VALUE STREAM MAPPING FOR BREWERIES

Introduction

Definition

Value stream mapping (VSM) is a lean tool that uses a flow diagram to show every stage of the process; it helps to identify and eliminate waste, decrease cycle time, and implement process improvement. VSM can be used for any product/material or process that starts with a raw material and ends with a final product [***ASQ***].

Purpose

The primary purpose of VSM for breweries is to identify energy consumption and water usage at each individual step of the beer making process from raw material to fermenter. VSM helps in detecting energy/water loss associated with production and aids in improving environmental performance.[1] For the purpose of this document, VSM will focus only on the water and energy inputs starting from grain storage to wort transferred into the fermenter.[2]

Application

VSM is used in different industries for different purposes. Below are several examples of how VSM has been applied to different sectors of industry.

a) In the automotive manufacturing industry, VSM has been used to look at time. In this ***case study***, it was observed that non-value added time was reduced by approximately 26%.

b) Looking into ***military logistics***, VSM methods were found to improve lead-time by 69% while reducing deviation by nearly 62%.

c) Most office environments operate differently when it comes to processes, this ***case study*** shows how VSM can still be applied to office settings.

Application Background

VSM concepts were first developed by the ***Toyota Production System (TPS)*** to reduce inefficiencies in manufacturing steps from supplier to customer through the VSM tool.[3] The concept of "Value Stream" and mapping was first used in the 1980's by Jim Womack and Dan Jones while studying the automotive industry.[4] While VSM methods were first developed for the automotive production industry, today VSM is used in many different industries as discussed earlier.

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[1] For more information on the benefits of VSM, please visit: ***https://www.epa.gov/e3/e3-value-stream-mapping-how-guide***

[2] The fermentation process is not included in this VSM as each process varies by brewery and style.

[2] *Value stream mapping examples for different industries.* MOSIMTEC. (2021, July 9). Retrieved July 7, 2021, from ***https://mosimtec.com/value-stream-mapping-examples-for-different-industries/***

[4] Zabelle, Todd R. "Operations Science View of Value Stream Mapping." *Operations Science View of Value Stream Mapping*, 6 Dec. 2018, ***https://projectproduction.org/journal/operations-science-view-of-value-stream-mapping/***.

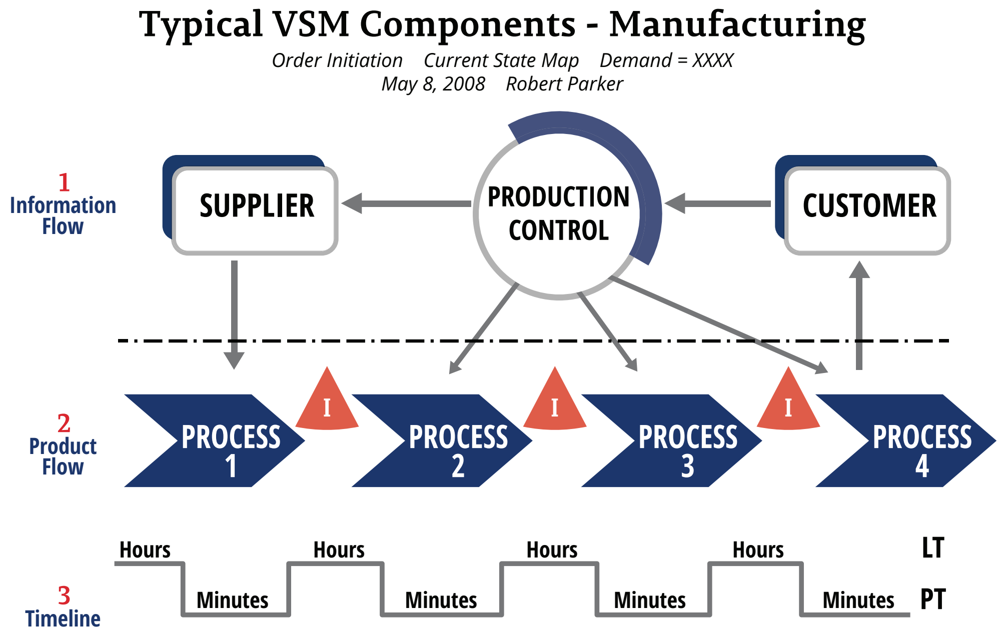


Fig 1: Retrieved from [Mosimtech]

VSM Elements

VSM has four essential elements and three basic parts. Four elements are categorized as follows.[5] Note, Figure 1 shows the process flow for each four elements.[6] A process flow for breweries have been created and can be found in Appendix A for the purpose of these guidelines.

