Energy inputs – yield relationship and sensitivity analysis for tomato greenhouse production in Iran

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Abstract: This paper studies the energy balance between the input and the output energies per unit area for greenhouse tomato production. For this purpose, the data on 30 tomato production greenhouses in Isfahan province, Iran were collected and analyzed. The results indicated that a total specific input energy of 116,768.4 MJ ha^{-1} was consumed for tomato production. Diesel fuel (with 40%) and chemical fertilizers and manure (with 30%) were amongst the highest input energies for tomato production. The energy productivity was estimated to be 1.16 kg MJ^{-1}. The ratio of output energy to input energy was approximately 0.92. 19% and 81% of total energy input was in renewable and non-renewable forms, respectively. The regression results revealed that the contribution of input energies on crop yield for human power, machinery, pesticides and electricity inputs was significant. The human power energy had the highest impact (1.45) among the other inputs in greenhouse tomato production. The marginal physical productivity of diesel fuel, seed and total chemical fertilizer with manure was negative. It can be because of applying the inputs more than required or improperly applying. The highest shares of expenses were found to be 34% and 21% for human power and total diesel fuel and machinery, respectively. Cost analysis revealed that total cost of production for 1 ha greenhouse tomato production was around US$34939. Accordingly, the benefit-cost ratio was estimated as 2.74. Results of greenhouse gas emission indicated that tomato production is mostly depended on diesel fuel sources. Diesel fuel had the highest share (2,719.98 kg $CO_{2eq}.ha^{-1}$) followed by electricity (729.6 kg $CO_{2eq}.ha^{-1}$) and nitrogen fertilizer (409.5 kg $CO_{2eq}.ha^{-1}$).

Keywords: tomato, greenhouse, energy productivity, economic analysis, Cobb-Douglas function

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1 Introduction

Greenhouse production is one of the most intensive parts of the world agricultural production. It is intensive in the sense of yield and annual production, as well as in the energy consumption, investments and costs (Heidari and Omid, 2011). Greenhouses use large quantities of locally available non-commercial energies, such as manure, animate and seed energies and commercial energies directly and indirectly in the form of diesel, electricity, fertilizer, pesticides, irrigation water, machinery, etc. (Mandal et al., 2002). Efficient use of these energies helps to achieve increased productivity and contributes to the economy, profitability and competitiveness of agricultural sustainability of rural communities (Manes and Singh, 2005).

Future agricultural sustainability will be achieved from an equilibrated solution of many productive, environmental, and economic issues (Park and Seaton, 1996). Among these, improved energy efficiency and reduced greenhouse gas (GHG) emissions are fundamental (Dyer and Desjardins, 2003; Alluvione et al., 2011). While the energy requirements of agriculture are low compared to other production sectors (Tol et al., 2009), realizing efficient use of its own energy needs is pivotal to achieving economic sustainability and GHG

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emission reductions (Alluvione et al., 2011). Usually, input–output energy analysis is used to evaluate the efficiency and environmental impacts of the production systems. Therefore, there was an immediate need to carry out such an analysis for future steps to be taken for any improvement in greenhouse production systems regarding the energy values of the inputs and the output. By reaching beyond agricultural boundaries and including all the steps of crop input production, energy analysis is a useful indicator of environmental and long-term sustainability (Alluvione et al., 2011).

On this basis, the main objective of this study is to examine energy use pattern and specification of GHG emission for greenhouse tomato production in Isfahan Province of Iran. The study also sought to reveal the relationship between inputs energy and yield, cost and income by developing mathematical models in Isfahan Province, Iran.

2 Materials and methods

The survey was made in 2010-2011 by interviewing 30 enterprises that produced greenhouse tomato in Isfahan Province of Iran. The greenhouses were selected for energy analysis and efficiency of tomato. Inquiries were conducted in a face-to-face interviewing. The selection of greenhouses was based on random sampling method.

Firstly, the amounts of inputs (pesticides, human power, machinery, total chemical fertilizers and manure, diesel fuel, electricity, seed and irrigation water) used in production of tomato were specified in order to calculate the energy equivalences in the study. The values in Table 1 were used to find the input amounts.

