Planning of Energy Saving with Cogeneration System

by Budi Gunawan

TELKOMNIKA, Vol.16, No.3, June 2018, pp. 989~996
ISSN: 1693-6930, accredited **A** by DIKTI, Decree No: 58/DIKTI/Kep/2013
DOI: 10.12928/TELKOMNIKA.v16i3.5651

Planning of Energy Saving with Cogeneration System

Imam Abdul Rozaq*[1], NYD Setyaningsih[2], Budi Gunawan[3]
[1,2,3] Departement of Electrical Engineering, Universitas Muria Kudus (UMK)
Gondangmanis PO.BOX 53, Telp: +62291-438229/ Fax: +62291-437198
*Corresponding author, e-mail: Imam.rozaq@umk.ac.id[1], noor.yulita@umk.ac.id[2],
Budi.Gunawan@umk.ac.id[3]

Abstract

PT Dua Kelinci is one of the largest food industries in Pati Regency one of whose products is egg peanut which needs huge electric and heat energy so that energy saving needs to be done. One of the efforts of energy saving is by conducting cogeneration (merging between electric and heat). This research started from a data collection, i.e. finding out the need of electricity and heat in the process of egg-peanut manufacture by a cogeneration technology at PT Dua Kelinci. The research method includes technical analysis and economic analysis. From the technical analysis, it is found that the electric energy saving by using cogeneration 103.680 kW and the heat energy saving is 4,075 TJ/year. From the economic analysis it is seen that before using cogeneration the cost that should be expended is USD 75.209,61 while after using cogeneration the cost is USD 60.6014,04 therefore from the economic aspect there is energy saving as much as USD 15.19,57/year.

Keywords: *Planning, energy saving, cogeneration*

1. Introduction

PT Dua Kelinci which is located in the 6.3 km of Pati-Kudus street is one of the biggest industries in Pati, and has a lot of equipment that requires a lot of electrical energy of 4950 kVA from PLN. With that much electric power then PT Dua Kelinci is considered as one of the large electric energy users so that if the electricity is not efficiently used then a lot of energy is wasted. In order that the energy is not wasted, there are a lot of things to do one of which is energy saving. To do energy savings there are several alternatives which can be taken, which include improving the quality of electrical power, the use of energy-saving devices, energy management, the application of cogeneration and so on.

The electric power source of PT Dua Kelinci comes from two sources, i.e. PLN-Pati of 2770 KVA using two transformers and from PLN-Kudus of 2180 KVA which also uses two transformers. The division of the load is illustrated in the scheme as follows. Cogeneration or Combine Heat And Power (CHP) is a technology which combines two energies, i.e. heat and electricity [1]-[4]. The illustration of the use of cogeneration can be seen in Figure 1. Distribution of electrical load from PLN Kudus as shown in Figure 2.