1. ***Customer:*** The customer element is the first component of the VSM, as the flows go from bottom to top (i.e., shipping to raw material sourcing). The customer demand will help in finding the pace required to meet production as per customer demand, which in turn, aids in finding the total production units required.
2. ***Supplier:*** The supplier element comes second in the VSM, after the customer. The supplier can be one or many depending on the required inputs for the product.
3. ***Product/material flow:*** This aspect of the VSM shows the flow of material from the start/raw material source to finish/product reaching the finished product.
4. ***Information flow:*** This depicts the product flow. Information flows enlist the details on various areas like customer, supplier, which helps in planning the production [***Lean process***].

[5] "4 Elements You Need on Your Value Stream Map." Lean Process, 8 Jan. 2016, https://www.leanprocess.net/value-stream-map/.

[6] Although the original VSM concept was designed around raw materials to customers, these elements are repurposed to applied to beer production from milling grain to fermentation.

The three basic parts which divide the VSM are as follows.

1. Information flow: It shows the interaction/activity between the various components amongst VSM.
2. Process map: It contains information on the step and the associated processes.
3. Timeline: It points at exactly where the waste/loss (nonvalue-added) product or energy is generated; it also shows cycle time (C/T) for the product (value-added) [*Smartdraw*].

Benefit

VSM has been found to reduce utility costs/consumption and identify areas of opportunity.[7] Below, are a few ways VSM can help improve production processes while reducing utility consumption.

I. Identify the waste/loss: Waste refers to any actions or steps that do not add value to the product. For instance, during liquor production defected product is considered a waste, while loss refers to the energy loss or product loss due to inefficiency of equipment or process.

II. It helps to make the process efficient: Developing a flow chart for a process helps to identify the individual steps in detail along with overall process. Visual representation through flow charts can help identify flaws to fix and improve efficiency.

III. Excellent tool to bridge the gap: Through monitoring the current state of production processes, a plan can be made to fix inefficiencies.

IV. Helps in focusing on the value-added activities/products: Through VSM, more attention is given to product/process which adds value to the company, like the production of liquor (which brings profits) in contrast with non-value-added activities, energy loss, or water loss.

Overview of the Brewing Process

Beer

Beer is an alcoholic beverage produced by fermentation of cereals like malted barley (primarily used), rye, oats, maize, and/or wheat. During the fermentation process, starch/sugar (malted barley) in wort is converted to alcohol and CO_2. Hops are added for bitterness/preservation.

Beer is milder than spirits with a lower alcohol content. Beers are primarily classified into two categories.

[7] EPA, Environmental Protection Agency, ***https://www.epa.gov/e3/e3-value-stream-mapping-how-guide***.

a. *Ale:* This is prepared by top-fermenting yeast with a warm temperature; 60–75°F (16-24°C).

b. *Lager:* Lager is prepared by bottom-fermenting yeast with cold temperature; 45-55°F (7-13°C) [*Beer and Brewing*].

Beer Production

Fig: 2 below shows the beer making process from milling grain to product in the fermenter. This process flow is a simple representation of the beer making process and clarifies the VSM flow.

