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Study on Energy Use Pattern, Optimization of Energy Consumption and CO$_2$ Emission For Greenhouse Tomato Production

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Abstract

This study applied a non-parametric method to analyze the efficiency of farmers, discriminate efficient farmers from inefficient ones and to identify wasteful uses of energy in order to optimize the energy inputs for tomato greenhouse production in Esfahan province of Iran. DEA creates a best practice production frontier based on the growers that produce their level of tomato yield with the least amount of input energy. The data used in this study was obtained through a face to- face questionnaire method in the surveyed region – Esfahan province of Iran. The results indicated that total energy inputs were 116768.4 MJha^{-1}. About 40% of this was generated by diesel fuel and 30% from total fertilizer. Two basic DEA models (CCR and BCC) were used to measure the TEs of the greenhouses based on seven energy inputs and one output. The CCR and BCC models indicated 3 and 8 greenhouses were efficient, respectively. The average values of TE, PTE and SE of greenhouses were found to be 0.79, 0.89 and 0.88, respectively. Moreover, energy saving target ratio for tomato production was calculated as 12.16%, indicating that by following the recommendations resulted from this study, about 14194MJ ha^{-1} of total input energy could be saved while holding the constant level of tomato yield. The result of greenhouse gas emission analysis showed that optimization of energy decreases the CO$_2$ emission by 0.54 ton ha^{-1}. The diesel fuel input has the highest impact on environmental pollution.

Keywords: Data envelopment analysis, Energy use efficiency, Management, Tomato production

INTRODUCTION

Tomato is one of the major greenhouse vegetables products worldwide. In Iran, it was cultivated on 49,000 ha and the production was 1.34 million tons in 2008. From 2002 to 2007, greenhouse areas of Iran increased from 3380 ha to 6630 ha with an increasing rate of 96%. The shares of greenhouse crops production were as follows: vegetables 59.3%, flowers 39.81%, fruits 0.54% and mushroom 0.35% [1].

Efficient use of resources is one of the major assets of eco-efficient and sustainable production, in agriculture [2]. Efficient use of energy is one of the principal requirements of sustainable agriculture. Energy use in agriculture has been increasing in response to increasing population, limited supply of arable land, and a desire for higher standards of living. Continuous demand in increasing food production resulted in intensive use of chemical fertilizers, pesticides, agricultural machinery and other natural resources.

However, intensive use of energy causes problems threatening public health and environment. Efficient use of energy in agriculture will minimize environmental problems, prevent destruction of natural resources, and promote sustainable agriculture as an economical production system. The development of energy efficient agricultural systems with a low input of energy compared to the output of products should therefore help to reduce the emissions of greenhouse gasses in agricultural production [3]. Energy use is one of the key indicators for developing more sustainable agricultural practices. Wider use of renewable energy sources, increase in energy supply and efficiency of use can make a valuable contribution to meeting sustainable energy development targets [4].

Agriculture is both a producer and consumer of energy. It uses large quantities of locally available non-commercial energies, such as seed, manure and animate energy, and commercial energies directly and indirectly in the form of diesel, electricity, fertilizer, plant protection, chemicals, irrigation water and machinery. Efficient use of energies helps to achieve increased production and productivity and contributes to the economy, profitability and competitiveness of agriculture sustainability in rural living [4].

In recent years, Data Envelopment Analysis (DEA) has become a central technique in productivity and efficiency analysis applied in different aspects of economics and management sciences. Although within this context, several researchers have focused on determining efficiency in agricultural units and various products ranging from cultivation and horticulture to aquaculture and animal husbandry for example: surveying the quantity of inefficient resources which are used in cotton production in Panjab in

Pakistan [5], reviewing energy performance used in wheat production [6], surveying improving energy efficiency for cucumber production [7], evaluation and development of optimum consumption of energy resources in greenhouse cultivation in Tehran province [1], checking the efficiency and returning to the scale for greenhouse cucumber in Iran by using Non-parametric method of data envelopment analysis [8], determination of the amount of energy consumption in wheat cultivation of Fars province with the approach of data envelopment analysis [9]. Abdi et al [10] studied energy balance for wheat, corn silage, cucumber and tomato production. Results show that the value of energy ratio for cultivating wheat, corn silage, cucumber and tomato crops were calculated at 0.74, 2.55, 0.46 and 0.73, respectively. The results of CO_2 emission analyzes showed that the total amount of CO_2 emission for wheat, corn silage, cucumber and tomato production was 2.07, 4.35, 4.99 and 4.66 tones ha^{-1}, respectively.

Based on the literature, there wasn't any study on optimization of energy inputs for tomato production in Esfahan province of Iran. Accordingly, the main objectives of this study were to determine the efficiencies of farmers, rank efficient and inefficient ones, identify target energy requirement and optimization of greenhouse gas emission for tomato production in Shahreza city, Esfahan province of Iran.

