7-2015

TEA (Techno-economic analysis) and LCA (Life cycle assessment) of small, medium, and large scale winemaking processes

Congmu Zhang
Iowa State University, congmuzh@iastate.edu

Kurt A. Rosentrater
Iowa State University, karosent@iastate.edu

TEA (Techno-economic analysis) and LCA (Life cycle assessment) of small, medium, and large scale winemaking processes

Abstract

The objective of this project was to conduct TEA (Techno-economic analysis) and LCA (Life cycle assessment) for the production of red wine. Small, medium and large scale winemaking processes were chosen for analysis. For LCA, the consumption of water, energy, green house gas emissions, and solid waste generation were considered for environmental impacts. For TEA, a spreadsheet-based economic model was developed. The results of the LCA and TEA were compared amongst all scales. The results of the LCA showed that both bottle manufacturing and winemaking processes contributed the greatest environmental impacts, while for TEA, the relationship between cost and profit among all three scales fitted an exponential model.

Keywords

TEA, LCA, winemaking, different scale, economic analysis, life cycle assessment

Disciplines

Agriculture | Bioresource and Agricultural Engineering

Comments

This proceeding is from 2015 ASABE Annual International Meeting, Paper No. 152188570, pages 1-16 (doi: 10.13031/aim.20152188570). St. Joseph, Mich.: ASABE. Posted with permission.

2950 Niles Road, St. Joseph, MI 49085-9659, USA
269.429.0300 fax 269.429.3852 hq@asabe.org www.asabe.org

An ASABE Meeting Presentation

Paper Number: 152188570

TEA (Techno-economic analysis) and LCA (Life cycle assessment) of small, medium, and large scale winemaking processes

Congmu Zhang and Kurt A. Rosentrater

Department of Agricultural and Biosystems Engineering, Iowa State University
Ames, IA 50011

Written for presentation at the

2015 ASABE Annual International Meeting

Sponsored by ASABE

New Orleans, Louisiana

July 26 – 29, 2015

Abstract. *The objective of this project was to conduct TEA (Techno-economic analysis) and LCA (Life cycle assessment) for the production of red wine. Small, medium and large scale winemaking processes were chosen for analysis. For LCA, the consumption of water, energy, green house gas emissions, and solid waste generation were considered for environmental impacts. For TEA, a spreadsheet-based economic model was developed. The results of the LCA and TEA were compared amongst all scales. The results of the LCA showed that both bottle manufacturing and winemaking processes contributed the greatest environmental impacts, while for TEA, the relationship between cost and profit among all three scales fitted an exponential model.*

Keywords. *TEA, LCA, winemaking, different scale, economic analysis, life cycle assessment.*

Introduction

Wine is one of the most important and most popular alcoholic beverages in the world. In 2005, the consumption of wine accounted for 8.6% of the total alcoholic beverages consumption all over the world, preceded only by spirits and beer (WHO, 2011). Wine is made from fermented grapes or other fruits. Grapes could ferment without the addition of acids, sugars, enzymes, water or other nutrients because of their natural chemical balance (Johnson, 1989). Under the action of yeast, the sugars in the grapes are converted into alcohol and carbon dioxide and thereby make wine. Besides its role as a popular beverage due to its distinctive flavor and aroma, wine could be a psychoactive drug, as are all alcoholic beverages (ISCD, 2013), and could be used for its intoxicating effects. The history of wine is rich; the earliest traces discovered so far having occurred Christian era 6000 B.C. in Georgia, and Christian era 5000 B.C. in Iran (Keys, 2003; Berkowitz, 1996), the first recovered crashed grapes of Christian era 4500 B.C. were discovered at Grecian Macedonia (Viegas, 2007), and the first winery dated to Christian era 4100 B.C was discovered in Armenia (Owen, 2011).

Wine making is the process that input of grape and output of wine. It starts with selection of grape and ends with bottling of wine. In terms of final product, winemaking could be divided into still wine production, which produces wine without carbonation and sparkling wine production, which produces wine with carbonation. The still wine production could be further divided into red wine production and white wine production (Considine and Frankish, 2013). Different wine products were produced due to different process. For red wine, red grapes were harvested, de-stem, and crushed; all berry parts including skins, pulps and seeds were fermented. There are double fermentation for red wine: first convert sugar to alcohol by using yeast, and then utilize the conversion from malic acid to lactic acid with a bacterium. The purposes of latter fermentation are to reduce acidity, to ensure the stability against secondary fermentation in the bottle, and to add flavors that enhance the wine, especially with the storage in ‘toasted’ oak barrels (Considine and Frankish, 2013).

According to Sacchi et al. (2005), red wine making is an extractive process of skins, seeds and even some stems. In terms of their research, with the present of high levels of antioxidants such like tannins and anthocyanins that were extracted, the red wine making was less prone to oxidation. The ‘cap’ formed by floating skins that was buoyed by carbon dioxide generated from fermentation should mix with the must regularly to effectively extract tannins and anthocyanins to prevent the growth of spoilage yeast (Sacchi et al., 2005). The secondary fermentation of red wines and some white wines are also beneficial for the stability of wine against spoilage and in-bottle fermentation because the malic acid as fermentation substance was used up due to its conversion to lactic acid by applying of a bacterium, *Lactobacillus oeni* (Considine and Frankish, 2013).

Different from red wine, white wine is only fermented by yeast and then chilled and stabilized. Only the juice or must pressed from the pulps of white grapes is fermented. Very careful filtration should be applied in order to remove all microorganisms thus prevent malic acid fermentation right after bottled. The whole process is very quickly therefore could produce the wine with dry, crisp, and aromatic palate. Compared to red wine production, white production needs much greater control of oxygen status, hygiene, yeast nutrition and temperature, thus, it is possible to produce an acceptable red wine in just ‘backyard’ but hard to make a sound white in the same environment (Considine and Frankish, 2013). As white wine after fermentation is sensitive to oxidation, it is not extractive and sterile filtration must be applied to stabilize it. Chilling before bottling process is required for white wine to precipitate excess potassium bi-tartrate salts to prevent it form unsightly crystalline deposits in refrigerated bottle. Clay could be used to remove excess protein in the wine that might coagulate and form an unsightly haze when the wine gets too hot during storage or transportation. Copper sulfate could be also utilized to remove hydrogen sulfide which may be formed when starving yeast metabolize grape proteins. Other fining process such as the use of natural products like protein from eggs, fish or gelatin could be applied to remove bitter tannins, and the precipitate should be removed before bottling (Considine and Frankish, 2013).

Life cycle assessment (LCA) is the assessment of all environmental burdens regarding a product, a service or a process from raw material to waste removal (Klopffer, 1997). It was invented in the USA at the Midwest Research Institute around 1970 (Hunt and Franklin, 1996), and the structure applied nowadays of LCA was defined by ISO, including goal and scope definition, inventory analysis, impact assessment and interpretation (ISO, 2006). There are a lot of applications of LCA in winemaking process and winery operation. Fusi et al. (2014) conducted a ‘cradle to grave’ LCA (total LCA) to identify and assess the environmental burdens along the white wine life cycle stage, including grape planting, wine production, wine bottling, packaging, distribution and disposal of wine bottle. In their research, the glass bottle production was considered the most determinative to the environmental performance of production of a bottle of white wine. And in their analysis of agricultural phase including vine planting and grape production, vine planting was not negligible on environmental impact compare to the whole agricultural operation. Same as this research, Neto et al. (2013) and Point et al. (2012) also carried out ‘cradle to grave’ analysis that including distribution. In which the authors also indicated that the production of wine bottles play a very important part in environmental effect of the life cycle of wine. Some researches added vine planting into considerate (Bosco et al., 2011; Benedetto, 2013). From which the vine planting contributed a lot to the environmental impact. Several other studies only conducted ‘cradle to gate’ research (Vazquez-Rowe et al., 2012: Benedetto, 2013). They did not take distribution into considerate in their studies. However, from their conclusions, glass bottle production was still the most significant element to affect the environment.