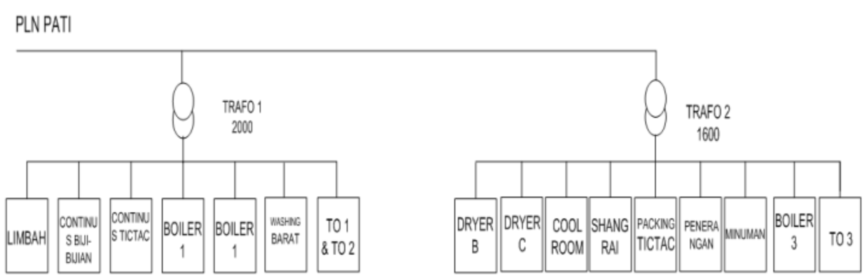

Figure 1. Distribution of Electrical Load from PLN Pati

Received January 17, 2017; Revised March 13, 2018; Accepted April 3, 2018

 ISSN: 1693-6930

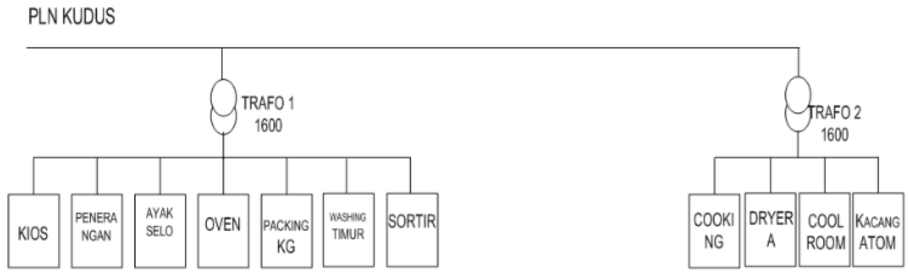

Figure 2. Distribution of Electrical Load from PLN Kudus

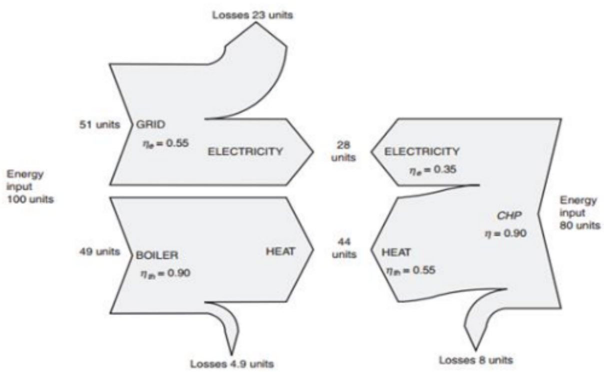

Figure 3. Conventional Generator Vs Cogeneration [5]

There are sixteen general principles of energy management proposed by Craig B. Smith in his book Energy Management Principles, which are general principles that need to be learned before an energy management program is undertaken. These principles include a review of the history of energy use, energy audits, analyzing the used energy, using more efficient equipment, using more efficient processes, energy retention (heat recovery and waste reduction), operation and maintenance, material replacement, material economy (recovery cuts, rescue and recycling), selection of material quality, the used energy collection, energy reduction, use of alternative energy sources, energy conversion, energy storage, and economic evaluation [6].

This paper presents an analysis of the five heating and cooling of energy saving system for high performance mid-level apartments in two Canadian regions: Calgary and Montreal [2]. Rade M. Ciric and Zoran Kuzmanovic present a feasibility analysis of biogas power plants for the combined heat and power plants including different aspects such as the available biomass resources, heat and power production, verification of requirements for connecting power plants to networks, as well as economic feasibility analysis [4].

2. Research Method

The sequence is done in this method are (1) Collect data consists of observations Flow Production Process, (2) Calculated for Electricity and Heat, (3) After knowing the demand for electricity and heat then determine whether to cogeneration or not, (4) Having considered necessary cogeneration then determine the fuel used, (5) Perform feasibility studies, (6) after the feasibility study, we will find that our plans if feasible or not feasible then continue if it does not stop [3,7,8].

Energy use PT Dua Kelinci is electrical energy in supply of PLN and Genset while heat energy derived from Boiler and Thermal Oil, and a new one this month PT Dua Kelinci using CNG (Compress Natural Gas). By looking at the beginning of system energy usage PT Dua Kellinci and make observations in PT Dua Kellinci then there are several processes that can be done as cogeneration application that requires electrical energy and heat energy. One was in the process of making eggs beans that require electrical energy and heat simultaneously. So the authors try to assess the application of cogeneration in the production of eggs beans in PT Dua Kellinci. For more details on the making of the energy consumption eggs beans will be depicted in Figure 4.

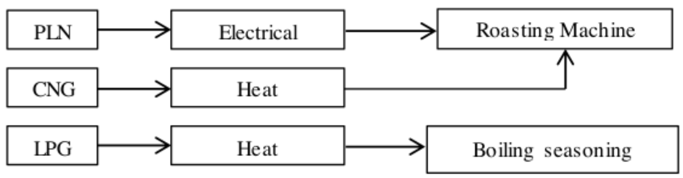

Figure 4. Initial Condition System on Making Peanut Egg [9]

After looking at the initial condition of the use of energy resource on the egg peanut manufacturing process in PT Dua Kelinci, a scheme of cogeneration system is then created as described in Figure 5.

