six Sigma. The third step in applying Six Sigma tactics is Analysis.

During this step, the team analyzes data and the process itself, finally leading to determining the root causes of the poor sigma performance of the process. The fourth step of applying Six Sigma tactics is the Improve. In this step, the team generates and selects a set of solutions to improve Sigma’s performance. The fifth and last step is Control.

Here a set of tools and techniques are applied to the newly improved process so that the improved sigma performance holds up over time. This method is used in this study to improve the existing processes. The other method (DMADV) is used for new products or services.

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Six Sigma Techniques

Some of the Six Sigma techniques used in this study are as follows:

Brainstorming: It is a crucial step in many problem-solving techniques. It is typically applied during the DMAIC methodology's enhancement phase. Before someone uses any tools, it is a prerequisite process for energy management.

Histogram: It is often suggested that the data be organized into graphs or charts to more easily understand what the data is saying about the process. For continuous data, the best tool to use is the histogram, a graphical display of the number of times a given event is seen in a set of observations.

Pareto Chart: This approach is named after an economist, Vilfredo Pareto, who mathematically proved in the sixteenth century that 80 percent of the world's wealth was controlled by 20 percent of the population. This concept is popularly called the 80–20 rule.

SIPOC Diagram: It is used for documenting the business process from beginning to end. Because the diagram doesn't contain much detail about the process, it is often called a high-level process map.

Process Flowchart: This is nothing more than a flowchart used to visualize a process. A straightforward process flowchart can be made. Anyone should consider the fundamental shapes and use them to symbolize the various process stages.

The Defining Stage

The service utility to supply electrical energy is the Isabela 1 Electric Cooperative Inc., through a substation based at Alicia, Isabela. The institution has a maintenance committee to oversee the operation and safe use of electricity. Load inventory was done and the identified potential loads are enumerated in Fig. 1. These enumerated loads are human-dependent since occupants are the direct users, and decide when to use them anytime of the day.

