J. Agr. Sci. Tech. (2022) Vol. 24(4): 767-777

Energy Productivity and Efficiency in Sunflower Production

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ABSTRACT

Agricultural production is very important in terms of both energy production and consumption. The main purpose of this study was to calculate the energy values, productivity, and energy efficiency of inputs used in sunflower production in Konya. The sample volume was calculated as 51 by using the Neyman Method of the Stratified Random Sampling Method. In the energy balance analysis of enterprises, the energy equations of all outputs and inputs used in sunflower production were acquired by multiplying with conversion coefficients. Energy output and input equations were calculated for unit sunflower production (MJ kg^{-1}). In conclusion, it was ascertained that 25.26% of the total energy input per hectare comprised direct energy and 74.74% consisted of indirect energy. Energy use efficiency in the research area was 4.94, while the specific energy value was 5.06 MJ kg^{-1}. In other words, 5.06 MJ kg^{-1} of energy was consumed for 1 kg of sunflower production. The price of 1 kg of sunflower is USD 0.60. The average Technical Efficiency (TE) of the enterprises in the research area was 0.874, and 29.41% of the enterprises producing sunflowers were efficient in energy use per production, whereas 70.58% were less efficient enterprises. Saving energy in sunflower production will have a positive economic impact on the business.

Keywords: Energy balance analysis, Konya, Technical efficiency,

INTRODUCTION

As the Green Revolution has led to higher consumption of high-yielding crops, use of chemical inputs in agriculture and consumption of energy (diesel fuel and electricity) has become more intense. In order to investigate the effects of energy use in agricultural systems, it is important to consider the impact of the use of limited natural resources and high amounts of various energy inputs on the environment and human health. Energy consumption analysis is generally applied to evaluate the efficiency and environmental impacts of production in agricultural ecosystems (Ozkan *et al*., 2004; Hatirli *et al*., 2005; Yousefi *et al.*, 2017). One of the most important environmental impacts of energy consumption, especially energy derived from fossil fuels, is Greenhouse Gas (GHG) emissions. Today, environmental problems such as global warming and air pollution result from the use of fossil energy (Esengün *et al*., 2007). For the sustainability of agricultural production, energy must be used efficiently in agriculture. Increasing modernization in agricultural production has revealed use of more input and energy (Mandal *et al*., 2002). Energy use generally occurs in plant protection, irrigation, agricultural control, fertilization, harvesting and other processes (Moreno *et al*., 2011). The efficient use of energy in rural areas enhances sustainability, efficiency, and agricultural investments, preserves fossil resources and diminishes air pollution (Singh, 2002; Rafiee *et al*., 2010; Mousavi-Avvale *et al*., 2011). Energy consumption in agricultural production is classified as direct and indirect. Direct energy consumption is the consumption of fossil fuels, while indirect energy consumption is the

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conversion of fossil fuels into products such as fertilizers and pesticides (McLaughlin *et al*. 2002).

Comparison of the total energy value of the inputs utilized in agricultural production processes with the energy value of the acquired product is a more realistic approach in terms of evaluation of production efficiency (Öztürk, 2011; Bayhan, 2016). Davoodi and Housyar (2009) reported that the energy ratio for sunflowers was 2.17, while the specific energy value was 12.52 MJ kg^{-1} in Iran. Baran *et al*. (2014) calculated the net energy production in the second crop sunflower production as 34,404.90 MJ ha^{-1}, the energy productivity as 0.12 kg MJ^{-1}, and the specific energy value as 8.19 MJ kg^{-1} in Kırklareli. Additionally, the energy output/input ratio was calculated as 3.21, and irrigation energy, by 30.36%, was the highest among the total energy inputs, followed by fertilizer energy by 28.78% and fuel-oil energy by 24.74%. Bayhan (2016) compared the energy use efficiency of 4 different tillage and direct sowing methods in production of sunflower as the second crop and concluded that the highest energy rate was 11.82, the lowest specific energy value was 2.23 MJ kg-1 and the highest energy productivity was 0.45 kg. The highest net energy yield was obtained from the rotary tiller method with a 63,047.59 MJ ha^{-1} value in Tekirdağ.