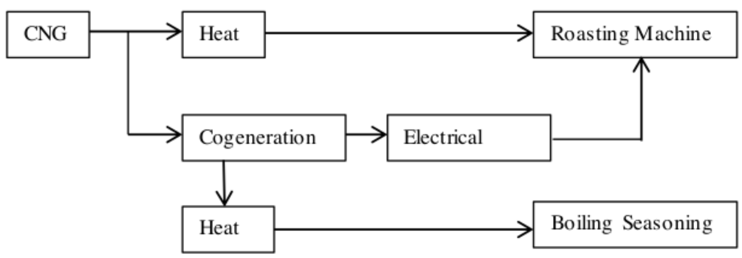

Figure 5. Scheme Implementation Plan Cogeneration System [9]

Figure 5 shows that the implementation of cogeneration or CHP is more efficient, it is seen from the use of three types of energy sources into one source of energy that is CNG as required roasting machine and the main fuel cogeneration that can generate heat and electricity, electricity from cogeneration is used to meet the electrical needs of the roasting machine and the heat generated from the cogeneration results are used in boiling spices so as to meet all the energy needs in the manufacture of peanuts. more details can be seen in the result and analysis

7

3. Results and Analysis

3.1. Initial Energy Before Using Cogeneration

The Electrical energy calculation here is divided into two, those are the calculation of electrical energy at the Peak Load Time (PLT) and the calculation of electrical energy at the Outside Peak Load Time (OPLT), the result as shown in Table 1.

Table 1. Energy Needs In Initial Condition [9]

Description	Energy Needs
Electricity Needs (PLN)	1,49 TJ
LPG demand (boil seasoning)	0,525TJ
Needs CNG (Oven)	8,25 TJ
Total Energy Needs Initial Condition	10,265 TJ

3.2. The resulting plan Energi Cogeneration

The Electrical energy calculation here is done without using Peak Load Time (PLT) and the calculation of electrical energy at the Outside Peak Load Time (OPLT), the result can be seen in Table 2.

Table 2. The energy produced Cogeneration plans [9]

Description	Energy per Year
Substitute Eectical PLN	1,86 TJ
Substitute Heat LPG	4,6 TJ
Heat Oven of CNG	4,125 TJ
Total	10,585 TJ

Hence, the comparison between the initial energy use and the cogeneration use will be shown in Table 3.

Table 3. comparison between the initial energy use and the cogeneration

Description	Innitial Condition	Cogeneration
Use of Electrical Energy (PLN)	1,49 TJ	0
Use of Heat Energy in Seasoning Boiling (LPG)	0,525TJ	0
Use of CNG	8,25 TJ	10,585 TJ
Total	10,265 TJ	10,585 TJ

3.3. Emission in Initial Condition

The emission of the electric use from PLN is by multiplying the baselin emission factor with the generated energy [10]. By using the electrical emission factor of JAMALI (Java Madura Bali) that is 0.725 kgCO_2/kWh, the generated energy is 414,720 kWh/year. The Green House Gas (GHG) emission of the PLN is 0,725x414.720 which equals to 300.672 kgCO2/year or equals to 300,67 tonCO2/year. The GHG emission of LPG is 0,525 TJ/yarx20 Ton C/TJx0,99x 44 tonCO_2/12 tonC=38,115 ton CO_2 /year.

The GHG emission of the use of CNG for heating the roasting oven machine is 8,25x 15,3x0,995x44/12=460,5 ton CO_2/year. The GHG emission of the excess heat to be sold is 4,075x15,3x0,995x44/12=227,5 ton CO_2/year. Hence, the GHG emission which is the GHG emission of PLN+the GHG emission of LPG+CNG emission+the heat excess emission is as follows. GHG Emission=(300,67+38,115+460,5+227,5) ton CO_2/year=1026,785 ton CO_2/year

3.4. GHG Emission Using Capstone Microturbine C-30

Before calculating the emission what should be calculated is the amount of fuel consumption of Capstone Microturbine C-30 that is:

The Use of CNG Fuel for Cogeneration=433.000 BTUx2x8640
=7.482.240.000 BTU
=7,9 TJ

After knowing the amount of fuel consumption of Capstone Microturbine C-30 for one year which is 7.9x15.3x0.995x44/12=435.4 tons CO2/year. The emissions from the use of CNG for heating roasting oven machines are 8.25x15.3x0.995x44/12=460.5 tons CO_2/year. So GHG emissions when using cogeneration are (435.4+460.5) tons CO_2/year=895.9 tons CO2/year.