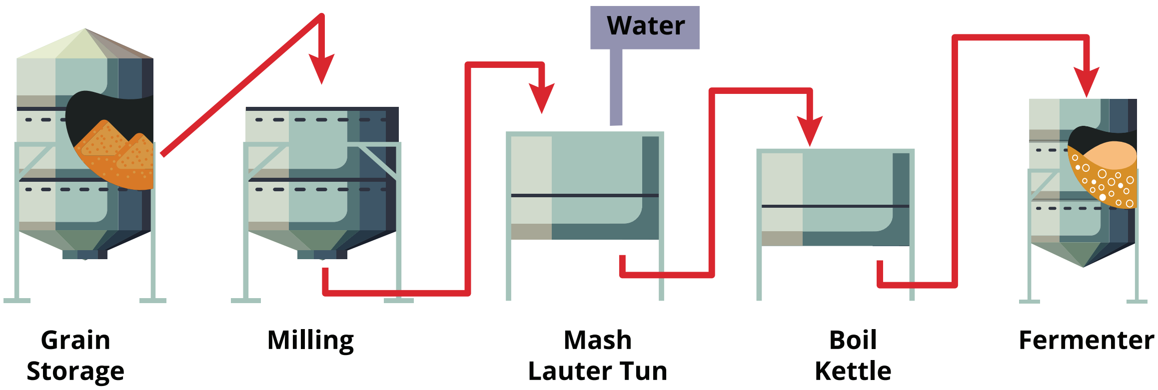


Figure 2: Brewing Process

Most beers are made using malted barley, hops, water, and yeast. A typical brewing process follows these steps:

a. *Milling:* The process of brewing starts by milling grains, where grain is crushed by mills to a defined size and turned into grist.

b. *Mashing:* Grist is mixed with hot water (145-161 deg. F) to convert the starch into simple sugars.

c. *Lautering:* The process in which hot water (170 deg. F) strips additional sugars from the grain. This sugary liquid, known as wort, is then separated from the grain, collected, and boiled.

d. *Boiling/Cooking (Addition of flavorings and hops):* The separated wort is cooked/boiled, and hops and other adjuncts are added for flavoring. The boiling process typically lasts for about 60 to 90 minutes.

e. *Whirlpooling:* This step separates hops from wort by constant stirring in one direction.

f. *Cooling:* Cooling causes the solids to break and separate out during transfer to the fermentation kettle. The cooling is carried out by passing the wort through a heat exchanger. Most heat exchangers utilize cool water or glycol as the cooling agent.

g. ***Fermentation (Addition of yeast):*** The cooled-off wort (55-80 deg. F) is allowed to sit and ferment. Fermentation typically takes 4-7 days and sometimes up to several months. During this time, yeast consumes sugars and converts them into CO_2 and alcohol.

h. ***Ageing/Maturing:*** After the completion of fermentation, the beer is cooled to approximately 32 deg. F, promoting flocculation or settling (yeast is settled in the bottom). The beer is then conditioned or matured.

i. ***Filtering:*** Post the conditioning stage, beer is racked or filtered into a "bright tank" where beer is carbonated and kegged or bottled (this is an optional process).

j. ***Packaging/bottling:*** Beer is transferred into cans, kegs, or bottles and packed.

k. ***Distribution:*** The packaged beer is then sent for distribution in truck.[8]

Value Stream Mapping in Brewing

VSM is a way to map out inputs and outputs during the production process. While each industry is different, the brewing process is similar throughout the brewing industry. With a uniform process, VSM guidelines can be applied to all brewing systems.[9]

Steps of VSM

For the purposes of this document, the Value Stream Map will cover steps from grain milling to wort in the fermenter.

1. Identify the process information from grain milling to fermenter and make a flow diagram of the steps.
2. Collect the data for individual steps, (i.e., the amount of material, water, and energy consumed at each step) and record each input. This may involve collecting the amount of time a motor is running, the amount of gas used, and/or the amount of water used.
3. With the data you collected from the previous step including processing time, equipment use, and utility (water) and energy (KWH, Therm) usage, enter this data into the individual VSM boxes. This data can be used to determine the overhead cost and identify the loss at each step [***KPPC***].
4. Show the points where water, process heat, and other byproducts can be reused or repurposed. For instance, hot water (used) can be used for cleaning/primary wash.