Energy input and output analyses are applied to measure the efficiency and environmental impact of production systems. However, in addition to environmental analyses, economic and energy analyses are also important in agricultural production (Mobtaker *et al*., 2010). Numerous studies have been conducted to determine the energy use efficiency of agricultural products. For instance, studies on the following subjects: sunflower production (Kallivroussis *et al*., 2002; Kasap and Coşkun, 2006; Yousefi *et al*., 2017), sunflower seed (Uzunoz *et al*., 2008; Kallivroussis *et al*., 2002; Cui *et al*., 2019), soybeans (Mandal *et al*., 2002; Sartori *et al*., 2005), cereals, cluster bean, mustard, maize (Singh *et al*., 2003), rice, cassava (Soltani *et al*. 2013), and tuberous crops and sugar beet plants (Asgharipour *et al*., 2012; Karimi *et al*., 2008). However, almost all of these studies focus on energy input-output analysis. In addition, there are many efficiency analysis studies in the literature, yet, analysis of energy use efficiency has not been performed in these studies (Salvioni and Agovino, 2015; Kashiwagi *et al*., 2016; Musliu *et al*., 2019).

In the present study, in addition to input-output energy analysis, efficient and ineffective enterprises in terms of energy use were determined and technical efficiencies, pure technical efficiencies, and scale efficiencies of enterprises were calculated. With the study, it has been revealed whether the inputs are used effectively in terms of energy output/input. Unconscious use of chemicals and fertilizers causes both environmental damage and waste of inputs. In addition, increased productivity in agriculture can be achieved within certain limits. However, the energy use efficiency value can be reduced by the conscious use of inputs (tillage, spraying, mechanization, fertilization, etc. For this reason, in the study, it has been revealed how much saving can be made in input energy by determining the enterprises that are effective or inefficient in terms of energy use in agriculture.

MATERIALS AND METHODS

The main material of the research was the data obtained through surveys from the agricultural enterprises involved in sunflower cultivation in the Karatay District of Konya, in 2016. The sample volume was calculated as 51 by using the Neyman Method of the Stratified Random Sampling Method.

$$n = \frac{\sum(Nh.Sh)^2}{N^2.D^2 + \sum Nh.(Sh)^2} \quad (1)$$

$$D^2 = (\frac{d}{t})^2 \quad (2)$$

Where, n: Number of samples, N: Total unit Number belonging to the sampling frame, Nh: Number of enterprises in layer h, Sh: Standard deviation of layer h, d: Allowable margin of error from the population average, t: t-table value corresponding to the anticipated 99% confidence limit (Yamane, 1967).

Gross Production Value (GPV), Total Costs (TC), Gross Profit (GP) and Net Profit (NP) were calculated as an outcome of the economic activities of the enterprises (Canakci *et al*., 2005; Erdal *et al*., 2007; Erkus and Demirci, 2007; Mousavi-Avval *et al*., 2010). With regard to the calculation of the results of this economic activity, the USD rate was taken as 2.56, the rate in 2016, when the survey was carried out. GPV was calculated by adding the increase of fixed costs in plant and animal production to the value of the output produced by the enterprises, which were evaluated with the farmyard prices. (Oguz and Bayramoglu, 2018).

TC= Variable Costs (VC)+Fixed Costs (FC)

GP= GPV-VC

Net Profit= GPV-Production costs

To calculate the energy efficiency of sunflower production enterprises, energy inputs and outputs must first be calculated (Table 1).

Calculation of Energy Inputs

The energy inputs used in sunflower production were divided into direct energy (fuel oil, labour and water) and indirect energy (machine energy, seeds, fertilizer and pesticide) categories. Energy output, on the other hand, was sunflower yield.

Human Labour Energy (HLE)

In the research area, human labour involves work such as hoeing, irrigation, reaping, etc. EE is the Energy Equivalent of human labour (MJ ha^{-1}).

HLE= (Working hours/ha)×EE (3)

Machine Energy Input (MEI)

MEI included the use of tractors and other

Table 1. Energy values used in sunflower production.

Inputs and Outputs	Unit	MJ/Unit	Sources
Inputs			
Human labour	ha	1.96	Yaldiz *et al*. (1993)
Machine			
Soil preparation	ha	62.70	Singh (2002); Singh *et al*. (2003)
Marketing	ha	29.80	Fluck (1992); Biondi *et al*. (1987); Bonnie (1987)
Fertilizer			
N	kg	75.40	Spugnoli *et al*. (1993); Bonnie (1987)
P	kg	10.90	Spugnoli *et al*. (1993); Bonnie (1987)
K	kg	9.90	Spugnoli *et al*. (1993); Bonnie (1987)
Pesticides			
Herbicides	kg	288	Green (1987); Hülsbergen *et al*. (2001)
Fungicides	kg	196	Green (1987); Hülsbergen *et al*. (2001)
Insecticides	kg	237	Green (1987); Hülsbergen *et al*. (2001)
Fuel-Oil	L	56.31	Singh (2002); Singh *et al*. (2003)
Water	m^3	0.63	Yaldiz *et al*. (1993)
Seed	kg	3.60	Ozkan *et al*. (2004)
Output			
Sunflower	kg	25	Hatirli *et al*. (2005)

machines used in crop production (Pishgar *et al.*, 2012). G is the machine weight (kg), EE is the machine Energy Equivalent (MJ ha^{-1}), t is the duration of machine energy equivalent used per hectare (h), and T is the economic life of the machine (h).