3.5. The Reduction of Green House Gas (GHG) Emission

The Reduction of GHG Emission is by reducing the emission before using cogeneration and after using cogeneration, 1026,785 tonCO2-895,9 ton CO_2=130,885 ton CO_2. If the reduction of greenhouse gas emission (CO_2) amounts 130,885 ton CO_2/year and to analogize that 1 kg of CO2/year is equal to planting 1 lush tree, then using Capstone microturbine C-30 is the same as planting as many trees as 130.885 kg/13 kg per tree=100.885 trees and by an analogy in which 4,5 ton CO2 can be absorbed by one hectare of tree then 130,885 ton of CO_2 divided 4,5 equals to 29,085 hectares of tree.

3.6. Analyzed Cost Method

Analyzed Cost Method can be used to investigate the characteristics of an economy based on the total annual expenditure and the total annual income [8]. The total annual expenditure of cogeneration covers the ivestment cost, fuel cost, operational and maintenance cost [8]. The total annual income covers income of the electric energy use, heat energy use, excess of heat energy and carbon emission trade. Before proceeding to the economic analysis, there are some assumptions to know, i.e. the price of one unit of Capstone Microturbine C-30 which amounts $ 40.000,00, with bank interest of 10%, operation and maintenace $0,0054/kWh.

3.7. Total Annual Expenditure

The total annual expenditure covers investment, fuel cost, and operation as well as maintenance.

a. Investment Cost

Investment cost is investment cost which should be paid every year. With a 10% interest and an estimated lifespan of 9 years then the annual investment cost is

$$Ica=Cr(i,\ n)\times Ic$$

with

$$Cr(i,n) = \frac{0,1(0,1+1)^5}{(0,1+1)^5-1}$$

$$Cr(i,n) = \frac{0,1\ x\ 1,6}{1,6-1}$$

$$Cr(i,n) = \frac{0,16}{0,6}$$

$$Cr(i,n) = 0,26$$

Hence, the annual investment is

Ica = Cr(i,n)xIc
= 0,26xRp 960.000.000,00
= Rp 249.600.000,00
= USD 18.113, 20

b. Fuel Cost

Fuel costs are used to determine the costs used to purchase fuel within a year.

Cogeneration fuel cost=5,5 USD/mmBTUx433.000 BTUx2x8640 h
=5,5 USD/mmBTUx866.000 BTUx8640 h
=5,5 USD/mmBTUx0,866 mmBTUx8640 h
=USD 41.152,32

The roasting machine fuel cost=7.824.726.135 BTU/tahun
=7.824,726135 mmBTU/tahun
=$ 5,5 /mmBTUx7824,7mmBTU
=$ 43035.85

c. Operational and Maintenance Cost

Capstone Microturbine C-30 with the use of 100% heat energy needs operational and maintenance cost as much as Rp 64,8/kWh. Therefore, the cost of operation and maintenance of the output electric power is Rp 64,8x518.400 kWh=Rp 33.592.320,00, while the cost of operation and maintenance of the output heat is Rp 64,8 x 1.277.777 kWh=Rp 82.799.949,6.

Hence, the operational and maintenance cost is Rp 33.592.320,00+Rp 82.799.949,00= Rp 116.392.269,00. The annual expenditure is Rp 249.600.000,00+Rp 538.721.289,00+ Rp 16.392.269,00 which equals to Rp 904.773.549,00. In detail, the total resulted annual cost can be seen in Table 4.