TEA (Techno-economic analysis) is widely used in food industry. The usefulness of TEA on cost analysis, profit assessment and production strategy determination has already been demonstrated. Marouli and Maroulis (2005) developed a model that utilized existing food factories data by analyzing them systematically to indicate the particular characteristics of concerned operation of the food industry. Another TEA was applied to characterize and improve pastoral dairy goat systems in Andalusia (Ruiz et al., 2008), and with that TEA a profitable production strategy was made. For winery and winemaking, Dillon et al. (1992) conducted a research leads to the development of an economic decision making model for small to medium-sized wineries, from their model, the break-even prices were indicated from 3.50 dollars to 6.00 dollars per 750ml bottle for winery sizes from 100,000 gallons per year to 5,000 gallons per year, the larger the winery size, the lower the break-even price. An economic model was developed to evaluate costs of raw materials such as grape, labels and bottles (Dillon et al., 1993), the cost of the raw materials was demonstrate to have substantial effect on the annual net profit. In this research, winery profits could fluctuate more than 60% when the change of grape price approximately equal to 25%. Furthermore, Sellers-Rubio (2010) compared different approaches of traditional profitability and productivity measures and a non-parametric technique to estimate efficiency only. And found out that none of the methodologies could be said to be better than the rest on evaluations of winery economic performance. In spite of numerous researches of diverse economic analyses have been applied to winemaking and winery operation, to the author's knowledge, there is no genuine TEA that focus on winemaking processes.

The present study was carried out for conducting TEA and LCA for the particular red wine production processes, the LCA was carried out from vine planting to product distribution, while the TEA was conducted for small (5,000 gallons per year), medium (50,000 gallons per year), and large (500,000 gallons per year) size production.

Materials and Methods

Life Cycle Assessment (LCA)

The boundary of LCA was chosen from vine planting to wine bottle disposal, including vine planting, wine making, wine distribution and wine bottle disposal. The energy consumption and water consumption within this boundary were considered as input impacts while the green house gas emission and solid waste disposal were considered as output impacts (Figure 1). The unit of energy consumption was kilojoule (kj), of water consumption was gallon, of green hose gas emission was gram carbon dioxide equivalents (g CO_2 eq.), and of solid waste disposal was gram (g).

Assuming 70% of glass was recycled for wine bottle production. Assuming the impacts occurred during energy production was not considerate. The chosen functional unit (FU) was a 750ml bottle of red wine.

Data regarding energy consumption and green house gas emission were collected via EioLCA (2014) (Table 1 and Table 2). Data with respect to water consumption and solid waster disposal were referred to Fusi et al. (2014) (Table 1 and Table 3). The processes within boundary were separated into four parts, including vine planting, wine making, bottle manufacture and wine distribution. All the impact data of these 4 parts were analyzed and the contribution to total impact of each part was calculated (Table 1, Table 2 and Table 3).

Techno-economic Analysis (TEA)

The TEA was conducted for wine production processes, including vine planting and wine making. Assuming land cost was not considerate, part time labor cost was 10 dollars per hour per person, full time labor cost was 40,000 dollars per year per person, grape vine was 100 percent recycle so no cost for it, and grape output was 6 tonnes per acre per year. Assuming wine output was 120 gallon per tonne of grape, the useful life of all the equipment was 15 years, the diesel price was 3 dollars per gallon, no pesticide was applied during vine planting and the ex-factory price of wine was 10 dollars per 750ml bottle.

All the relevant data of the wine production processes was collected based on three scale wine production, which were small (5,000 gallons per year), medium (50,000 gallons per year), and large (500,000 gallons per year), the data was obtained from Alibaba (2014), the vintner's vault (2014), Novak and Burg (2013) and Dillon et al. (1992) (Table 4).

The TEA was conducted for annual base of those three scales productions. Annual cost of each scale was calculated and was divided into three parts, which were labor cost, equipment and material cost and cost for purchasing wine bottle (Table 5). The contribution to total annual cost of each part was assessed (Figure 6), while the relationship of each cost of each production scale was analyzed (Figure 4 and Figure 5). Annual revenue of each scale was calculated and the relationship among three scales was assessed (Table 6, Figure 8 and Figure 9). Annual net profit of each scale was calculated while the analysis of relationship among three sales was carried out (Table 5, Figure 11 and Figure 12). Break-even unit price was calculated based on the annual total cost (Table 5) in the condition of the price of wine is not assumed (Figure 13).

Results and Discussion

Life Cycle Assessment (LCA)

For the energy consumption, the bottle manufacture and the wine making contributed the most impact, which account to 35 percent and 31 percent separately (Figure 2). Since compared to vine planting and wine distribution, the process of bottle manufacture and wine making were much more complex and the units of energy consuming within them were more than vine planting and wine distribution, it is no doubt that the bottle manufacture and the wine making contributed the most energy consumption impact.

For the water consumption, the wine making contributed the most impact, account to 91 percent (Figure 2). It could be estimate that in the wine production, water is mainly used within the wine making.

For the output aspect, vine planting and bottle manufacture contributed the most green house gas emission impact, which account to 38 percent and 25 percent separately (Figure 2). While bottle manufacture and wine making contribute the most solid waste disposal impact, which account to 32 percent and 59 percent separately (Figure 2).

Compared to the research conducted by Fusi et al. (2014), which was a 'cradle to grave' LCA (total LCA) to identify and assess the environmental burdens along the white wine life cycle stage, including grape planting, wine production, wine bottling, packaging, distribution and disposal of wine bottle, had the conclusion that the glass bottle production was the most determinative to the environmental performance of production of a bottle of white wine, the present study achieved the same conclusion. Additionally, from the LCA, the wine making also play a very important part on impacting the environment.

Techno-economic Analysis (TEA)

For the annual cost, the cost increases while the production scale increases (Figure 3). The relationship of annual cost of small (5,000 gallons per year), medium (50,000 gallons per year), and large (500,000 gallons per year) fits the exponential increase well with r square value equals to 0.93 (Figure 4). However, it fits the liner increase better with r square equals to 0.99 (Figure 5). While the production scale increases, the contribution of labor cost decreases and the contribution of cost of purchasing wine bottle increases (Figure 6).

For the annual revenue, same as the annual cost, increases while the production scale increases (Figure 7). The relationship of annual revenue of small, medium, and large scales production also fits the exponential increase well with r square value equals to 0.82 (Figure 8). However, from Figure 9, the increase of annual revenue fits linear increase perfectly and the r square value equals to 1. This is because the revenue was calculated purely based on production scale.

For the annual profit, same as the annual cost and annual revenue, increases while the production scale increases (Figure 10). The relationship of annual revenue of small, medium, and large scales production also fits the exponential increase well with r square value equals to 0.78 (Figure 11). Compared to exponential increase, from Figure 12, the increase of annual profit fits linear increase better and the r square value equaled to 1. This 1s because the annual profit is affected more by annual revenue than by annual cost, as the amount of annual revenue is much more than that of annual cost.