Fig. 1 The Process and Components of the Study

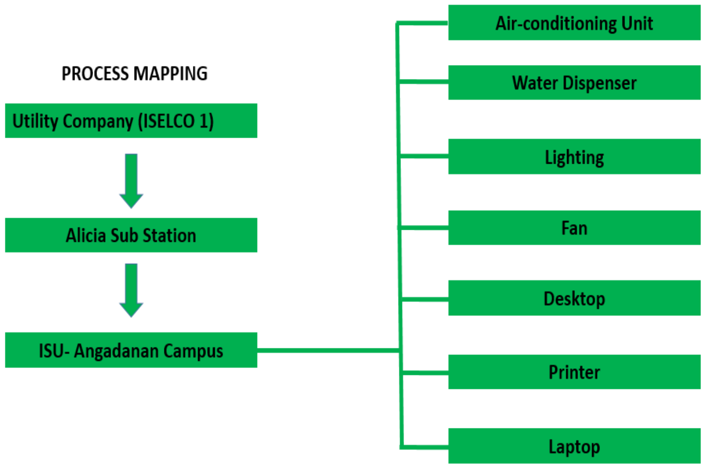

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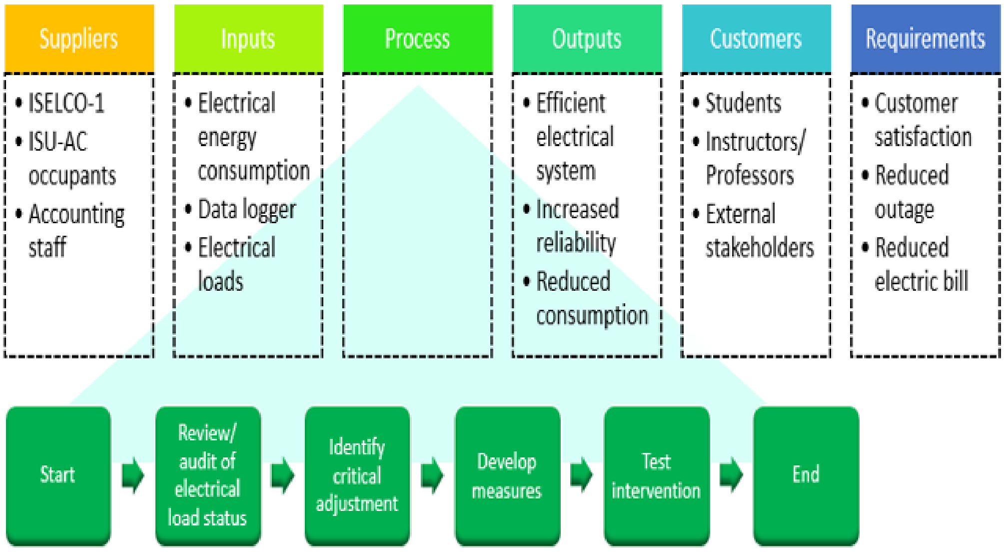
Figure 2. S-I-P-O-C Diagram for Energy Conservation of ISU-AC



The SIPOC diagram in figure 2 details the variables that have direct relation in the study. Suppliers are persons or entities responsible to supply inputs to the process. For this study, the providers start from the electric utility up to the accounting office which provides data on the operation and utilization of electrical energy. Inputs are resources, materials, or data such as monthly bills giving the information needed along the process. The process illustrates activities that have to be done that were performed to satisfy customers' requirements. The outputs are material, data, products, or services that result in the process. Customers are whoever receives the output of the process. In this case, faculty members and students were involved.

The Measurement Stage

Six years of energy consumption was recorded for table 1 starting in year 2017 up to 2022. Year 2020-2021 are the lowest due to Covid 19 crisis. The average energy consumption for this period is 83,851.37 kWhr. Compared with the year 2022 (137,557 kWhr), it has a significant increase of 164%. In figure 4, the monthly consumption reveals an increase in usage was recorded for the months of September to November. The trend has substantially increased that has to be addressed.

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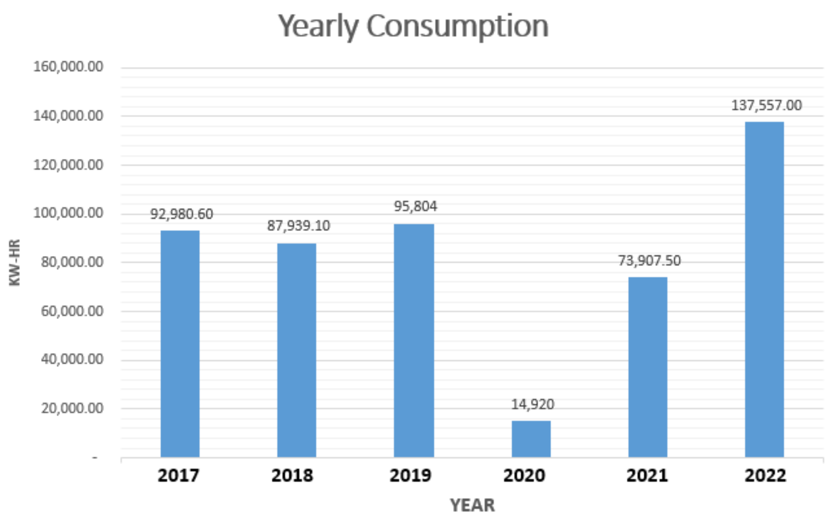