MEI= (G×EE×t)/T (4)

Fuel and Lubricant Energy (FE)

FE is Fuel Energy per hectare (MJ ha^{-1}), Qf indicates fuel expense (L ha^{-1}), and EE is the Energy Equivalent (MJ ha^{-1}).

FE = Qf×EE (5)

Lubricant Energy (LE)

LE indicates Lubricant Energy input (MJ ha^{-1}), FE is Fuel Expense (L ha^{-1}), and LE is Energy value of Lubricant (MJ L^{-1})

LE= (FE×0.045)×LE (6)

Calculation of Total Energy Output (TEO)

The energy output per unit area was obtained by the following formula (Öztürk, 2011):

TEO=SY×SEE (7)

Where, TEO: Total Energy Output (MJ ha^{-1}), SY: Sunflower Yield (kg ha^{-1}), SEE: Sunflower Energy Equivalent (MJ kg^{-1}).

In this study, energy use efficiency, energy productivity, specific energy, energy intensity, energy intensiveness, and net energy gain (Equations 8-13) were calculated by using the following formulas (Mobtaker *et al.*, 2010):

Energy Use Efficiency (EUE)= Energy output (MJ ha^{-1})/Energy input (MJ ha^{-1}) (8)

Energy Productivity= Sunflower yield (kg ha^{-1})/Energy input (MJ ha^{-1}) (9)

Specific Energy= Energy input (MJ ha^{-1}) /Sunflower yield (kg ha^{-1}) (10)

Energy Intensity= Sunflower input (MJ ha^{-1})/Energy output (MJ ha^{-1}) (11)

Energy Intensiveness= Energy input (MJ ha^{-1})/Cost of production (USD ha^{-1}) (12)

Net Energy Gain (NEG)= Energy output (MJ ha^{-1})-Energy input (MJ ha^{-1}) (13)

The Data Envelopment Analysis (DEA) method is one of the non-parametric models and measures the relative effectiveness of "n"-times decision-making units (Coelli, 1996). This model was used in the study in order to calculate the resource usage efficiency of the enterprises producing sunflower according to the energy usage amount. Sunflower yield per enterprise is included in the model as an output variable.

As agricultural enterprises tend to control inputs, Farrell's (1957) input efficiency-oriented measures were used in the study. In efficiency measurements, sunflower producing enterprises consider fertilizer (MJ ha^{-1}), fuel oil (MJ ha^{-1}), water (MJ ha^{-1}), pesticide (MJ ha^{-1}), seed (MJ ha^{-1}), machine energy (MJ ha^{-1}) and human labour (MJ ha^{-1}) as inputs. The Data Envelopment Analysis includes CCR and BCC models. CCR and BCC models were used to reveal the resource usage efficiency of sunflower producing enterprises. The CCR model is based on the assumption of constant returns on scale and its limit is given below (Banker *et al.*, 1984; Charnes *et al.*, 1978). Technical efficiency, pure efficiency and scale efficiency were calculated for the sunflower yield (MJ kg^{-1}) as energy input. The main efficiency criterion in the Data Envelopment Analysis is the division of weighted totals of the outputs to the weighted totals of the inputs. In the case of multiple input and output factors, TE score was found as follows (Cooper *et al.*, 2004; Coelli *et al.*, 2002).

$$TE_j = \frac{U_1 Y_{j1} + U_2 Y_{2j} + \cdots \ldots + U_n Y_{nj}}{V_1 X_{j1j\iota} + V_2 X_{2j} + \cdots \ldots + V_n X_{nj}} = \frac{\sum_{r-1}^{n} + U_r Y_{rj}}{\sum_{s-1}^{m} + V_s X_{sj}} \quad (14)$$