For the break-even price, based on the total cost and output of each scale, the relationship between net profit and unit price could be calculated (Figure 13). The break-even price is 4.55 dollar per 750ml bottle for 5,000 gallons per year production, is 1.36 dollar per 750ml bottle for 50,000 gallons per year production, and is 1.12 dollar per 750ml bottle for 500,000 gallons per year production. It showed that the larger the winery production size, the lower the break-even price.

Compared to the research conducted by Dillon et al. (1992), which leaded to the development of an economic decision making model for small to medium-sized wineries, had the conclusion that the larger the winery size, the lower the break-even price, the present study achieved roughly the same result as it found that there was an exponential increase of profit while the winery size increases. However, different from the result that Dillon et al. (1993) found, which was the cost of the raw materials was demonstrate to have substantial effect on the annual net profit, the present study found that the cost of labor and bottle purchasing contribute the most to the total cost (Figure 6).

Implications

Life Cycle Assessment (LCA)

Improve bottle manufacture and wine making process could be efficient to reduce impact of energy and water consumption, as well as reduce impact on solid waste disposal. Improve vine planting and bottle manufacture process could be efficient to reduce impact of greenhouse gas emission.

Techno-economic Analysis (TEA)

Since the annual cost of purchasing wine bottle contributed the most to the annual cost of the large-scale winery, it could build glass bottle factory to reduce the cost of purchasing bottle, therefore increase the profit. Further economic analysis is needed to clarify this.

Conclusions

Life Cycle Assessment (LCA)

For the input impact, bottle manufacture and wine making contributed the most impact on energy consumption while wine making contributed the most impact on water consumption. For the output impact, vine planting and bottle manufacture contributed the most impact on green house gas emission while bottle manufacture and wine making contributed the most impact on solid waste disposal.

Techno-economic Analysis (TEA)

The relationship of the annual cost among small (5,000 gallons per year), medium (50,000 gallons per year), and large (500,000 gallons per year) size production fitted the exponential increase well but fitted the linear increase better. The labor cost contribution to total cost decreased while production size increased while the bottle cost contribution to total cost increased while production size increased. The relationship of the annual revenue among small, medium and large scales production followed the exponential increase well but it fitted linear increase perfectly as it was calculated purely based on production scale. The relationship of the annual net profit among the three scales followed the exponential increase well but due to the effect of the annual revenue, it fitted linear increase better. The break-even prices were 4.55 dollars, 1.36 dollars and 1.12 dollars per 750ml bottle separately for winery sizes of 5,000, 50,000 and 500, gallons per year, the larger the winery size, the lower the break-even price.

References

Alibaba. (2014). Retrieved from http://www.alibaba.com.

Benedetto, G. (2013). The environmental impact of a Sardinian wine by partial life cycle assessment. *Wine Economics and Policy*, *2*(1), 33-41.

Berkowitz, M. (1996). World's Earliest Wine. *Archaeology*, *49*(5), 26.

Bosco, S., Di Bene, C., Galli, M., Remorini, D., Massai, R., & Bonari, E. (2011). Greenhouse gas emissions in the agricultural phase of wine production in the Maremma rural district in Tuscany, Italy. *Italian Journal of Agronomy*, *6*(2), 15.

Considine, J., & Frankish, E. (2013). *Complete guide to quality in small-scale wine making*. Waltham, MA: Elsevier.

Dillon, C. R., Morris, J. R., Price, C., Ward, D., & Metz, D. (1992). Economic Considerations for Small-Sized to Medium-Sized Wineries. *Wine East*, 6-23.

Dillon, C. R., Morris, J., & Price, C. (1993). Effects of grape and other raw material prices on winery profitability. Retrieved from http://www-dev.uark.edu/depts/ifse/grapeprog/articles/ahs114wg.pdf.

EioLCA. (2014). Retrieved from http://www.eiolca.net.

Fusi, A., Guidetti, R., & Benedetto, G. (2014). Delving into the environmental aspect of a Sardinian white wine: from partial to total life cycle assessment. *Science of the Total Environment, 472*, 989-1000.

Hunt, R., & Franklin, W. E. (1996). LCA-how it came about-personal reflections on the origin and the development of LCA in the USA. *Int. J. LCA, 1*(1), 4-7.

ISCD. (2013). Drugs info-alcohol. January 2013.

ISO. (2006).14040: Environmental management: Life cycle assessment: Principles and framework. Vernier, Geneva, Switzerland: International Organization for Standardization.

Johnson, H. (1989). *Vintage: The story of wine*. New York, NY: Simon & Schuster.

Keys, D. (2003). Now that's what you call a real vintage: professor unearths 8,000-year-old wine. *The Independent*, 28.

Klopffer, W. (1997). Life cycle assessment: from beginning to the current state. *Environ. Sci. & Pollut. Res., 4*(4), 223-228.

Marouli, A. Z., & Maroulis, Z. B. (2005). Cost data analysis for the food industry. *Journal of Food Engineering, 67*, 289-299.

Neto, B., Dias, A. C., & Machado, M. (2013). Life cycle assessment of the supply chain of a Portuguese wine: from viticulture to distribution. *Int. J. Life Cycle Assess, 18,* 590-602.

Novak, P., & Burg, P. (2013). Evaluation of harvest losses within a full mechanized grape harvest. *ACTA Universitatis Agriculturae et Silviculturae Mendelianae Brunensis, LXI*(3), 751-756.

Owen, J. (2011). Earliest known winery found in Armenian cave. *National Geographic News*, 10.

Point, E., Tyedmers, P., & Naugler, C. (2012). Life cycle environmental impacts of wine production and consumption in Nova Scotia, Canada. *J. Clean Prod., 27*, 11-20.

Ruiz, F. A., Castel, J. M., Mena, Y., Camunez, J., & Gonzalez-Redondo, P. (2008). Application of the Techno-economic analysis for characterizing, making diagnoses and improving pastoral dairy goat systems in Andalusia (Spain). *Small Ruminant Research, 77,* 208-220.

Sacchi, K. L., Bisson, L. F., & Adams, D. O. (2005). A review of the effect of winemaking techniques on phenolic extraction in red wines. *Am. J. Enol. Vitic., 56*, 197-206.

Sellers-Rubio, R. (2010). Evaluation the economic performance of Spanish wineries*. International Journal of Wine Business Research, 22*(1), 73-84.

The vintner's vault. (2014). Retrieved from http://www.thevintnervault.com.

Vazquez-Rowe, I., Villanueva-Rey, P., Moreira, M. T., & Feijoo, G. (2012). Environmental analysis of Ribeiro wine from a timeline perspective: harvest year matters when reporting environmental impacts. *J. Environ. Manag., 98*, 73-83.

Viegas, J. (2007). Ancient mashed grapes found in Greece. *Discovery News*, March 16, 2007.

World Health Organization. (2011). Global status report on alcohol and health. ISBN 9789241574151.