Figure 3: Yearly energy consumption in kW-Hr

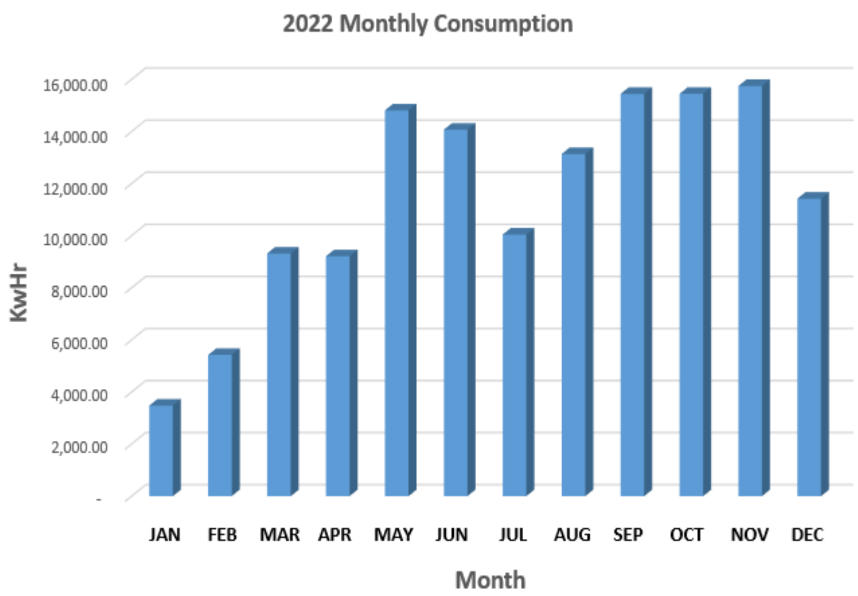

Figure 4: The monthly trend of energy consumption for the year 2022

A Pareto chart (Figure 5) was utilized after knowing the load demands for each of the identified devices. The table shows differences in capacities to use energy. Airconditioning units account for 68.60% or more than two-thirds of the total demand. This illustrates that other combined loads are just half the demand of the latter. Printers and laptops are among the least, respectively. This chart clearly emphasizes that ACUs are critical in this study. To apply for 80-20 rule, the analysis should commence on the airconditioning units.

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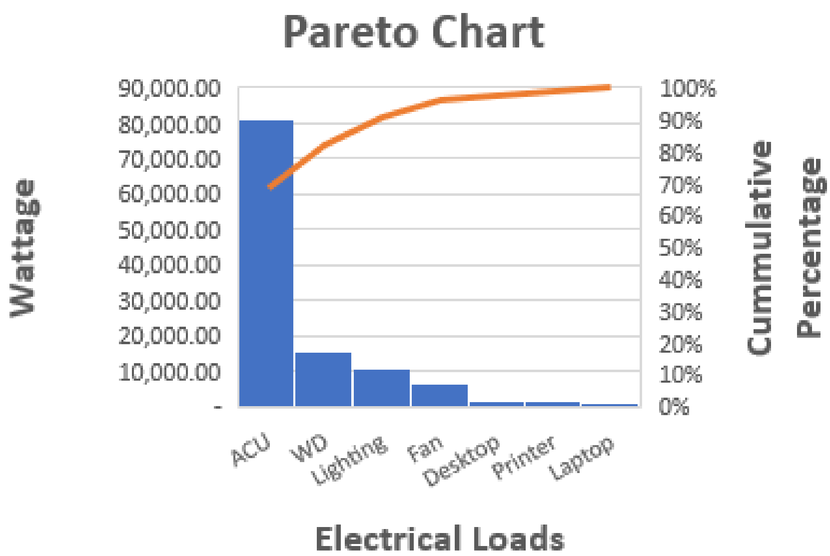
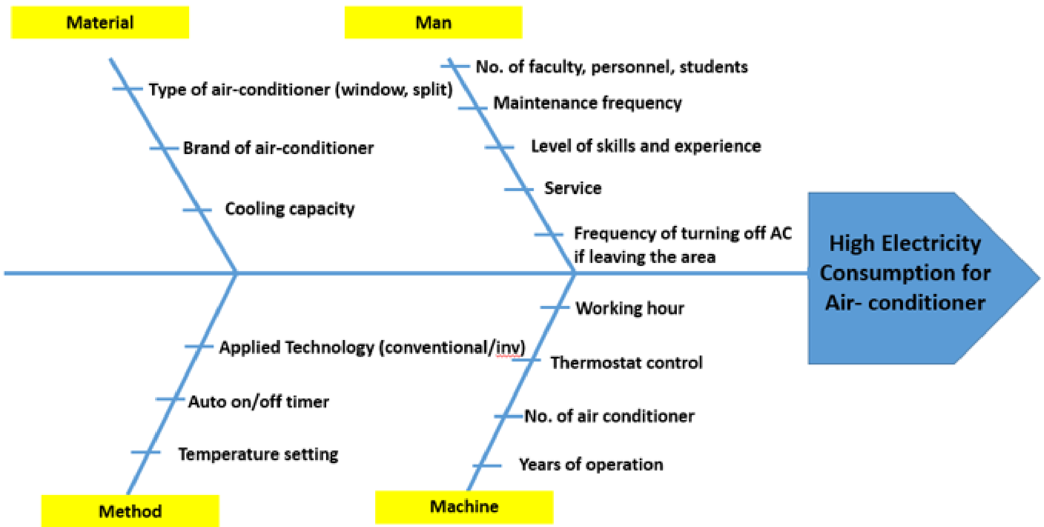