MATERIALS AND METHODS

Case study and data collection

The survey was made in 2010-2011 by interviewing 30 enterprises that produced tomato. Thirty greenhouses were selected to energy analysis and efficiency of tomato. Data were collected from 30 farmers growing tomato in greenhouse in Shahreza city, Esfahan province of Iran. Inquiries were conducted in a face-to-face interviewing. The selection of greenhouses based on random sampling method.

Energy equivalents used

Firstly, the amounts of inputs (chemicals, human power, machinery, fertilizers, fuel, electricity and irrigation water) used in the production of tomato were specified in order to calculate the energy equivalences in the study. The units in Table 1were used to find the input amounts.

The amounts of input were calculated per hectare and then, these input data were multiplied with 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) unit. The total input equivalent can be calculated by adding up the energy equivalences of all inputs in mega joule (MJ).

Data envelopment analysis

In this study, a non-parametric method of DEA was employed to evaluate the technical, pure technical and scale efficiencies of individual farmers. So, the energy consumed from different energy sources including: human labor, machinery, diesel fuel, total fertilizer, chemicals, water for irrigation, electricity and seeds, were defined as input variables; while, the tomato yield was the single output variable; also each farmer called a DMU.

In DEA, an inefficient DMU can be made efficient either by reducing the input levels while holding the outputs constant (input oriented); or symmetrically, by increasing the output levels while holding the inputs constant (output oriented) [17-18]. The choice between input and output orientation depends on the unique characteristics of the set of DMUs under study. In this study the input oriented approach was deemed to be more appropriate because there is only one output while multiple inputs are used; also as a recommendation, input conservation for given outputs seems to be a more reasonable logic [19]; so the tomato production yield is hold fixed and the quantity of source wise energy inputs were reduced.

Technical efficiency

The technical efficiency (*TE*) can be expressed generally by the ratio of sum of the weighted outputs to sum of weighted inputs. The value of technical efficiency varies between zero and one; where a value of one implies that the DMU is a best performer located on the production frontier and has no reduction potential. Any value of *TE* lower than one indicates that the DMU uses inputs inefficiently [18]. Using standard notations, the technical efficiency can be expressed mathematically as following relationship:

$$TE_j = \frac{u_1 y_{1j} + u_2 y_{2j} + \cdots + u_n y_{nj}}{v_1 x_{1j} + v_2 x_{2j} + \cdots + v_m x_{mj}} = \frac{\sum_{r=1}^{n} u_r y_{rj}}{\sum_{s=1}^{m} v_s x_{sj}} \quad (1)$$

where, u_r, is the weight (energy coefficient) given to output n; y_r, is the amount of output n; v_s, is the weight (energy coefficient) given to input n; x_s, is the amount of input n; r, is number of outputs ($r = 1, 2, . . ., n$); s, is number of inputs ($s = 1, 2, .., m$) and j, represents jth of DMUs ($j = 1, 2, . . ., k$). To solve Eq. (1), Linear Program (LP) was used, which developed by Charnes *et al* [20]:

$$\text{Maximize} \quad \theta = \sum_{r=1}^{n} u_r y_{ri} \quad (2)$$

$$\text{Subjected to} \quad \sum_{r=1}^{n} u_r y_{ri} - \sum_{s=1}^{m} v_s x_{sj} \le 0 \quad (3)$$

$$\sum_{s=1}^{m} v_s x_{sj} = 1 \quad (4)$$

$$u_r \ge 0, v_s \ge 0, \quad and \quad (i \ \ and \ \ j = 1, 2, 3, \ldots, k \quad (5)$$

where, θ is the technical efficiency and i represents ith DMU (it will be fixed in Eqs. (2) and (4) while j increases in Eq. (3). The above model is a linear programming model and is popularly known as the CCR DAE model which assumes that there is no significant relationship between the scale of operations and efficiency [21]. So the large producers are just as efficient as small ones in converting inputs to output.

Pure technical efficiency

Pure technical efficiency is another model in DEA that introduced by Banker et al. in 1984. This model called BCC and calculates the technical efficiency of DMUs under variable return to scale conditions. Pure Technical efficiency could separate both technical and scale efficiencies. The main advantage of this model is that scale inefficient farms are only compared to efficient farms of a similar size [22]. It can be expressed by Dual Linear Program (DLP) as follows [18]:

$$\text{Maximize} \quad z = uy_i - u_i \tag{6}$$

$$\text{Subjected to} \quad vx_i = 1 \tag{7}$$

$$-vX + uY - u_0 e \leq 0 \tag{8}$$

$$v \geq 0, \ u \geq 0 \quad \text{and} \quad u_0 \ \text{free in sing} \tag{9}$$

where, z and u_0 are scalar and free in sign. u and v are output and inputs weight matrixes, and Y and X are corresponding output and input matrixes, respectively. The letters x_i and y_i refer to the inputs and output of *i*th DMU.