Table 1. Data inventory for energy and water consumption

	Vine planting	Wine making	Bottle Manufacture	Distribution
Energy (kj)*	10.015	26.755	8.885	6.39
Water (gallon)**	7.37	34.515	11.655	6.53

*EioLCA, 2014

**Fusi et al., 2014

Table 2. Data inventory for greenhouse gas emission (g CO2 equivalents)*

	Vine planting	Wine making	Bottle Manufacture	Distribution
CO2	24.1	28.3	40.7	33.6
CH4	0	0	0	0
N2O	37.9	0	0	0
HFC/PFCS	0	0	0	0
Total	62	28.3	40.7	33.6

*EioLCA, 2014

Table 3. Data inventory for solid waste disposal (g)*

	Vine planting	Wine making	Bottle Manufacture	Distribution
Nitrate	0.48	0	0	0
Sulfur	2.21	0	0	0
Glyphosate	0.17	0	0	0
Mancozeb	0.24	0	0	0
Dimethomorph	43.13	0	0	0
Metiram	0.24	0	0	0
Copper oxychloride	0.23	0	0	0
Marc and lees	0	270	0	0
Stalks	0	50	0	0
Glass	0	0	170	0
Total	46.7	320	170	0

*Fusi et al., 2014

Table 4. Data inventory for TEA

Scale		Small (5,000 gallons/year)	Medium (50,000 gallons/year)	Large (500,000 gallons/year)
Land (acre)		7	70	700
Grape output (tonne)		42	420	4200
Tillage*	Amount of machine	1	5	20
	Machine work time (h)	47.2	95	236
	Fuel consumption (gallon/h)	0.25	1.25	5
	Work efficiency (m^2/h)	600	3000	12000
	Machine cost (dollars/machine)	500	500	500
Fertilizer*	Amount of fertilizer (lb)	105	1050	10500
	Fertilizer cost (dollars/tonne)	300	300	300
Harvester**	Amount of machine	1	1	1
	Machine work time (h)	3	30	300
	Fuel consumption (gallon/h)	4.8	4.8	4.8
	Work efficiency (tonne/h)	14	14	14
	Machine cost (dollars/machine)	170,000	170,000	170,000
Fermentation Tank cost (dollars)*		40000	230000	900000
Oak barrel***	Unit cost (dollars/gallon)	15	15	15
	Total cost (dollars)	75600	756000	7560000
Bottling equipment cost (dollars)****		7000	130000	500000
Bottle cost***	Unit cost (dollars/750ml bottle)	0.5	0.5	0.5
	Total cost (dollars)	12700	127000	1270000
Crush, press, rack, filter equipment cost (dollar)****		15000	80000	500000
Full time employee or wine making process (person)****		2	3	22

*Alibaba, 2014

**Novak and Burg, 2013

*** The vintner's vault, 2014

****Dillon et al., 1992

Table 5. Annual economic data

Scale		Small (5,000 gallons/year)	Medium (50,000 gallons/year)	Large (500,000 gallons/year)
Grape vine	Recycle	0	0	0
Tillage (dollars/year)	Labor	472	950	2360
	Machine	33	167	700
	Energy	36	360	3600
Fertilizer (dollars/year)		14	140	1400
Harvest (dollars/year)	Labor	30	300	3000
	Machine	12,000	12,000	12,000
	Energy	43.2	432	4320
Fermentation Tank (dollars/year)		2,700	15,500	60,000
Oak barrel (dollars/year)		5,040	50,400	504,000
Bottling equipment (dollars/year)		470	8700	35000
Bottle (dollars/year)		12,700	127,000	1270,000
Crush, press, rack, filter equipment (dollars/year)		1,000	5,400	35,000
Labor cost for full time employee (dollars/year)		80,000	120,000	880,000
Cost of equipment and material (dollars/year)		21,336	93,099	656,020
Cost of labor (dollars/year)		80,502	121,250	885,360
Cost of bottle (dollars/year)		12,700	127,000	1270,000
Total cost (dollars/year)		114,587	341,839	2,816,280
Revenue (dollars/year)		252,360	2,523,600	25,236,000
Net profit (dollars/year)		137,773	2,181,761	22,419,720