Figure 5: The Pareto Chart for Electrical Loads

The Analysis Stage

Figure 6 shows the cause and effect of high electricity consumption using ACU system. The Four M's helps identify the factors associated with consumption.

Figure 6. Cause and Effect Diagram for Air conditioner



Under the "Man" factor, it has to assess the number of people being served; if it is periodically cleaned as dusts create insulation to cooling; if attending A/C technicians are skilled; that room occupants are religiously observing to shot off the unit when leaving a room. For the "Material" factor, choosing the type, brand and cooling capacity are also vital, especially on the type of

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compressor used. In the "Method" factor, choosing between conventional and inverter type A/C has significant differences; timer and temperature settings are also game changer when overlooked. For the "Machine", a continuous operation throughout the day is impractical as this creates additional heat loss; control of the thermostat and the number of ACUs should be observed also, likewise, every year of operation lowers its efficiency, and inefficiency creates more waste energy, hence decide when to purchase a new unit.

An immediate if not an initial intervention was introduced. Energy awareness campaigns were conducted for the group of students and faculty. Flyers and stickers in aid of the campaigns were given and pasted in conspicuous places, respectively. A comparison of a month's consumption was recorded as shown in Figures 4 and 5.

The Improvement Stage

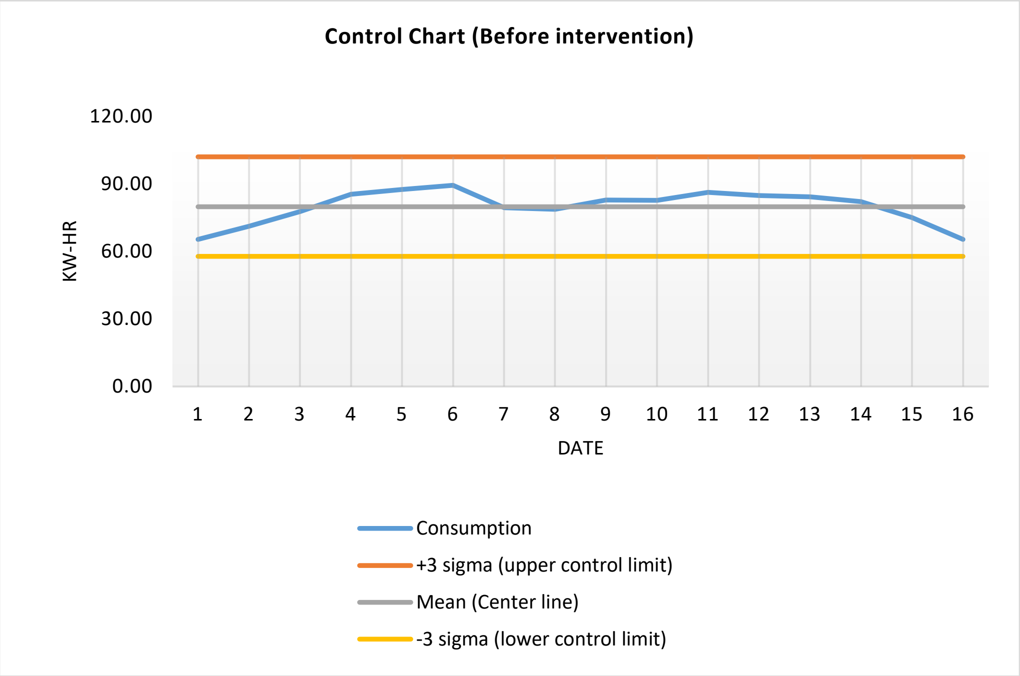

Figure 7: Before the Intervention Control Chart

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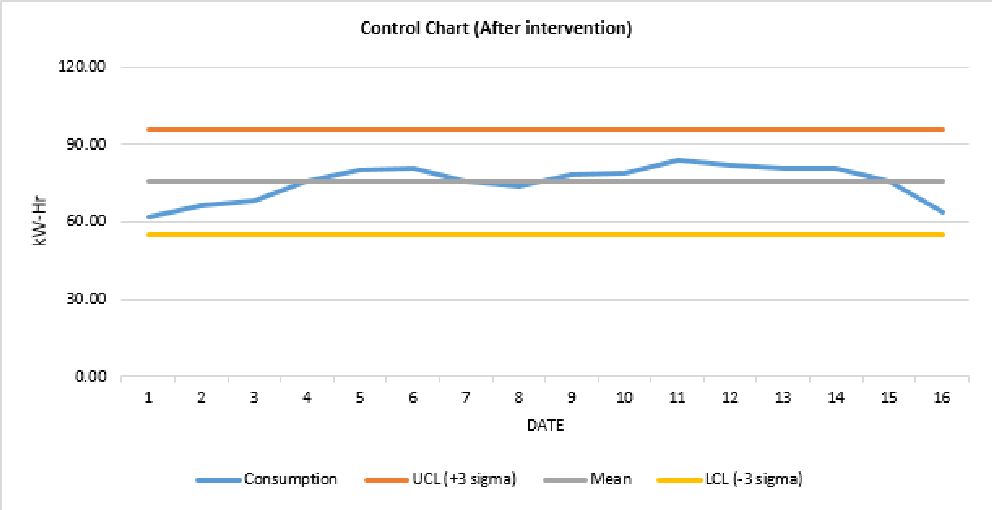

Figure 8: After the Intervention Control Chart

$$\text{Percentage Reduction} = \frac{\text{Mean kW-Hr consumption (before treatment) - Mean kW-Hr consumption (after treatment)}}{\text{Mean kW-Hr consumption (before treatment)}} \times 100$$