The amounts of the inputs were calculated per hectare and then, these inputs data were multiplied by the coefficient of energy equivalent. The previous studies were used to determine the energy equivalents coefficients. These sources are given in Table 1.

The energy equivalences of unit inputs are given in mega joule (MJ) per unit. The total input equivalent can be calculated by adding up the energy equivalences of all inputs. Based on the energy equivalents of the inputs and output (Table 1), the energy ratio (energy use efficiency), energy productivity, specific energy and net energy gain were calculated (Singh et al., 2002):

$$E_r = {}^{E_O}\!\big/_{E_I} \tag{1}$$

$$E_p = {}^{O_P}\!\big/_{E_I} \tag{2}$$

$$S_e = {}^{E_I}\!\big/_{T_P} \tag{3}$$

$$N_e = E_O - E_I \tag{4}$$

where, E_r is energy ratio; E_O is energy output (MJ ha^{-1}); E_I is energy input (MJ ha^{-1}); E_p is energy productivity (kg MJ^{-1}); O_p is output production (kg ha^{-1}); S_e is specific energy (MJ kg^{-1}); N_e is net energy (MJ ha^{-1}).

Table 1 Energy equivalents for different inputs and outputs in agricultural production

			Reference	Energy equivalent
Inputs	Human power/MJ h^{-1}		1.96	Mohammadi et al, 2008
	Machinery/MJ kg^{-1}		64.8	Singh et al, 2002
	Diesel fuel/MJ L^{-1}		47.8	Canakci and Akinci, 2006
	Chemicals/MJ kg^{-1}	Herbicides	238	Erdal et al, 2007
		Fungicides	216	Erdal et al, 2007
		Insecticides	101.2	Erdal et al, 2007
	Chemical fertilizer /MJ kg^{-1}	Nitrogen	66.14	Shrestha, 1998
		Phosphate	12.44	Shrestha, 1998
		Potassium	11.15	Shrestha, 1998
	Manure/MJ t^{-1}		303.10	Shrestha, 1998
	Water for irrigation /MJ m^{-3}		1.02	Rafiee et al, 2010
	Electricity/MJ kW h^{-1}		11.93	Heidari and Omid, 2011
	Seed/MJ kg^{-1}		1.0	Heidari and Omid, 2011
Output	Tomato/MJ kg^{-1}		0.8	Taki et al, 2012

The output-input energy ratio (energy use efficiency) is one of the indices that show the energy efficiency of agriculture. In particular, this ratio, which is calculated by the ratio of input fossil fuel energy and output food energy, has been used to express the ineffectiveness of crop production in developed countries (Unakitan et al., 2010). An increase in the ratio indicates improvement in energy efficiency, and vice versa. Changes in efficiency can be both short and long term, and will often reflect changes in technology, government policies, weather patterns, or farm management practices. By carefully evaluating the ratios, it is possible to determine trends in the energy efficiency of agricultural production, and to explain these trends by attributing each change to various occurrences within the industry (Unakitan et al., 2010).

In this study, the input energy was divided into direct, indirect, renewable and non-renewable forms. The indirect energy includes the chemical and farm fertilizers, chemical spraying agents and machinery. The direct energy includes human power, fuel and electricity power. The non-renewable energy sources include fuel, electricity, chemical fertilizer, spraying agents and machinery, whereas the renewable energy sources include human power and farm fertilizers (Yilmaz et al., 2005).

Realizing that the output is a function of inputs, production function can be expressed as $Y_t = F(h_t) \cdot \exp(e_t)$ where Y_t is output level, $h_t = (h_{1t}, h_{2t}, ..., h_{nt})$ is a vector of input variables that affect output such as fertilizer, diesel fuel, electricity etc, ε_t is the error term and t is a time subscript for time series or a cross-section unit for cross section data sets.