[8] Galitsky, Christina, et al. "Energy Efficiency Improvement and Cost Saving Opportunities for Breweries ." The Office of Scientific and Technical Information, 2003.
[9] While the brewing process can be uniform some processes may differ but minor adjustments to a VSM protocol can be easily adapted to any scenario.

5. Make necessary low-cost improvements to make the process more sustainable and save overhead costs.

The VSM uses symbols for flow (information, material, and utilities). Below, in Fig.3, is an example flow VSM for a brewery.

Symbols

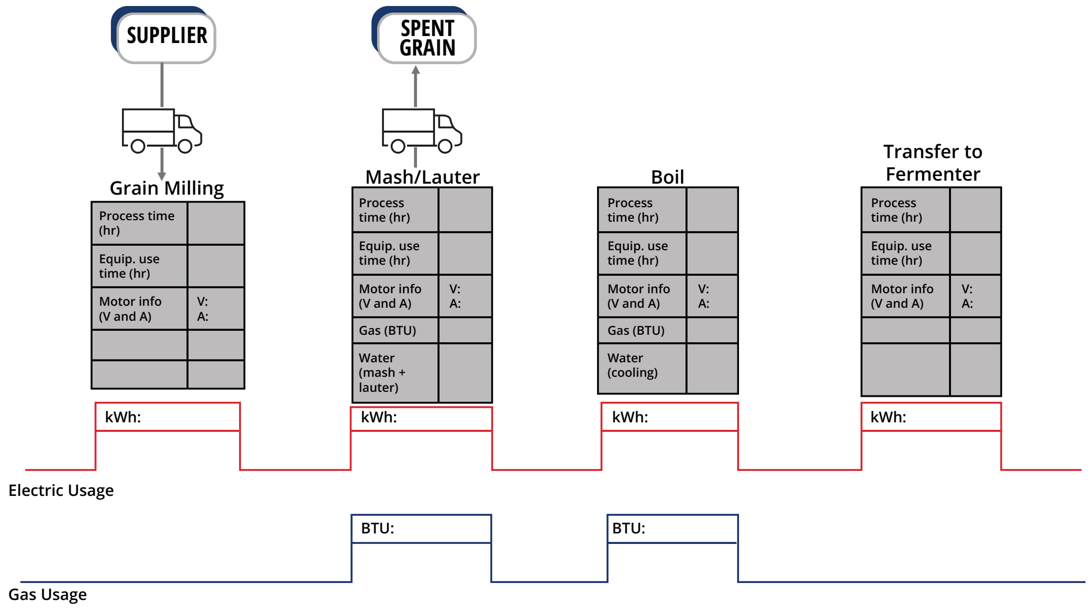


Figure 3: VSM for brewery (also shown in Appendix A)

Energy (source and units)

Energy is an essential criterion to be considered necessary for any industry, especially breweries. Knowing where and how much energy is consumed at different steps of the brewing processing helps to manage the energy cost, which can be advantageous in the long run in terms of improving efficiency (through saving cost) [*Brewers Association*].

To monitor energy consumption and regulate the overhead cost monthly and annually, the key indicators that help monitor energy use are the "Energy Use Ratio (EUR)." The EUR is defined as the amount of energy used to make one liter of beverage/beer, and it is measured in megajoule per liter (MJ/L)[10].

EUR (MJ/L)/ = Total Energy Consumption/Total Beer/Beverage Production [*BIER*].

Gas (direct fire or steam/boiler): The largest portion of energy consumption during the brewing process usually involves gas/electricity for heating. The amount of gas utilization differs from plant to plant depending on size, location, and production load. If a boiler is used, additional calculations will be required to determine the pounds per hour flow (pph) for each process using steam. [10]

[10] For more information on boilers and calculating pph, please visit: ***https://www4.eere.energy.gov/manufacturing/tech_deployment/amo_steam_tool/equipBoiler?random=superSteam***

Gas is utilized in a brewery by two means: Direct fire and Steam/boiler.