Using the percentage reduction formula, there is a percentage reduction of 5.59%. This is equivalent to 90 kWhr reduction for a month. If this will be quantified in carbon footprint equivalent, using the carbon intensity factor of 0.9991 metric tons of CO2 per megawatt hour (MWhr) of electricity generated (US-Environmental Protection Agency), it was able to mitigate .090 tCO2e of carbon footprint for that particular month. A test of significance was also done using two independent samples t-test and revealed that the intervention effort had given a sig-value of 0.85 at a confidence interval of 95%, and had no significant effect. However, in terms of monetary consideration, the reduction of 5.59% saved a considerable amount of money. This mitigation supports SGD 13 on climate action and SDG 9 on Industry, Innovation, and Infrastructure.

The Control Stage

Although the statistical gain in this study is not remarkable, it should be considered as an initial step toward other approaches. A periodic monitoring and reminder on the proper use of energy should be implemented by the school's maintenance committee. They should devise additional measures to strengthen the intervention program. Likewise, the control should include the cooperation of everyone, particularly the faculty members.

CONCLUSION

The application of the Six Sigma approach using the DMAIC method was proposed through the aid of different tools such as process mapping, SIPOC diagram, Pareto Chart, fishbone diagram, control chart, and statistical test. Analysis of energy consumption before and after the information dissemination on the conservation of energy revealed no significant impact on the

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treatment. Nevertheless, it saved a considerable amount of energy. A continuation of the study must be conducted using the same method but consider an automation process or a comprehensive energy audit.

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Conflict of Interest:

The authors declare no conflict of interest.

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