In order to estimate this relationship, a mathematical function needs to be specified. For this purpose, several functions were tried and the Cobb-Douglas production function was chosen since it produced better results among the others. The Cobb-Douglas production function was specified and estimated using ordinary least square estimation technique. One of the features of this production function is that estimated coefficients represent elasticity. Furthermore, Cobb-Douglas production function imposes a priori restriction on patterns of substitution among inputs. In particular, elasticity of substitution among all inputs must be equal to unity. From the view point of output-input ratios, higher input use, ceteris paribus, is bound to mean lower partial productivity or efficiency, if estimated coefficient is less than one (Mobtaker et al., 2010). The Cobb–Douglas production function is expressed in general form as follows (Hatirli et al., 2005):

$$\ln Y_t = b_0 + \sum_{i=1}^{n} b_i \ln(h_{it}) + e_t \tag{5}$$

where, Y_t denotes the yield of the t farmer; b_0 is a constant; b_i denotes coefficients, and e_t is the error term, assumed normally distributed with mean 0 and constant variance s^2.

Assuming that when the energy input is zero, the crop production is also zero, Equation (5) is reduced to:

$$\ln Y_t = \sum_{i=1}^{n} b_i \ln(h_{it}) + e_t \tag{6}$$

Total physical energy consisted of human power, electricity, diesel fuel, machinery, seed, chemical fertilizer, water for irrigation and pesticides. Following this explanation, Equation (6) can be given as:

$$\ln Y_t = b_1 \ln h_1 + b_2 \ln h_2 + b_3 \ln h_3 + b_4 \ln h_4 + b_5 \ln h_5 + b_6 \ln h_6 + b_7 \ln h_7 + b_8 \ln h_8 + e_t \tag{7}$$

where, h_1 is the chemical fertilizer; h_2 is the machinery; h_3 is the human power; h_4 is the total pesticides; h_5 is the seed; h_6 is the diesel fuel; h_7 is the electricity input and h_8 is the water for irrigation input.

The study was also aimed at investigating the relationship between output and different energy forms. More specifically, we considered different energy forms as renewable or nonrenewable, as direct or indirect. As a functional form, the Cobb-Douglas production function was selected and specified in the following forms (Hatirli et al., 2005):

$$\ln Y_t = f_1 \ln D_E + f_2 \ln I_{DE} + e_t \tag{8}$$

$$\ln Y_t = m_1 \ln R_E + m_2 \ln N_{RE} + e_t \tag{9}$$

where, R_E and N_{RE} denote renewable and non-renewable energy forms, respectively; D_E represents direct energy; I_{DE} denotes indirect energy.

In addition to the influence of each variable on the yield level, the impact of expenses and on yield was also investigated. For this purpose, Cobb-Douglas function was specified in the following Equation (10):

$$\ln Y'_t = b'_1 \ln h'_1 + b'_2 \ln h'_2 + b'_3 \ln h'_3 + b'_4 \ln h'_4 +'b_5 \ln h'_5 + b'_6 \ln h'_6 + b'_7 \ln h'_7 + b'_8 \ln h'_8 + e_t \tag{10}$$

where, Y'_t is the income level of the tth farmer; h'_1 is the chemical fertilizer and manure cost; h'_2 is the machinery and diesel fuel cost; h'_3 is the human power cost; h'_4 is the total pesticides cost; h'_5 is the seed cots; h'_6 is the packaging and transportation cost; h'_7 is the electricity cost input and h'_8 is the water for irrigation cost (Samavatean et al., 2011).

In the last part of the study sensitivity analysis of inputs energy on tomato yield was carried out based on the response coefficients of inputs by use of marginal physical productivity (MPP) technique. The MPP of a factor indicates the change in output with a unit change in the factor input in question, keeping all other factors constant at their geometric mean level. To calculate MPP, Equation (11) was used (Nguyen et al., 2007):

$$MPP_{xj} = \frac{GM(Y)}{GM(X_j)} \times a_j \tag{11}$$

where, MPP_{xj} is marginal physical productivity of jth input; a_j regression coefficient of jth input; $GM(Y)$ geometric mean of tomato yield and $GM(X_j)$ geometric mean of jth input energy on per hectare.

In production, returns to scale refer to changes in output subsequent to a proportional change in all inputs (where all inputs increase by a constant factor). In the Cobb-Douglas production function, it is indicated by the sum of the elasticity derived in the form of regression coefficients. If the sum of the coefficients is greater than unity ($\sum_{i=1}^{n} a_i > 1$), then it could be concluded that the increasing returns to scale, on the other hand if the latter parameter is less than unity ($\sum_{i=1}^{n} a_i < 1$), then it is indicated that the decreasing returns to scale; and, if the result is unity ($\sum_{i=1}^{n} a_i = 1$), it shows that the constant returns to scale (Mobtaker et al., 2011).