Table 4. Total of Annual Cost [9]

Description	Energy (TJ)/year
Cost of Annual Investment	USD 18.113,20
Cost of Fuel of CNG Cogeneration	USD 84.188,17
Cost of Operation and Maintenance	USD 8.446,46
Total of Annual Cost	USD 110.747,83

3.8. Total Annual Income Total

The total annual income in this chase is revenue to be earned within a year covering revenue of electricity usage, revenue of heat consumption, electricity excess revenue, heat excess revenue, and revenue of carbon emissions trading.

a. Revenue of the electricity use

The revenue of the electricity use at the Peak Load Time (PLT) is 86400 kWhx Rp 803,00x1,5=Rp 104.068.800,00 while the revenue of the electricity use at the Outside Peak Load Time (OPLT) is 328.320 kWhxRp 803,00=Rp263.640.960,00. Therefore, the revenue of the electric energy use is PLT+OPLT=Rp 104.068.800+Rp263.640.960,00=Rp 367.709.760,00 as much as 26790.76 USD [9].

b. Revenue of Electric Energy Excess

Revenue of Electric Energy Excess=103.680 kWhxelectric sale price
=103.680 kWhxRp 975,00
=Rp 101.088.000,00
=USD 7365.12

c. Revenue of Roasting Machine Heating

The revenue of the roasting machine heating means the use of heat energy for the roasting machine in a year, which can be calculated by multiplying the use of CNG fuel with the usage time, i.e.

Revenue of Roasting Machine Heating=7.824.726.135 BTU/year
=7.824.726.135 mmBTU/year
=US$ 5,5 /mmBTUx7824,7mmBTU
=US$ 43,035.85

d. Revenue of Heat Energy Use

The revenue of the heat energy use in this case means the use of heat energy for boiling the seasoning in a year, which can be calculated by multiplying the use of LPG fuel with the usage time, i.e

=125.478.011 kcal x11.000000000000000 Rp 7355,00
=10.284,8 kg xRp 7355,00
=Rp 75.644.704,00
=US$ 5489.46

e. Revenue of Heat Energy Excess

The excess of heat here is through reducing heat production by the heat use and multiplied by the LPG price. The revenue from the heat energy excess

=(4,6 TJ-0,525 TJ)xRp 7355,00
=4,075 TJxRp 7355,00
=973.925.000 kcalxRp 7355,00
=79.830 kgxRp 7355,00
=Rp 587.149.650,00
=USD 42.608,82

f. The Calculation of Green House Gas Emission

The carbon emission trade is as follows:

The carbon emission trade=130,885 ton CO_2/yearxRp 80.000,00=Rp 10.470.800,00. In detail, the Total Annual Revenue of Capstone Microturbine C-30 can be seen in Table 5.

Table 5. Annual Revenue of Cogeneration [9]

Description	Revenue
Revenue of the use of electric energy use of PLN	USD 26.790,76
Revenue of electric energy excess of PLN	USD 7.365,12
Revenue of CNG heating	USD 43.035,85
Revenue of Use without LPG	USD 5.489,46
Revenue of heat energy excess	USD 42.608,82
Revenue of carbon emission reduction	USD 759,85
Total Annual Revenue	USD 126.049,86

3.9. Total Net Revenue

After knowing the total annual cost that should be spent and the total annual revenue, then the net revenue can be found by reducing the total annual revenue by the total annual cost.

Total Net Revenue=total annual revenue–total annual cost
=USD126.049,86–USD110.747,83
=USD 15.302,03

To determine the savings that can be done after applying the cogeneration system using two capstone microturbine C-30 described in the comparison table between initial condition and cogeneration, it can be seen in Table 6.