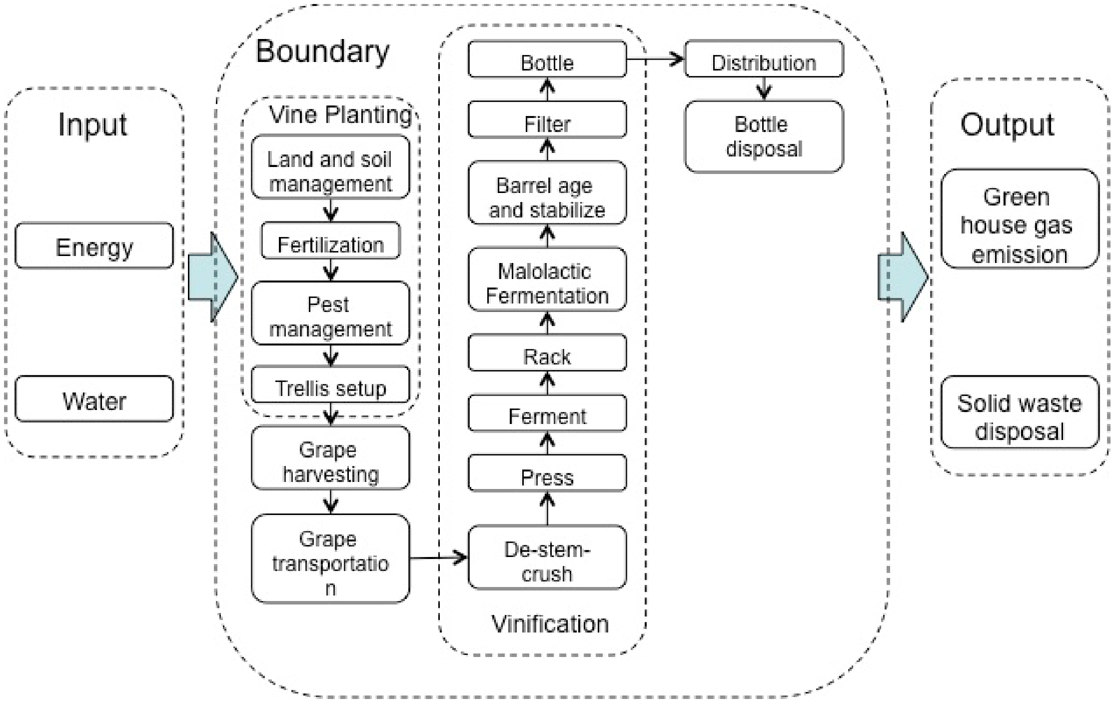

Figure 1. The boundary of LCA

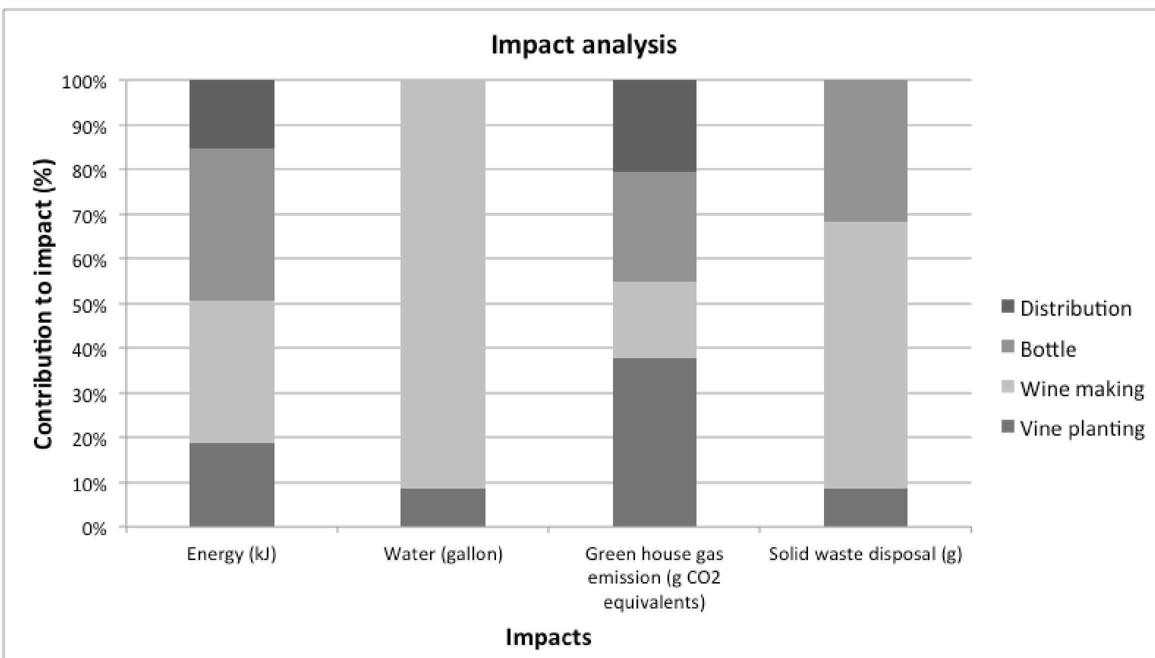

Figure 2. The impact contribution

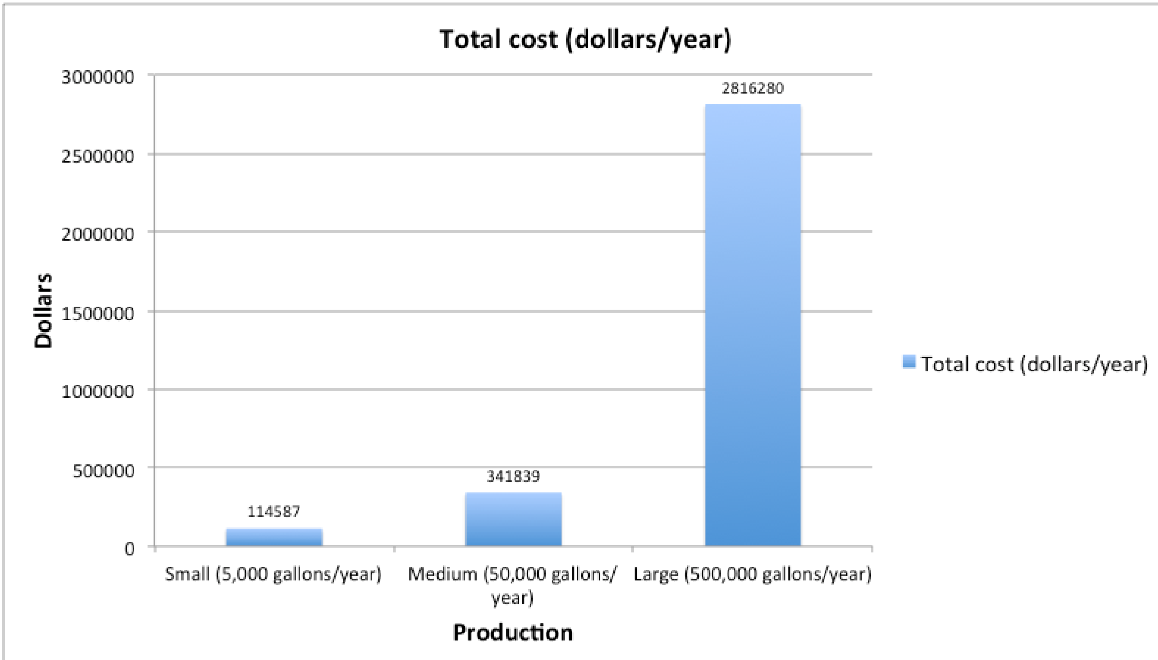

Figure 3. The total annual cost

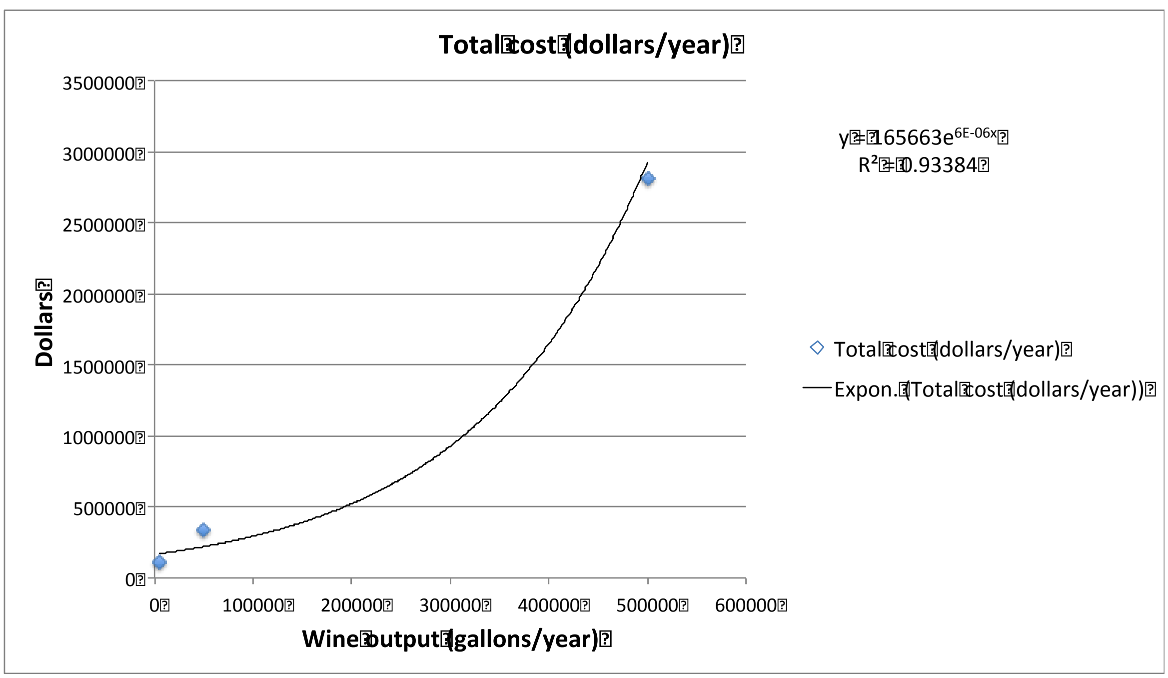

Figure 4. The annual cost relationship among three scales (exp.)