Adoption of recommended management practices for agriculture involves off-farm or external inputs which are carbon (C)-based operations and products (Marland et al., 2003; Pimentel, 1992). Application of these inputs leads to emission of CO_2 and other GHGs. Thus, an understanding of the emissions expressed in kilograms of carbon equivalent (kg CE) for different tillage operations, fertilizers and pesticides use, supplemental irrigation practices, harvesting and residue management is essential to identifying C-efficient alternatives such as biofuels and renewable energy sources for seedbed preparation, soil fertility management, pest control and other farm operations (Lal, 2004).

CO_2 emission coefficients of agricultural inputs were used for quantifying the GHG emissions of greenhouse tomato production. Table 2 summarizes GHG emission equivalents. GHG emission was calculated by multiplying the input application rate (machinery, diesel fuel, chemical fertilizers, pesticides, electricity and water for irrigation) by its corresponding emission coefficient.

Table 2 Greenhouse gas (GHG) emission coefficients of agricultural inputs

Inputs		GHG Coefficient per (unit/ kg CO_{2eq})	Reference
Machinery/MJ		0.071	(Dyer and Desjardins, 2006)
Diesel fuel/L		2.76	(Dyer and Desjardins, 2006)
Chemical fertilizers/kg	Nitrogen	1.3	(Lal, 2004)
	Phosphate	0.2	(Lal, 2004)
	Potassium	0.2	(Lal, 2004)
Pesticides/kg	Herbicide	6.3	(Lal, 2004)
	Insecticide	5.1	(Lal, 2004)
	Fungicide	3.9	(Lal, 2004)
Electricity/kW h		0.608	(Khodi and Mousavi, 2009)

The economic analysis of greenhouse tomato production was investigated. (Zangeneh et al., 2010):

$$T_{PE} = O_P \times T_P \tag{12}$$

$$CR = T_{PE} - V_{CP} \tag{13}$$

$$NR = T_{PV} - T_{PC} \tag{14}$$

$$BCR = {}^{T_{PV}}\!\big/_{T_{PC}} \tag{15}$$

$$P = {}^{T_P}\!\big/_{T_{PC}} \tag{16}$$

where, T_{PV} is total production value; O_P is output production (kg ha$^{-1)}$; T_P is tomato price (US\$kg^{-1}); CR is cross return; T_{PV} total production value (US\$ha^{-1}); V_{CP} is variable cost of production (US\$kg^{-1}); NR is net return; T_{PC} is total production cost; BCR is benefit to cost ratio; P is productivity.

Basic information on inputs energy and greenhouse yields were entered into Excel's spreadsheet and simulated using Eviews 5 software.

3 Results and discussion

In Table 3, the physical inputs and their energy equivalences used in the production of tomato are given.

As presented in Table 3, 315 kg nitrogen, 371 kg phosphate, 285 kg potassium, 21.2 t of farm fertilizer, 985.5 L diesel fuel, 3716 m^3 water, 9.7 kg chemical spraying agents, 5,815.2 h human power, 52.3 h machinery, 1,200 kWh electrical energy per hectare are used for the production of tomato in Isfahan Province of Iran. The average tomato output were found to be 85,120 kg ha^{-1} in the enterprises that were analyzed. The energy equivalent of this is calculated as 108,000 MJ ha^{-1}. The highest input energy is provided by fuel. Hatirli et al. (2006) applied a parametric method to establish relationship between the yield and total input energy for tomato production in Antalya province of Turkey. The results revealed that diesel (34.35%), fertilizer (27.59%), electricity (16.01%), pesticides (10.19%) and human power (8.64%) consumed the bulk of energy. Omid et al., (2011) concluded that the input energy for cucumber production was to be 152,908 MJ ha^{-1} and the average inputs energy consumption was highest for diesel fuel, total chemical fertilizer and electricity.