Where, U_r is the weight given to output "n", Y_r is the amount of output "n", "V_s" is the weight given to input "n", X_s is the amount of input "n", "r" is the number of outputs (r=1, 2, …., n), “s” is the number of inputs (s= 1, 2, …, m) and “j” represents the j[th] of DMUs (j =1, 2, …, k). Following linear programming, the Eq. can be solved as follows:

$$maximize\ TE = a_0 + \sum_{r-1}^{n} U_r Y_{rj} \quad (15)$$

$$\sum_{r-1}^{n} U_r Y_{rj} - \sum_{s-1}^{m} V_s X_{sj} \leq 0 \quad (16)$$

$$\sum_{s-1}^{m} V_s X_{sj} = 1, U_r \geq 0, V_s \geq 0\ ve\ (\text{"i" ve "j"} = 1,2,3,\ldots k) \quad (17)$$

If not all production units are on the optimal scale according to the BCC model, the use of a constant return to the scale results in a measure of technical efficiency mixed with scale efficiencies (Farrell, 1985; Coelli, 1996). In case the constant returns to scale and the Technical Efficiency Value (TE_{VRS}) of the return that changes according to the scale are different for a given production unit, it is determined that the production unit has ineffectiveness. Thus, Scale Efficiency (SE) takes advantage of the difference between the technical efficiency values obtained with these two assumptions (Farrell, 1957).

Total technical efficiency=Pure technical efficiency*Scale efficiency (TE_{CRS}= TE_{VRS}×SE)

$$maximize\ Z = uy_i - uy_i$$
$$Subjected\ to\ vx_i = 1$$
$$-vX + uY - u_0 e \leq 0$$
$$v \geq 0, u \geq 0_0$$

Where, “Z” and “u0” are scalar and free in sign, “u” and “v” are output and input weight matrices, and “Y” and “X” are the corresponding output and input matrices, respectively. The “xi” and “yi” refer to the inputs and outputs of its DMU, respectively. In addition, in the efficiency analysis, enterprises with a TE coefficient between 0.95 and 1 were classified as efficient, those between 0.90 and 0.95 as less efficient, and those below 0.90 as inefficient (Banker *et al*., 1984). In practice, it is recommended that the number of decision units must be at least the product of the number of inputs and the number of outputs or three times the total number of inputs and outputs (Cooper *et al*., 2007). According to Sherman (1984), if *n* is the number of observations, *m* is the number of inputs, and *s* is the number of outputs, then, the number of decision-making units should be $n > m+s$. However, the generally accepted equation is that the minimum number of decision-making units= 2×m×n (Kocakalay, 2003). In this study, source utilization efficiency-analysis of sunflower producing enterprises was formed in the DEA program.

RESULTS AND DISCUSSION

Energy Values in Sunflower Production

The input energy is divided into four parts as direct, indirect, renewable and non-renewable energy. The direct energy includes fuel oil, labour, and water used in sunflower production, while the indirect energy involved machinery, seed, fertilizer and pesticide. Renewable energy refers to human labour and seeds, while non-renewable energy includes machine energy, seeds, fertilizers and pesticides (Table 2).

In the research area, the highest share among production inputs belonged to non-renewable energy (machine energy, seed, fertilizer and pesticide) use by 96.81%, while 3.19% is the amount calculated for renewable energy (human labour, seed and water) consumption. Total energy output was 102,595.59 (MJ ha^{-1}), (Table 3). This shows that energy was used efficiently and the production systems of the enterprises were good (Table 3).

In similar studies carried out in Tokat Province and Iran, energy use efficiency (energy ratio) was determined as 2.15 and 2.95, respectively (Uzunoz *et al*., 2008; Davoodi and Houshyar, 2009). Energy use efficiency in sunflower+soybean production in Hamedan, Iran, was calculated as 7.44 (Hamzei and Seyyedi, 2016). High-energy productivity refers to high-energy efficiency in production. In the research area, energy efficiency in sunflower production was

Table 2. Energy coefficients used in sunflower production.

Parameter	Definitions	Units
Direct Energy (E_D)	Fuel-oil, human labour, water	MJ ha^{-1} per year
Indirect Energy (E_I)	Machine energy, seed, chemical fertilizer, pesticide,	MJ ha^{-1} per year
Renewable energy	Human labour, seed, water	MJ ha^{-1} per year
Non-renewable energy	Machine energy, chemical fertilizer, pesticide, fuel-oil	MJ ha^{-1} per year
Total Energy (E_T)	$E_T= E_d+E_i$	MJ ha^{-1} per year
Energy Output (E_O)		MJ ha^{-1} per year
Energy Ratio (E_O/E_I)	EO/EI	
Energy productivity	Sunflower yield (kg ha^{-1})/Energy input (MJ ha^{-1})	$MJ\ kg^{-1}$
Specific energy	ET/EO	MJ kg^{-1}
Energy Intensity	Sunflower input (MJ ha^{-1})/Energy output (MJ ha^{-1})	
Energy Intensiveness	ET/Cost of cultivation	MJ USD^{-1}
Net Energy Gain (NEG)	NEG= EO-EI	MJ ha^{-1}

Table 3. Input and output energies used by sunflower producing enterprises.