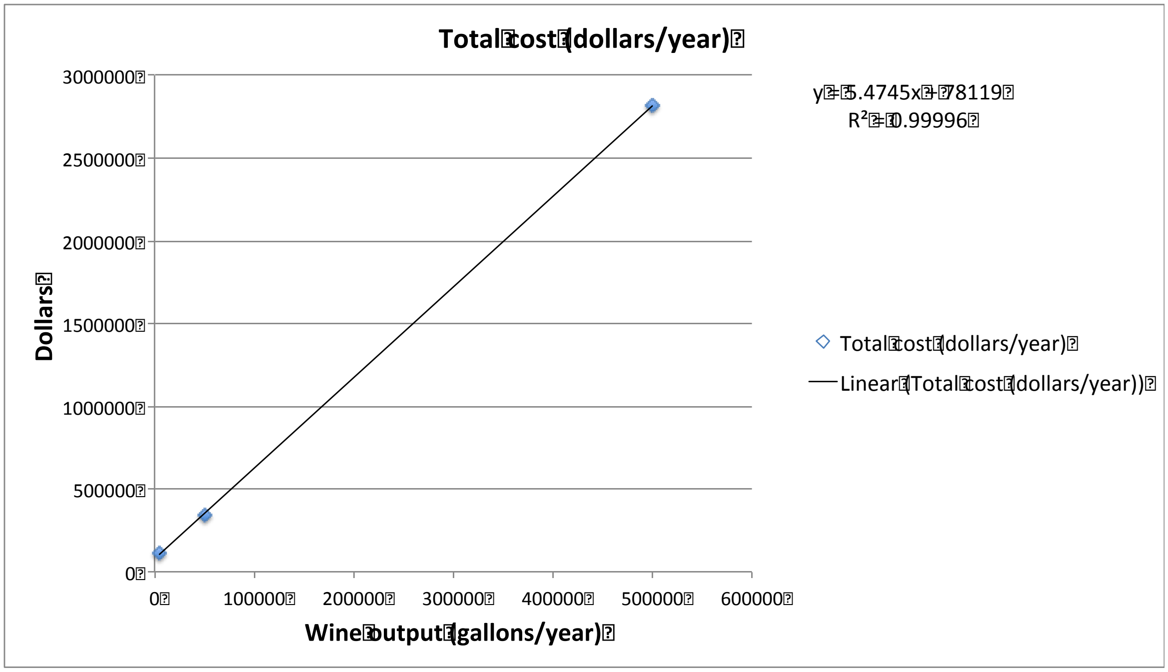

Figure 5. The annual cost relationship among three scales (linear)