Table 3 The physical inputs used in the production of tomato and their energy equivalences

Inputs (unit)		Quantity per unit area (ha)	Total energy equivalent/MJ	Percentage /%
Chemicals poisons	Herbicides	3.1 kg	737.8	2
	Fungicides	2.7 kg	584.2	
	Insecticides	3.9 kg	394.9	
Human power		5,815.2 h	11,397	10
Machinery		52.3 kg	3,389	3
Chemical fertilizers	Nitrogen fertilizer	315 kg	20,834	30
	Phosphate	371 kg	4,615	
	Potassium	285 kg	3,177	
Manure		21.2 t	6,425	
Seeds		0.1 kg	0.1	
Diesel fuel		985.5 L	47,106	40
Electricity		1,200 kWh	14,316	12
Water for irrigation		3,716 m^{3}	3,790	3
Total input energy		-	116,768.4	-
Yield		135,000 kg	108,000	

The input and output energy, energy use efficiency, specific energy, energy productivity and net energy of tomato production in the Isfahan province are tabulated in Table 4. Energy use efficiency (energy ratio) was calculated as 0.92. In Iran, Heidari and Omid (2011) reported tomato output/input ratio as 1.4. Hatirli et al., (2006) calculated in Turkey energy output/input ratio as 1.2. The average energy productivity of farms was 1.16. This means that 1.16 output was obtained per unit energy. It can be seen from Table 4, the total input energy consumed could be classified as direct energy (66%), indirect energy (34%) and renewable energy (19%) and non-renewable energy (81%).

Table 4 Energy indices for greenhouse tomato production in Isfahan province of Iran

Items	Tomato	Percentage/%
Energy use efficiency	0.92	
Energy productivity/kg MJ^{-1}	1.16	
Specific energy/MJ kg^{-1}	0.86	
Net energy gain/MJ ha^{-1}	-8768	
Direct energy [a]/MJ ha^{-1}	76610	66
Indirect energy [b]/MJ ha^{-1}	40158	34
Renewable energy [c]/MJ ha^{-1}	21613	19
Non- renewable energy [d]/MJ ha^{-1}	95155	81
Total input energy/MJ ha^{-1}	116768	100
Output energy/MJ ha^{-1}	108000	-

Note: [a] Includes human power, diesel, electricity, water;
[b] Includes chemical fertilizers, manure, chemicals, machinery;
[c] Includes human power, manure, water;
[d] Includes diesel, electricity, chemicals, chemical fertilizers, machinery.

Renewable energy resources (solar, hydroelectric, biomass, wind, ocean and geothermal energy) are inexhaustible and offer many environmental benefits over conventional energy sources. Each type of renewable energy also has its own special advantages that make it uniquely suited to certain applications (Miguez et al., 2006). The use of renewable energy offers a range of exceptional benefits, including: a decrease in external energy dependence; a boost to local and regional component manufacturing industries; promotion of regional engineering and consultancy services specializing in the use of renewable energy, decrease in impact of electricity production and transformation; increase in the level of services for the rural population; creation of employment, etc (Miguez et al., 2006).

Table 5 shows the CO_2 emission for tomato production in Isfahan Province of Iran. Results of this table indicated that tomato production is mostly depending on diesel fuel sources. Diesel fuel had the highest share (2,719.98 kg CO_{2eq} ha^{-1}) followed by electricity (729.6 kg CO_{2eq} ha^{-1}) and nitrogen fertilizer (409.5 kg CO_{2eq} ha^{-1}).

Using ethanol and biodiesel as biofuel is essential in the 21st century to reduce the high GHG emissions. Field operations with minimum machinery use (especially tillage operation) and machinery production are needed to be considered to reduce the amount of CO_2.

Table 5 Amount of greenhouse gas emission for tomato production

Inputs		Quantity per unit area	GHG Coefficient (kg CO_{2eq} $unit^{-1}$)	Quantity of GHG emission (kg CO_{2eq} ha^{-1})
Machinery		3,389 MJ ha^{-1}	0.071	240.619
Diesel fuel		985.5/L ha^{-1}	2.76	2,719.98
fertilizers Chemical	Nitrogen	315 kg ha^{-1}	1.3	409.5
	Phosphate	371 kg ha^{-1}	0.2	74.2
	Potassium	285 kg ha^{-1}	0.2	57
Pesticides	Herbicide	3.1 kg ha^{-1}	6.3	19.53
	Insecticide	3.9 kg ha^{-1}	5.1	19.89
	Fungicide	2.7 kg ha^{-1}	3.9	10.53
Electricity		1,200 k Wh ha^{-1}	0.608	729.6
Total CO_2		-	-	4,280.849