- Direct fire involves using direct flame under the kettle to heat it using coal (anciently) or natural gas burners. This method is advantageous for brewers who want to boil the product quickly while still controlling or changing the temperature. While direct fire systems are simpler to use and maintain they are not as efficient as a steam/boiler system.[11]
- Most brewers currently use steam/boiler with steam jackets for the even distribution of heat to facilitate uniform cooking [***Beer&Brewing***]. With regular maintenance, the burner and return condensate system is exposed to less wear and tear, saving utility costs.

Electricity (mainly motors): After gas and steam, electricity accounts for major utility costs. Electricity is often used as a combination of heat and power (“ CHP”) and is measured in kWh (kilowatt per hour). Brewing systems and equipment that account for the highest electricity usage are primarily turbines, motors, pumps, and refrigeration [***Sciencing***]. The electricity cost of making beer is measured as kWh/BBL.[12]

- ***Motors:*** Most motors in breweries are Variable Frequency Device (VFD) and are designed to run at different volts. The motor in the image below runs at 230 and 460 volts with phase 3 (draw heavy power at low voltage) and revolves at 1725 RPM (Revolution Per Minute) at 2 hp (Horsepower). With a full load, the motor draws 6.5 amps (ampere); if the voltage is double, then amps are lower, i.e. 2.9 (inverse relationship). With 2 HP, the motor can run continuously at 104 °F.

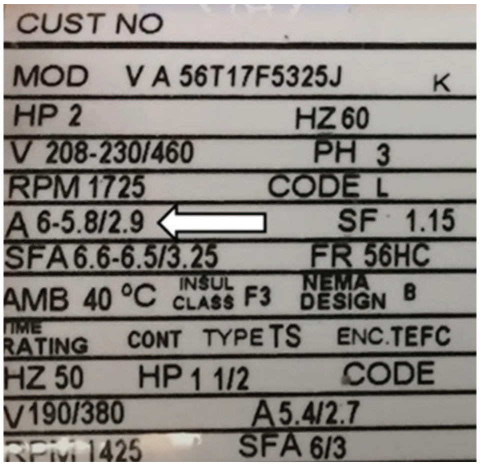


Fig 5: Retrieved from [***MotorLabels***]

[11] Direct fire systems only apply direct heat to the bottom of a kettle while steam systems apply heat to more surface area of a jacketed kettle which in turn improves efficiencies.

[12] 1 BBL= 31 U.S. gallons, BBL (Beer Barrel) is the common unit used in brewing to measure volume of beer.

The cost of electricity for a 3-phase motor is measured in a kilowatt hour and the formula to calculate the power consumed by a motor in wattage (W) is A*V (sqrt 3), where A is the ampere, V is volts, and sqrt 3 is 1.73. See the motor label is Figure 5 as an example. In this example (See Appendix B for a written-out version of this example), the motor uses 208 V and 6.5 A. Using the equation to solve for power, W= 6.5*208*1.73 = 2339 watts. As electricity is based on kilowatts, 2339 W is equal to 2.3 kW. If the motor runs 8 hours/day for 5 days, which is averages at 173.3 hours per month, then (2.3 kW *173.3 hours/month) = 399 kW/hour each month. This multiplied by a rate of $0.10kW/hour will cost $39.90 [***Sciencing***]. For the purposes of these guidelines, calculating the kWh for each motor (based on time used in the process) will be helpful in identifying energy used per process.

The exact cost of energy is hard to determine, although, as per Brewer's Association [*BA*], the average cost for using natural gas and electricity in the brewery is listed below.

- Average relative electrical usage is 12-22 kWh/bbl
- Average relative natural gas usage is 1.3-1.5 therms/bbl
- Combined energy usage is 50-60 kWh/bbl

Energy demand and its impacts on overall cost: The rate at which electricity/energy is used is called energy demand, and it is measured in kW. The actual amount of energy/electricity used/consumed (in particular duration) is referred to as energy consumption and is measured in kWh. If 2 hp motors run at 0.746 kW then energy demand is 1.5 kW, but when that motor runs for 2 hrs., then energy consumption is 3.0 kWh.