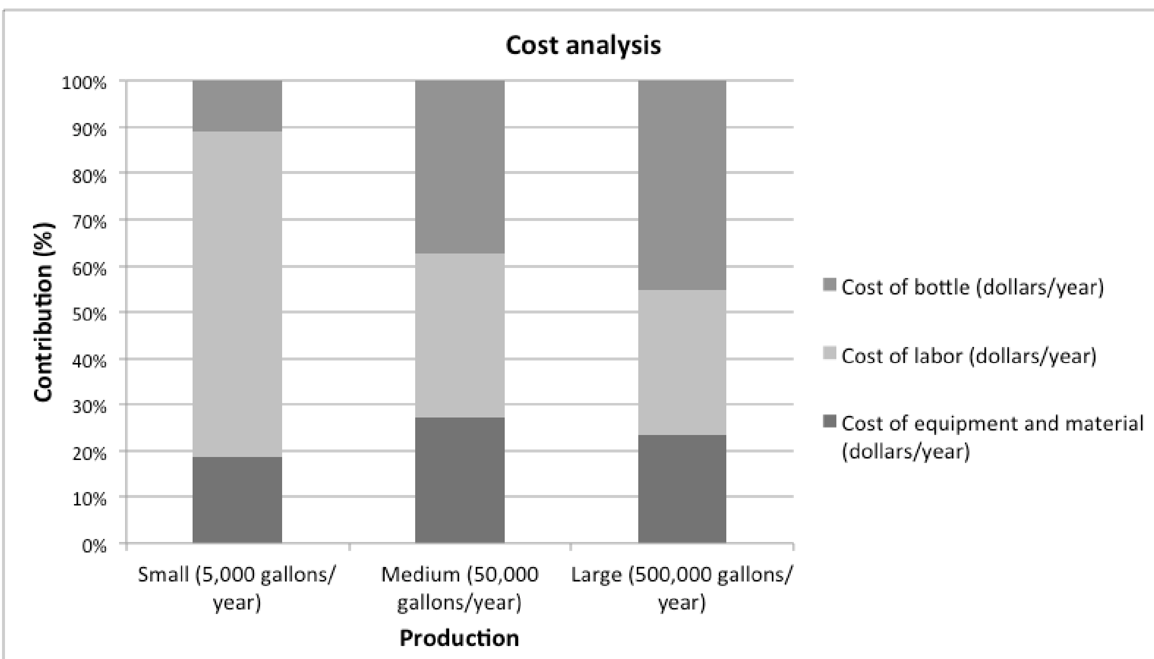

Figure 6. The annual cost analysis

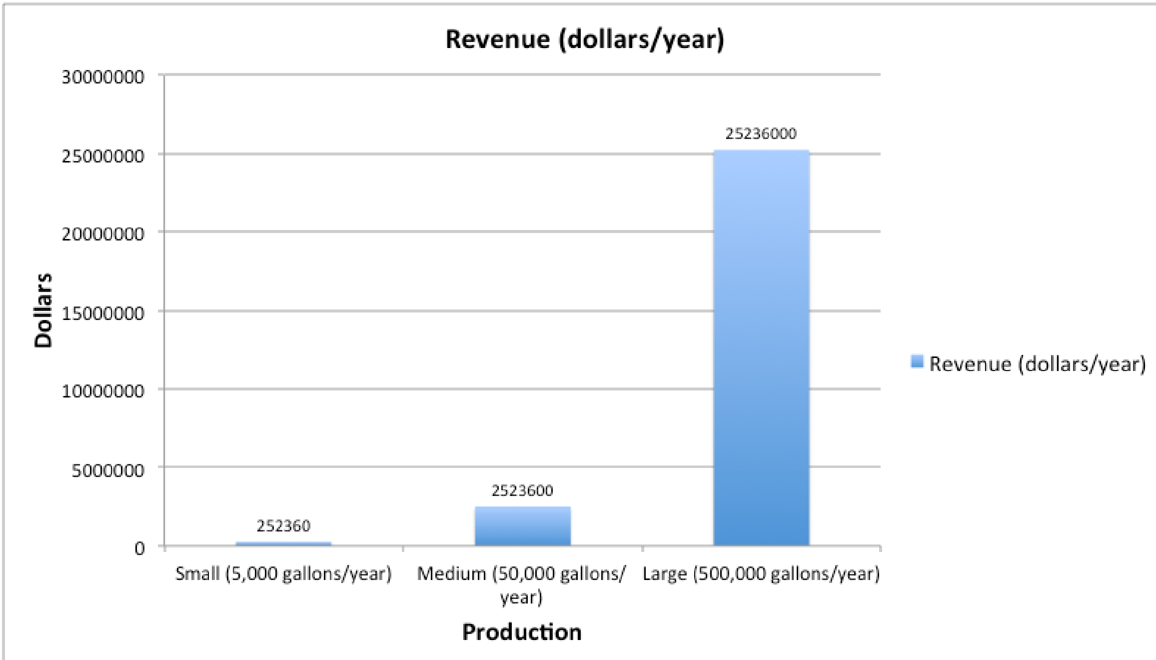

Figure 7. The total annual revenue

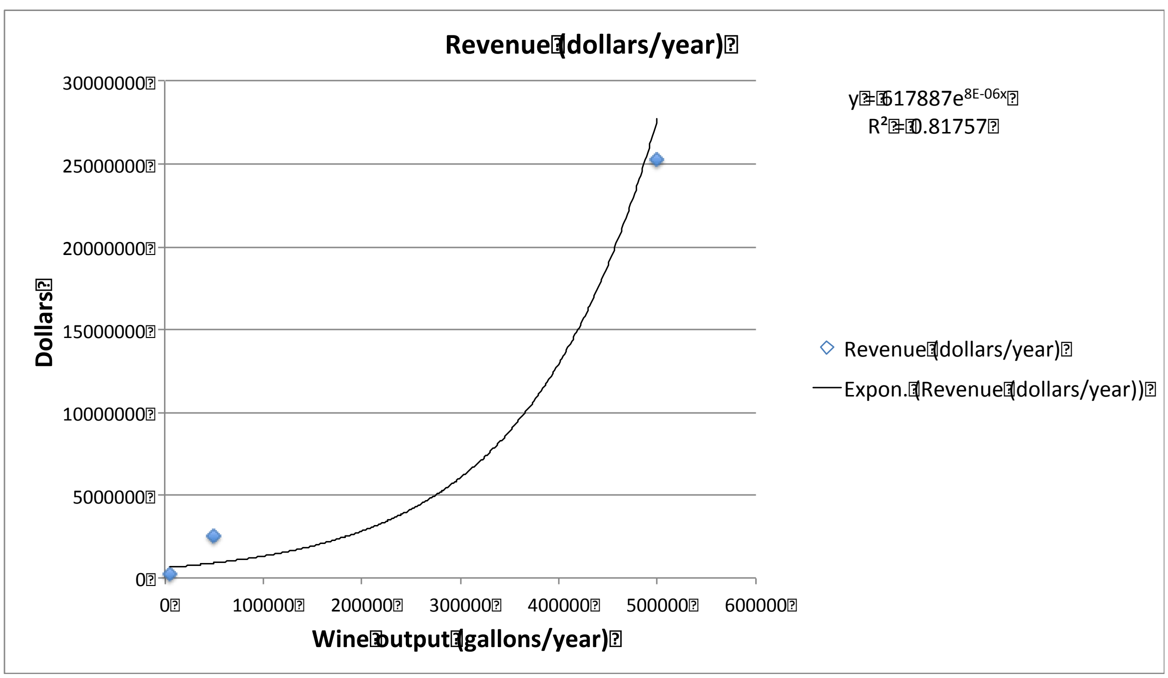

Figure 8. The annual revenue relationship among three scales (exp.)

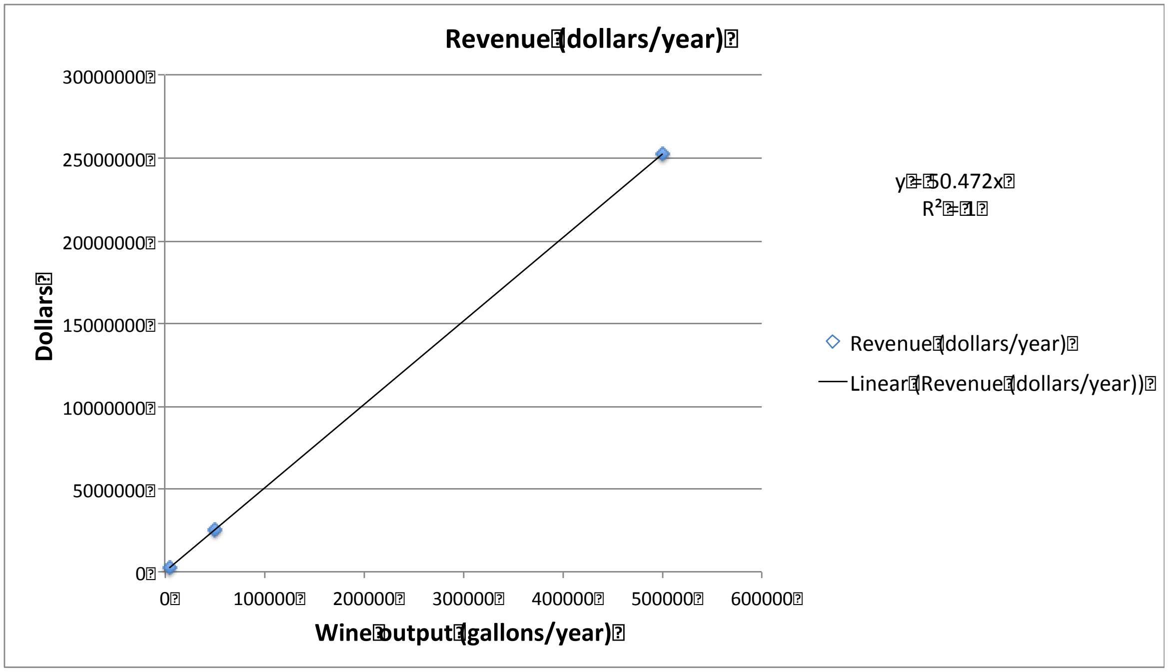

Figure 9. The annual revenue relationship among three scales (linear)