One of the main objectives of this study was to explore the relationship between total output and inputs energy in some detail. For this purpose Equations (17)–(19) were estimated using ordinary least squares estimation and the results are provided in Table 6.

$$\ln Y = b_1\ln F_R + b_2\ln M_A + b_3\ln H_U + b_4\ln C_H + b_5\ln S_E + b_6\ln D_S + b_7\ln E_L + b_8\ln W_A + e \quad (17)$$

$$\ln Y_t = f_1\ln D_E + f_2\ln I_{DE} + et \quad (18)$$

$$\ln Y_t = m_1\ln R_E + m_2\ln N_{RE} + et \quad (19)$$

Table 6 Econometric estimation results of inputs

MPP	*t*–ratio	Coefficient	Endogenous variable: yield
			Exogenous variables
Equation (17)			
4.23	1.45^{*}	0.78	Human power
2.12	1.14^{**}	0.27	Machinery
-0.67	-0.18^{ns}	-0.12	Diesel fuel
-1.53	-0.28^{ns}	-0.09	Chemical fertilizers and manure
3.42	1.32^{*}	0.57	Pesticides
1.98	1.09^{**}	0.20	Electricity
0.97	0.72^{ns}	0.02	Water for irrigation
-0.77	-0.09^{ns}	-0.13	Seed
		1.89	Durbin–Watson
		1.50	Return to scale
Equation (18)			
4.35	4.5^{*}	0.59	Direct energy
3.24	4.90^{*}	0.51	Indirect energy
		1.95	Durbin–Watson
		1.10	Return to scale
Equation (19)			
5.93	4.12^{*}	0.37	Renewable energy
7.12	6.54^{*}	1.21	Non–renewable energy
		2.13	Durbin–Watson
		1.58	Return to scale

Note: * Significance at 1%; **Significance at 5%; ^{ns} Not significant

Since time series data were used in this study, autocorrelation might be a potential concern, and therefore it should be tested, using the Durbin-Watson test. Computed Durbin-Watson values were calculated as 1.89, 1.95 and 2.13 for Equations (17)-(19), showing that there was no autocorrelation at the 5% significance level in the estimated models.

As can be seen from Table 6, all exogenous variables had a positive impact and were found statistically significant on greenhouse tomato yield (expected diesel fuel, chemical fertilizer and seed energy). Table 6 showed that, human power had the highest impact (1.45) among other inputs and significantly contributed on the productivity at 1% level. It indicates that a 1% increase in the energy human power input led to 1.45% increase in yield in these circumstances. The second important input was found as chemical fertilizers and manure with 1.32 elasticity followed by machinery with 1.14 elasticity. Mobtaker et al., (2011) developed an econometric model for alfalfa production in Hamedan Province of Iran and reported that machinery and seeds were important inputs significantly contributed to yield. Heidari and Omid (2011) examined the energy use patterns and input-output energy analysis of major greenhouse vegetable productions in Iran. They reported that the impact of human power for cucumber and chemicals for tomato was significant at 1% levels.

The sensitivity of inputs energy was analyzed by using MPP value. The results showed that human power and pesticides energy had the highest with MPP values of 4.23 and 3.42, respectively. These results shown in Table 6 indicate that additional use of MJ for each of human power and pesticides inputs would result in an increase of 4.23 MJ and 3.42 MJ in greenhouse tomato production yield, respectively. The MPP of diesel fuel, chemical fertilizer and seeds energy were found to be −0.67, −1.53 and −0.77 respectively; a negative value of MPP implies that additional units of inputs are contributing negatively to production, i.e. less production with more input.

Regression results for Equations (18) and (19) are given in Table 6. The results revealed that, the impact of all forms of energy inputs as direct, indirect, renewable and non-renewable were significant at 1% level. Indirect and non-renewable had more impact on output yield. The MPP values of direct, indirect, renewable and non-renewable were 4.35, 3.24, 5.93 and 7.12, respectively. This indicates that an additional use of 1 MJ of each of these energy forms would lead to an additional increase in yield by 3.24 - 7.12 MJ.