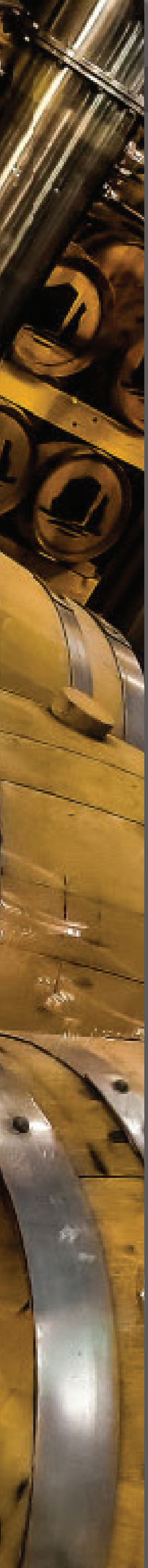
If a motor is run the most during peak demand, it can increase the energy cost and indirectly impact the overhead cost [KPPC].

Water (source and units)

Water quality is critical to producing good quality beer. To monitor water consumption, Water Use Ratio (WUR) is used to track water usage with production data. It is defined as the amount of water consumed in making per liter of beverage/beer.

WUR (L/L)/ = Total water Consumption/Total Beer/Beverage Production [*BIER*].

Water affects the quality of beer; in different regions water has different mineral content or hardness. These regional variations in water can give definitive character to beer. For instance, brew water containing high calcium and low carbonates helps in mash pH and enzymatic activity. *Note that most beer is made with filtered municipal water and different salts are added to the water based on recipe and style.*



- ***Municipal city water:*** Town or municipal city water is filtered, treated, and has acceptable microbiological quality; however, brewers tend to apply additional filtering to this source to filter out chlorine before use.
- ***Surface water:*** Surface water like lakes, rivers, reservoirs, and rainwater have high contaminants (microbial) but low mineral content. The quality is not constant and proper treatment is required prior to its utilization.
- ***Well water:*** Underground, well, or spring water is high in organics and microbial load. This water is high in mineral content, which is best suited for beer making, in some cases [***Water Source***].

Process water is the water needed in the manufacturing of the final product (beer). Water which was not reused or recycled is known as lost water, whereas the water consumed/added to the beer will be counted in the water consumption box (VSM) [***Best Management Practice***].

Conclusion

VSM is a way to visually map out energy and water consumption in the brewing processes. The process of creating a VSM may take time to measure consumption rates for each individual process but can help in determining areas of improvement. If processes do not change, a VSM may only need to be conducted once: before changes are made and once after. The VSM of processes after changes are made will help determine the efficacy of changes to the process.

For more information on improving sustainable practices at your facility please contact the Tennessee Sustainable Spirits Program at ***Sustainable.Spirits@tn.gov*** or visiting the website at: ***http://tnsustainablespirits.com***

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http://tnsustainablespirits.com/