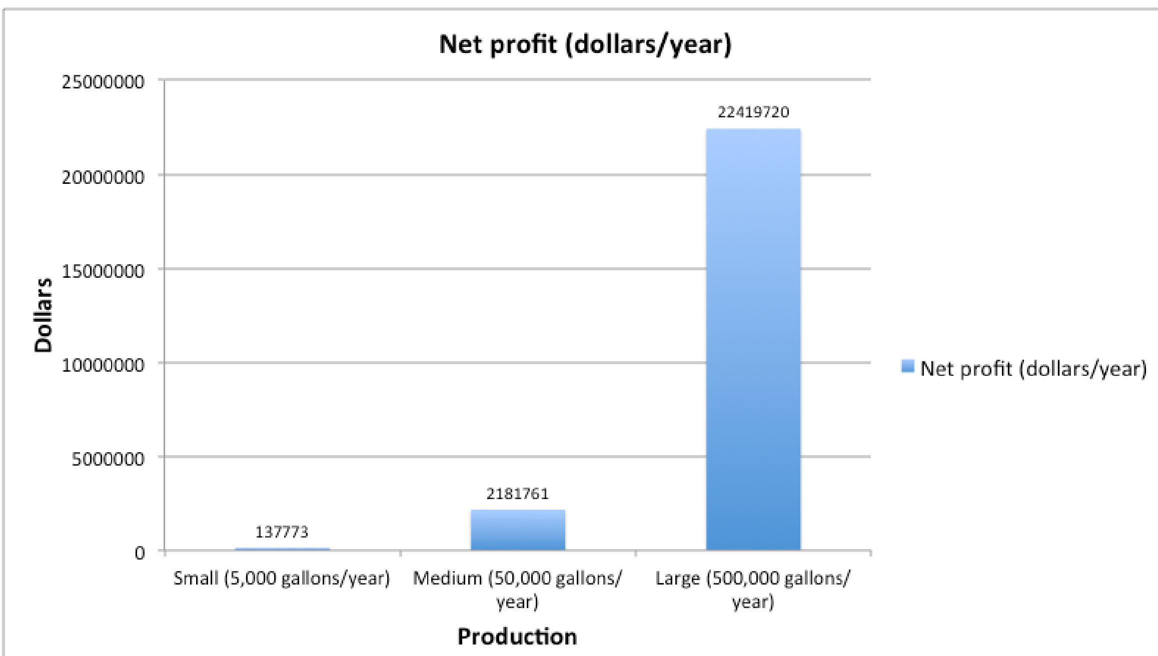

Figure 10. The total annual profit

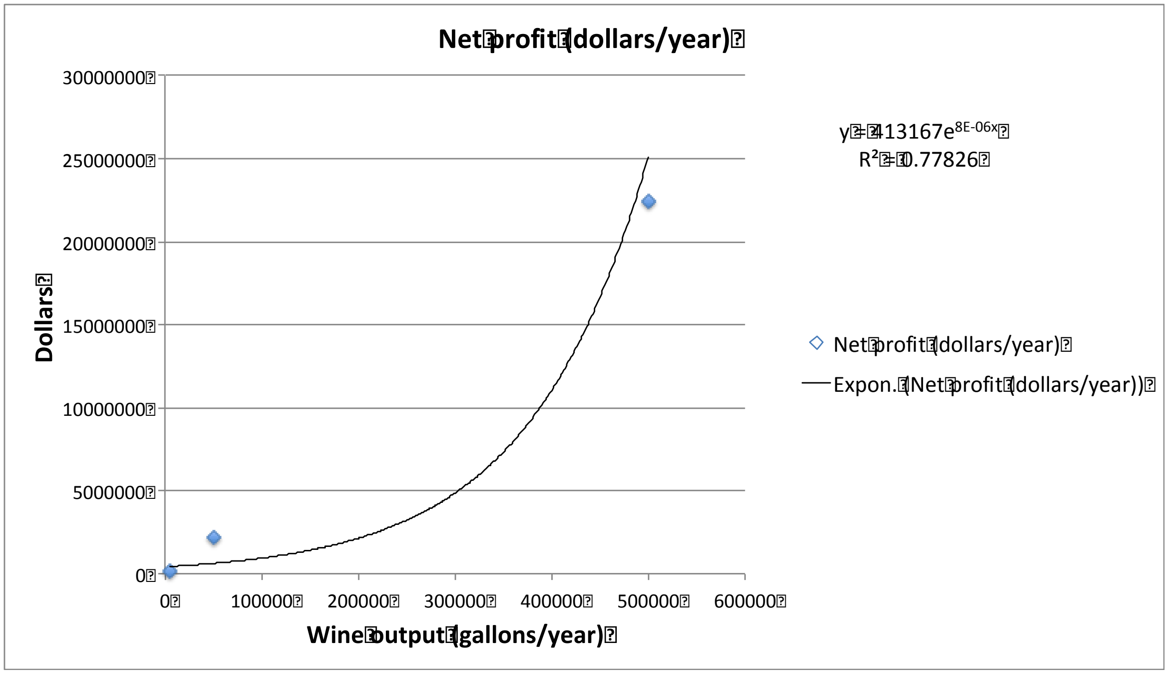

Figure 11. The annual profit relationship among three scales (exp.)

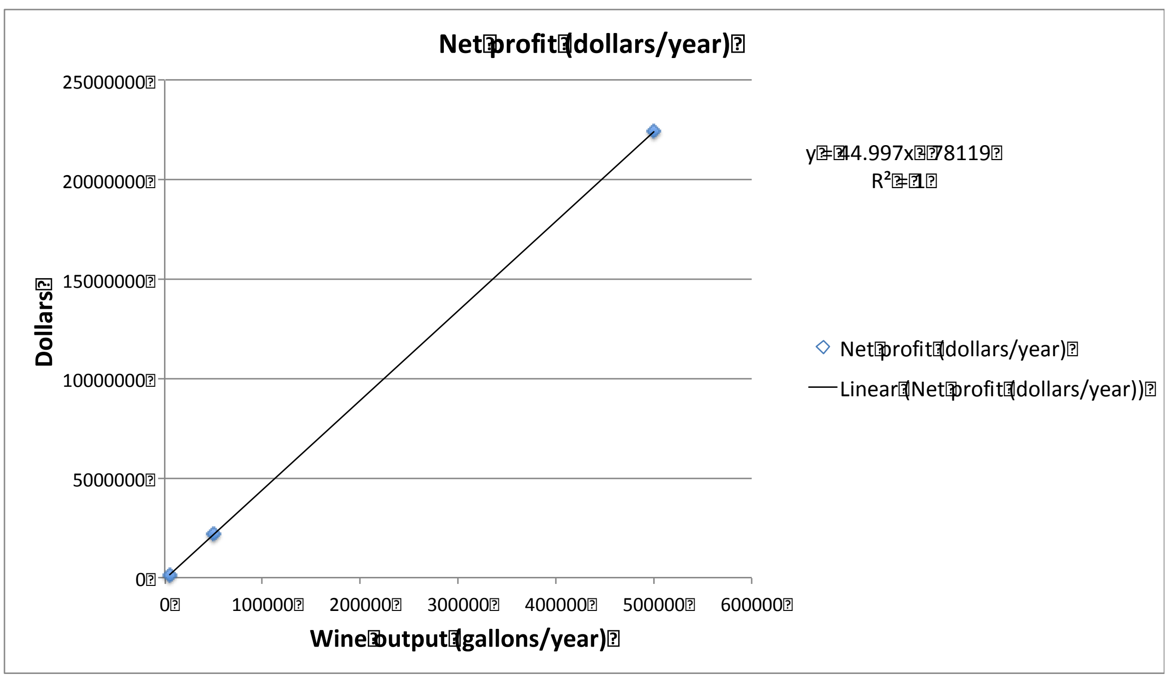

Figure 12. The annual revenue relationship among three scales (linear)

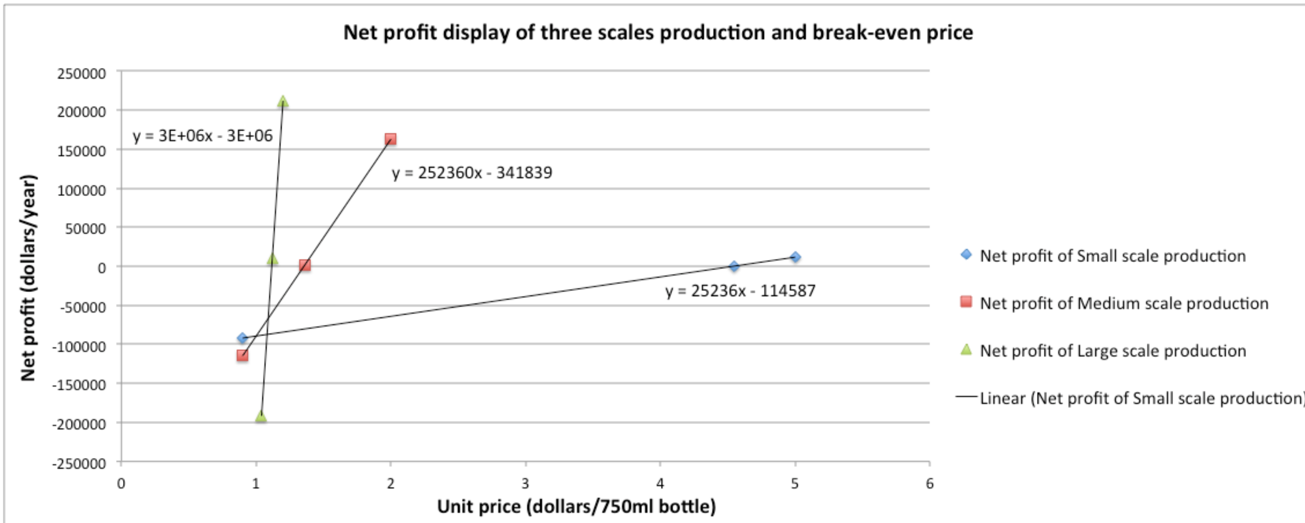

Figure 13. The net profit and break-even price