The return to scale (RTS) values for Equations (17)-(19) were calculated by gathering the regression coefficients and shown in Table 5. RTS values for Equation (17) was 1.50; thus, there prevailed an Increase Return to Scale (IRS) of tomato production for estimated model. This revealed that a 1% increase in the total inputs energy utilize would lead in 1.50% increase in the tomato yield for this model; also the RTS values for tomato production in Equations (18)-(19) were all IRS.

The total cost of production greenhouse tomato and the gross value of production were calculated and shown in Table 7. The fixed and variable expenditures included in the cost of production were calculated separately. The total expenditure for the production was US$34,939 ha^{-1} while the gross production value was found to be US$95,850 ha^{-1}. According to the results of the research about 66% of the total expenditures were variable costs whereas 34% were fixed expenditures. Based on these results, the benefit-cost ratio from greenhouse tomato production in the surveyed farms was calculated to be 2.74.

Table 7 Economic analysis of greenhouse tomato production

Value	Cost and return components components
135000	Yield/kgha^{-1}
0.71	Sale price/\$ kg^{-1}
95850	Gross value of production/\$ ha^{-1}
23159	Variable cost of production/\$ ha^{-1}
11780	Fixed cost of production/\$ ha^{-1}
34939	Total cost of production/\$ ha^{-1}
0.26	Total cost of production/\$ kg^{-1}
72691	Gross return/\$ ha^{-1}
60911	Net return/\$ ha^{-1}
2.74	Benefit to cost ratio
3.86	Productivity/kg \$$^{-1}$

The regression coefficients of cost on income were investigated through Equation (20). The results are given in Table 8. Regression results for this equation show among the variables included in the model, total chemical fertilizer with manure and total machinery with diesel fuel expenses were found as the most important variables that influence income. The elasticity of these expenses are 0.084 and 0.186, implying that a given 1% change in these expenses will result in 0.084% and 0.186% increase in income, respectively. The third important input was found as human power with a -0.047 elasticity. Other important variables that influence tomato income are packaging and water for irrigation with elasticity of 0.041 and -0.039, respectively (all significant at the 1% and 5% level).

$$\ln Y'_t = b'_1\ln h'_1 + b'_2\ln h'_2 + b'_3\ln h'_3 + b'_4\ln h'_4 +{}'b_5\ln h'_5 + b'_6\ln h'_6 + b'_7\ln h'_7 + b'_8\ln h'_8 + e_t \qquad (20)$$

Table 8 Percent of expenses in greenhouse tomato production

Endogenous variable: income	Coefficient	t-ratio
Chemical fertilizer and manure expense	0.084	4.56*
Machinery and diesel fuel expense	0.186	6.74*
Human power expense	-0.047	-2.31**
Total pesticides expense	-0.031	-2.09**
Seed expense	-0.009	-0.98ns
Packaging and transportation expense	0.041	3.24**
Electricity expense	-0.016	-1.09ns
Water for irrigation expense	-0.039	-2.23**
Durbin-Watson	2.12	

Note: * Significance at 1%; ** Significance at 5%; ^{ns} Not significant.

Figure 1 shows the percentage shares of each input and costs from expenses. As can be seen from Figure 1, of all the inputs, the human power expenses have the biggest share of 34%. Almost in all surveyed farms, most operations were performed by human power. Machinery and diesel fuel (21%) expenses are followed by packaging and transportation (15%), total chemical fertilizers and manure (14%), total pesticides (7%), seed (4%), electricity (3%) and water for irrigation (2%) accounted for most of expense in surveyed greenhouse tomato production.

The results revealed that the human expenses and diesel fuel had the highest share of total expenses and total energy consumption. Similar results have been reported for the share of human energy and the expense was 6.79% in the total energy and 45% in the total expense for garlic production in Iran (Samavateanet et al., 2011), against the share of chemical fertilizing energy and expense was 28.9% in the total energy and 5.5% in the total expense in cotton production (Yilmaz et al., 2005).