Inputs and outputs	Unit (ha)	Total energy (MJ ha^{-1})	%
Inputs			0.00
Human Labour (MLP)	283.60	555.86	2.68
Machine		1,649.55	0.00
Soil preparation (h)	20.00	1,254.00	6.04
Harvest (h)	10.00	395.55	1.91
Marketing (h)	3.50		0.00
Fertilizer		13,766.38	0.00
N (kg)	172.89	13,035.78	62.80
P (kg)	55.41	604.00	2.91
K (kg)	12.79	126.60	0.61
Pesticides			0.00
Herbicides (L)	0.25	72.00	0.35
Fungicides (L)	0.00	0.00	0.00
Insecticides (L)	0.00	0.00	0.00
Fuel-Oil (L)	81.84	4,608.49	22.20
Water (m^3)	125.41	79.01	0.38
Seed (kg)	7.61	27.39	0.13
Total Input (MJ)		20,758.68	100.00
Sunflower yield (kg ha^{-1})	4,103.82	0.00	0.00
Total Output (MJ)	0.00	102,595.59	0.00
Energy Parameters (MJ)			
Output/Input (EUE)		4.94	
Energy productivity (MJ kg^{-1})		0.19	
Specific energy (MJ kg^{-1})		5.06	
Energy intensity		0.20	
Energy intensiveness(MJ USD^{-1})		24.99	
Net energy gain (MJ ha^{-1})		81,836.91	

calculated as 0.18 MJ kg^{-1} by considering the amount of sunflower production per ha.

In other words, 1 kg of sunflower was produced with an energy consumption of 0.18 MJ kg $^{-1}$ in Konya Province conditions for sunflower production.

In the research area, specific energy value was calculated as 5.06. That is, 5.06 MJ kg[1] energy was consumed as specific energy for 1 kg of sunflower production when the market price of 1 kg of sunflower was 0.60 Kg/USD. Accordingly, for 1 kg of sunflower, 0.20 USD worth of energy was used. The net energy gain was calculated as 81,836.91(MJ ha $^{-1}$). A low specific energy value refers to the fact that energy efficiency in production is high (Baran *et al*., 2014).

Direct and indirect percentages of energy values were determined as 25.26% and 74.74%, respectively. The percentage of renewable energy is 3.19%, while it is 96.81% for non-renewable energy. Mousavi-Avval *et al*. (2011a), in their study on canola plant in Iran, reported a renewable energy rate of 94.80% whereas the rate of renewable energy was 5.20%. To reveal the current situation of sunflower production enterprises in the research area and to calculate the unit costs and profitability made for 1 kg sunflower production, the economic analysis of the enterprises is given in Table 5 to determine the data for energy consumption.

The production value per ha is 4,103.82 kg in sunflower producing enterprises. Other calculations are as follows: Total variable costs (per hectare): USD 574.08, Total fixed costs: USD 256.72, Total costs: USD 830.80, Sale price of sunflower: USD (per kg) 0.60, GPV: USD 2,462.29, Gross profit of sunflower: USD 1,888.22(per hectare), Net profit: USD 1,631.49 (per hectare). Gross profit measures the success of enterprises while net profit includes the profit of the entrepreneur (Oğuz and Bayramoğlu, 2018). In a similar study conducted in the Thrace region of Turkey, total variable costs were USD 483.75, total fixed costs were USD 622.38 while total costs were USD 1,106.13. The sunflower sale price was USD 0.74 and GPV was USD 1.132.20 (Unakıtan and Aydın, 2018).

Energy Efficiency Scores in Sunflower Production

Limited resources in production should be

Table 4. Total energy inputs of sunflower producing enterprises (MJ ha^{-1}).

	Energy value	%
Total energy input	20758,68	
Direct energy	5164.35	25.26
Indirect energy	15515.32	74.74
Renewable energy	583.25	3.19
Non-Renewable energy	20096.42	96.81

Table 5. Economic analysis of sunflower producing enterprises.