Table 6. Comparison between Initial Condition and Coogenaration [9]

Description	Innitial Condition	Cogeneration
Use of PLN Electricity	USD (-26.684,30)	-
Use of LPG	USD (-5.489,46)	-
Use of CNG	USD (-43.035,85)	USD (-84.188,17)
Purchase of Electric Excess	-	USD 7.365,12
Heat Excess Revenue	-	USD 42.608,82
Tax Reduction of CO_2	-	USD 759,85
Operational and Maintenance Cost	-	USD (-8.446,46)
Cost of Annual Investment	-	USD (-18.113,20)
Total	USD (-75.209,61)	USD (-60.014,04)
Saving	USD 15.195,57	

In the initial conditions, the company has to pay electricity and heat costs of USD 75,209.61 whereas when using cogeneration it only needs to pay the cost of electricity and heat costs as well as getting USD 60,014.04 thus the total saving is USD 15,195.57.

4. Conclusion

From the research it can be concluded that:

a. The application of cogeneration technology at PT Dua Kelinci with the excess of electricity sales of 103,680 kW, the excess of heat sales of 4,075 TJ/year, and the greenhouse emission trade of 130.88 tonCO2 which can be assumed as planting trees of 29 hectares.
b. In the initial conditions, the company has to pay electricity and heat costs of USD 75,209.61 whereas if using cogeneration it only needs to pay the electricity and heat costs amounting USD 60,014.04 thereby the total saving is USD 15,195.57 per year.

References

[1] AC Ferreira, ML Nunes, LB Martins, SF Teixeira. *Technical-Economic Evaluation of a Cogeneration Unit Considering Carbon Emission Savings. Int. J. Sustain. Energy Plan. Manag.* 2014; 2: 33–46.
[2] Anagal, Ashutosh S. *Performance Analysis of Gas Turbine Cogeneration Systems*. Faculty of Engineering and Applied Science, University of Ontario Institute of Technology. 2014.
[3] JC Ho, KJ Chua, SK Chou. Performance study of a microturbine system for cogeneration application. *Renewable Energi*. 2003; 29.

[4] Rade MC and Zoran K. Techno-Economic Analysis of Biogas Powered Cogeneration. *Journal of Automation and Control Engineering*. 2014; 2(1).
[5] D Raghavan. Application of microturbine for power and cooling Master work at National University of Singapore. Department of Mechanical and Production Engineering. 2000.
[6] M Kegel, J Tamasauskas, R Sunye, D Giguere. Techno-Economic Analysis of Heat Pump and Cogeneration Systems for a High Performance Midrise Apartment in the Canadian Climate. 2014.
[7] Craig BS. Energy Management Principles. 2015.
[8] RH Sumbiring. Analisis Tekno-Ekonomi Pemanfaatan Gas Alam Menggunakan Sistem Kogenerasi di Rumah Sakit (Studi Kasus Rumah Sakit Kanker Dharmais). Universitas Indonesia, Depok. 2009.
[9] IA Rozaq, Perencanaan Penghematan Energi Dengan Sistem Kogenerasi / Combine Heat And Power (CHP) Capstone Microturbine C-30 Di PT Dua Kelinci. Universitas Islam Sultan Agung, Semarang. 2014.
[10] P Vivek, Kumar, P Vijaya. Heat Recovery Steam Generator by Using Cogeneration. *International Journal of Engineering Research*. 2014; 3(8): 512-516.

Planning of Energy Saving with Cogeneration System

ORIGINALITY REPORT

4%	3%	1%	0%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	www.joace.org Internet Source	1%
2	docs.lib.purdue.edu Internet Source	1%
3	Submitted to School of Business and Management ITB Student Paper	<1%
4	Muhammad Nauman Saeed, Mohammad Shahrivar, Gajanan Dattarao Surywanshi, Tharun Roshan Kumar et al. "Production of aviation fuel with negative emissions via chemical looping gasification of biogenic residues: Full chain process modelling and techno-economic analysis", Fuel Processing Technology, 2023 Publication	<1%
5	eprints.gla.ac.uk Internet Source	<1%
6	www.adb.org Internet Source	<1%

7	"Cold Climate HVAC 2018", Springer Science and Business Media LLC, 2019 Publication	<1%
8	Craig B. Smith, Kelly E. Parmenter. "General Principles of Energy Management", Elsevier BV, 2016 Publication	<1%
9	worldwidescience.org Internet Source	<1%

Exclude quotes	Off	Exclude matches	Off
Exclude bibliography	On		