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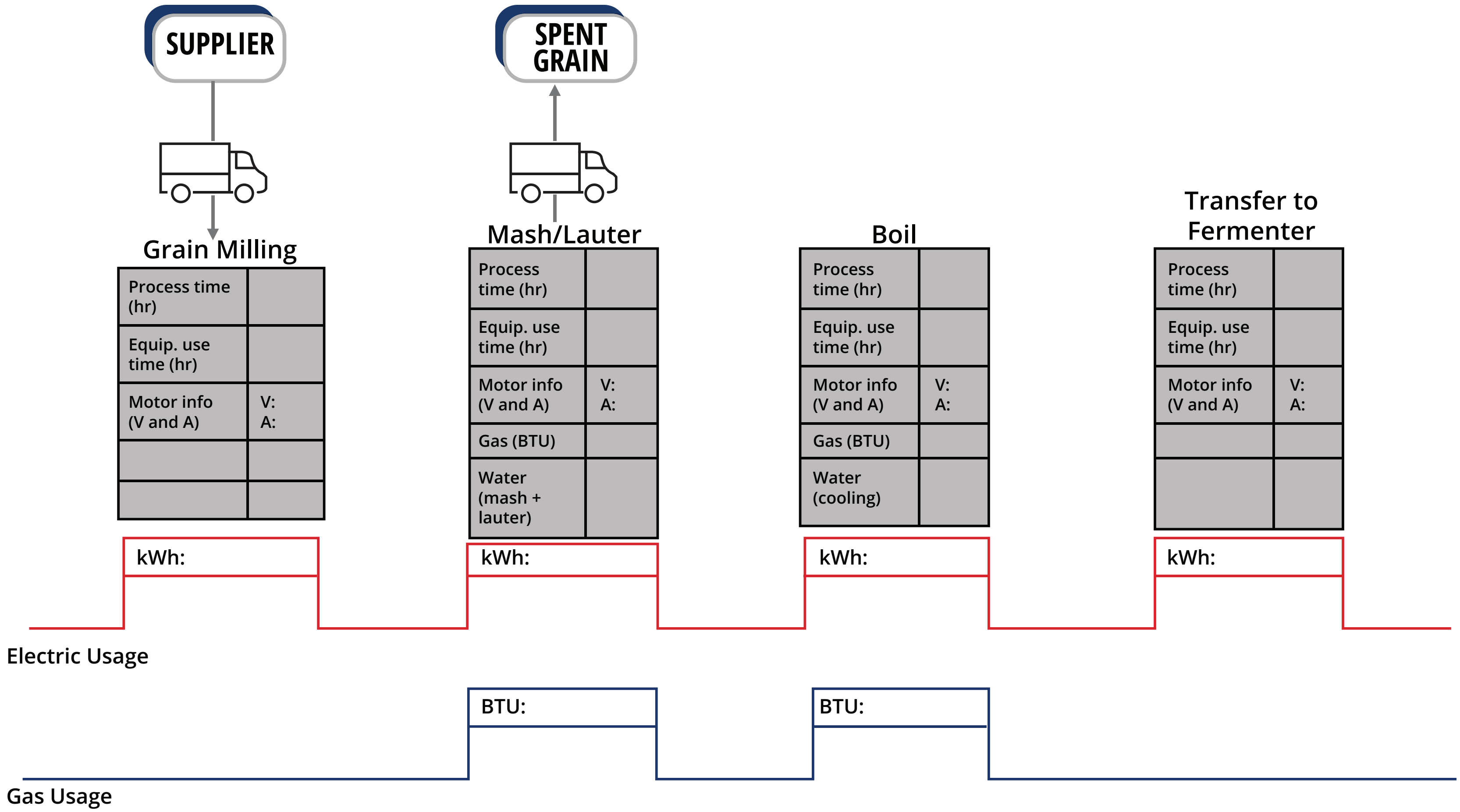
Appendix A: VSM Template for Brewery



Appendix B: Example Calculations for an Electric Motor

Calculating the Cost of an Electric Motor Based on Time

W = watts   A = amperes   V = volts   hr = hours   kW = kilowatts   kWh = kilowatt hour

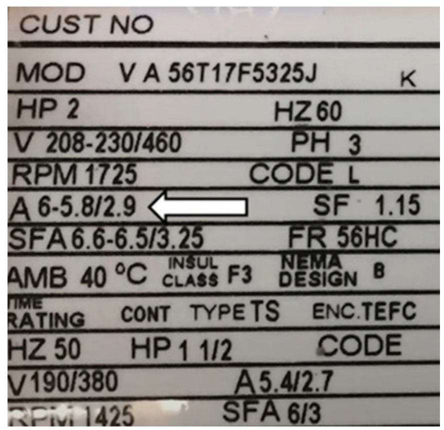
Formula

$W = A \times V \times \sqrt{3}$

Known

- V = 208
- A = 6.5
- Time = 8hrs/day for 5 days or 173.3hrs/month
- Electricity rate = $0.10/kW/hr

Electric Motor Label



Example

Calculate the monthly cost of electricity to run an electric motor (see motor label) for 8hrs/day for 5 days with an electricity rate of $0.10/kW/hr

$W = 208 \times 6.5 \times \sqrt{3} = 2339$ watts

2339 W = 2.3 kW

kWh/month = 173.3 x 2.3 = 399 kWh/month

Monthly Cost = 399 x $0.10 = $39.90