Hectare	Value
Yield (kg ha^{-1})	4103.82
Sale price (kg/USD)	0.60
Gross Production Value (kg/USD)	2462.29
Fixed costs (kg/USD)	256.72
Variable costs (kg/USD)	574.08
Total costs (kg/USD)	830.80
Gross profit (kg/USD)	1888.22
Productivity[c]	4.94
Net profit (kg/USD)	1631.49
Benefit/Cost ratio	2.96

Table 6. Technical, pure and scale efficiency of sunflower producing enterprises.

Farm size (Head)	No of businesses	Technical efficiency	Total technical efficiency	Pure Technical efficiency	Scale efficiency	Efficient	Less efficient	Inefficient
0-50	7	0.954	1	0.954	0.954	5	2	0
51-150	9	0.888	1	0.888	0.888	3	6	0
151-+	35	0.855	1	0.855	0.855	7	28	0
Avg	51	0.874	1	0.874	0.874	15	36	0

handled effectively to ensure the sustainability of enterprises. Efficiency is the difference between optimum input-output quantities and is the indicator of success in achieving the goal.

Table 6 presents the total energy inputs per enterprise and energy efficiencies according to the total output of the sunflower producing enterprises in the research area. Technical Efficiency (TE) was calculated as 0.874 as an enterprise average. Pure technical efficiency was calculated as 0.874 as an enterprise average. The technical efficiency and pure technical efficiency scores for sunflower were 0.82 and 0.92, respectively (Karadaş and Külekçi, 2020). Accordingly, to achieve the same amount of production, the amount of input should be reduced by 12.6%.

CONCLUSIONS

By its very nature, agricultural production consumes many inputs. Hence, the use of fertilizer, pesticide, mechanization, fuel, and inputs that harm the environment should be approached more sensitively, and energy consumption must be diminished by using the right methods. Non-renewable energy consumption was, indeed, found to be quite high in the research area. Besides, efficiency of renewable energy sources must be increased. Therefore, it is vital to reduce the use of chemical fertilizers and fuel in sunflower production. In that way, negative effects on both human health and the environment will decrease, and energy use efficiency will improve. Saving energy in sunflower production will have a positive economic impact on the business. Energy use efficiency in the research area was found to be 4.94, which shows that energy is used efficiently in itself and the production systems of the enterprises are good according to the literature. Effective energy use was, however, not good enough, while it was observed that insufficient energy was used at the technical efficiency level. Technical Efficiency (TE) was calculated as 0.874% as an enterprise average. Accordingly, to achieve the same amount of production, the amount of input should be reduced by 12.6%.

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بهره وری و کارایی انرژی در تولید آفتابگردان

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چکیده

تولیدات کشاورزی از نظر تولید و مصرف انرژی بسیار مهم است. هدف اصلی این پژوهش محاسبه مقادیر انرژی، بهره‌وری و کارایی انرژی نهاده‌های مورد استفاده در تولید آفتابگردان در منطقه Konya بود. تعداد نمونه با استفاده از روش نمونه گیری تصادفی طبقه ای Neyman برابر 51 محاسبه شد. در تجزیه و تحلیل تراز انرژی شرکت ها، معادلات انرژی تمام خروجی ها و نهاده های مورد استفاده در تولید آفتابگردان با ضرب در ضرایب تبدیل به دست آمد. معادلات انرژی خروجی و ورودی برای واحد تولید آفتابگردان (مگاژول بر کیلوگرم) محاسبه شد. در نتیجه مشخص شد که 25/26٪ از کل انرژی ورودی در هر هکتار انرژی مستقیم و 74/74٪ انرژی غیرمستقیم است. راندمان مصرف انرژی در منطقه تحقیق 4/94 و مقدار انرژی ویژه 5/06 مگاژول بر کیلوگرم بود. به عبارت دیگر، برای تولید 1 کیلوگرم آفتابگردان 5/06 مگاژول در کیلوگرم انرژی مصرف شد. قیمت 1 کیلوگرم آفتابگردان 0.60 دلار امریکا است. میانگین بازده فنی (TE) شرکت‌ها در منطقه مطالعه شده 0.874٪ بود و 29.41 ٪ از شرکت‌های تولیدکننده گل آفتابگردان در مصرف انرژی در تولید کارآمد بودند، در حالی که 70.58 ٪ شرکت‌ها کارایی کمتری داشتند. صرفه جویی در انرژی برای تولید آفتابگردان تاثیر اقتصادی مثبتی بر کسب و کار خواهد داشت.