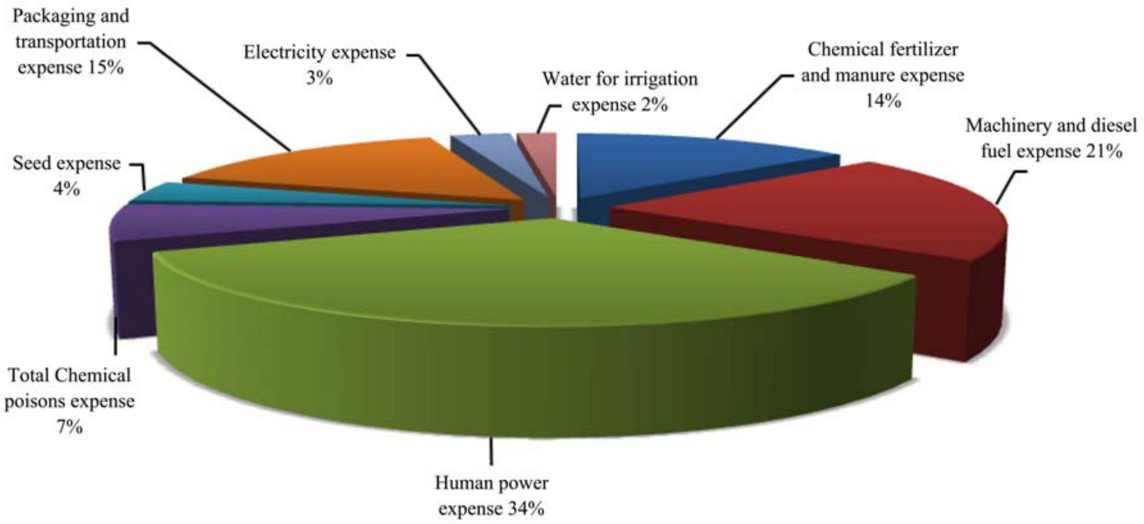

Figure 1 Contributions of specific cost categories to the total cost of greenhouse tomato production

Optimal consumptions of electricity, chemical fertilizers and other major inputs would be useful not only in reducing negative effects to environment, but also in maintaining sustainability. Lack of soil analysis in the area leads to unconscious usage of chemical fertilizer. In order to reduce the electricity consumption, using the modern methods of irrigation with high efficiency (which leads in saving water consumption) can be suggested. Also it is suggested that new policies are to be taken to reduce the negative effects of inputs energy such as plant, soil and climate pollution. Therefore, analysis of energy consumption is an important task (Mobtaker et al., 2011).

4 Conclusions

Based on the present study the following conclusions are drawn:

1) Greenhouse tomato production consumed a total energy of 116,768.4 MJ ha^{-1}, which was mainly due to diesel fuel (40% of total energy). The input energy of total chemical fertilizer and electricity have the secondary and tertiary share within the total energy inputs. Energy output was calculated as 108,000 MJ ha^{-1}.

2) The direct and indirect input energies were 66% and 34% of the total input energy, respectively. Renewable energy sources among the inputs had a share of 19% of the total energy input, which was smaller than that of non-renewable resources.

3) The elasticity estimates of human power energy was found as 1.45, had major impact in tomato production, followed by chemicals poisons (1.32) and machinery input (1.14).

4) Total amount of CO_2 emission in greenhouse tomato production was calculated as 4,280.849 kg $CO_{2eq}.ha^{-1}$. Diesel fuel had the highest share (63.54%) followed by electricity (17.05%) and nitrogen fertilizer (9.57%). It is possible to decrease greenhouse gas emission in agricultural production by reduction of non–renewable energy sources that create environmental problems. Therefore, policy makers should take the necessary measurements to ensure more environmental friendly energy use patterns in the Persian agriculture.

5) Reducing diesel fuel consumption and fertilizer usage, mainly nitrogen, is important for energy reduction. A saving in diesel fuel by improving tillage and hitting performance may be possible. Using direct and local marketing improves profitability for growers while reducing the amount of energy used to transport products.

6) The benefit-cost ratio was found to be 2.74. The impacts of human power and total diesel fuel with machinery expenses were found as the most important variables that influence income.

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