Scale efficiency

Scale efficiency shows the effect of DMU size on efficiency of system. Simply, it indicates that some part of inefficiency refers to inappropriate size of DMU, and if DMU moved toward the best size the overall efficiency (technical) can be improved at the same level of technologies (inputs) [6]. If a DMU is fully efficient in both the technical and pure technical efficiency scores, it is operating at the most productive scale size. If a DMU has the full pure technical efficiency score, but a low technical efficiency score, then it is locally efficient but not globally efficient due to its scale size. Thus, it is reasonable to characterize the scale efficiency of a DMU by the ratio of the two scores [23]. The relationship among the scale efficiency, technical efficiency and pure technical efficiency can be expressed as [24]:

$$Scale\ efficiency = \frac{Technical\ efficiency}{Pure\ technical\ efficiency} \tag{10}$$

In the analysis of efficient and inefficient DMUs the energy saving target ratio (ESTR) index can be used which represents the inefficiency level for each DMUs with respect to energy use. The formula is as follow [25]:

$$ESTR_j = \frac{(Enegy\ Saving\ Target]}{(Actual\ Energy\ Input)} \tag{11}$$

where energy saving target is the total reducing amount of input that could be saved without decreasing output level and *j* represents *j*th DMU. The minimal value of energy saving target is zero, so the value of ESTR will be between zero and unity. A zero ESTR value indicates the DMU on the frontier such as efficient ones; on the other hand for inefficient DMUs, the value of ESTR is larger than zero, means that energy could be saved. A higher ESTR value implies higher energy inefficiency and a higher energy saving amount [25].

In order to calculate the efficiencies of farmers and discriminate between efficient and inefficient ones, the Microsoft Excel spread sheet and Frontier Analyst software were used.

RESULTS AND DISCUSSION

Energy use pattern

In Table 2, the quantity of consumed inputs and their energy amounts used in the production of greenhouse tomato are given. Also, in Fig. 1, distribution of the anthropogenic energy input ratios in production of tomato are given.

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

	Unit	Energy equivalent (MJ Unit^{-1})	Reference
Inputs			
Human power	hr	1.96	[11]
Machinery	hr	64.8	[7]
Diesel fuel	L	47.8	[12]
Chemicals	kg		
Herbicides		238	[13]
Fungicides		216	[13]
Insecticides		101.2	[13]
Fertilizer	kg		
Nitrogen		66.14	[14]
Phosphate		12.44	[14]
Potassium		11.15	[14]
Manure	t	303.10	[14]
Water for irrigation	m^3	1.02	[15]
Electricity	kWh	11.93	[16]
Seed	kg	1.0	[16]
Output			
Tomato	kg	0.8	[16]

Table. 2. The physical inputs used in tomato production and their energy equivalences

Input (unit)	Quantity per unit area (MJ Unit^{-1})	Total energy equivalent (values)	Percentage
1. Chemicals (kg)	-	-	2
Herbicides (kg)	3.1	737.8	
Fungicides (kg)	2.7	584.2	
Insecticides (kg)	3.9	394.9	
2. Human power (h)	5815.2	11397	10
3. Machinery (kg)	52.3	3389	3
4. Fertilizer (kg)	-	-	30
Nitrogen fertilizer (kg)	315	20834	
Phosphate (kg)	371	4615	
Potassium (kg)	285	3177	
Manure (tones)	21.2	6425	
5. Seeds (kg)	0.1	0.1	
6. Diesel fuel (l)	985.5	47106	40
7. Electricity (kWh)	1200	14316	12
8. Water for irrigation (m^3)	3716	3790	3
Total energy input (MJ)	-	116768.4	100
Yield (kg ha^{-1})	135000	108000	

As it can be seen in the (Table 2), 315 kg nitrogen, 371 kg Phosphate, 285 kg potassium, 21.2 tons of manure, 985.5 L diesel fuel, 3716 m3 water, 9.7 kg chemical spraying agents, 5815.2 h human power, 52.3 h machinery, 1200Kwh electrical energy per hectare are used for production of tomato in Esfahan province of Iran. The average tomato output were found to be 135000 kg ha^{-1} in the enterprises that were analyzed. The energy equivalent of this is calculated as 108000 MJ ha^{-1}. It can be seen in Table 2 that the energy used in the production of tomato consists of 2% chemicals, 10% human power, 3% machinery, 30% fertilizers, 40% fuel (diesel), 12% electricity and 3% water inputs. The highest energy input is provided by fuel. Omid *et al.* (2011) concluded that the input energy for cucumber production was to be 152908 MJha^{-1} and the average inputs energy consumption was highest for diesel fuel, total chemical fertilizer and electricity. Similar results have been reported in the literature that the energy input of diesel fuel and chemical fertilizers has the biggest share of the total energy input in agricultural crops production [4-7]. Consequently, Börjesson and Tufvesson [26] reported that fertilizers and diesel fuel were the main energy consuming inputs in wheat, sugar beet, canola, ley crops, maize and willow productions.

Technical, pure technical and scale efficiency

Results obtained by application of the input-orientated DEA are illustrated in Table 3. The mean radial technical efficiencies of the samples under CCR and BCC assumptions are 0.79 and 0.89, respectively. This implies first, that on average, greenhouses could reduce their inputs by 21% (11%) and still maintains the same output level, and second, that there is considerable variation in the performance of greenhouses. Increasing the technical efficiency of a greenhouse actually means less input usage, lower production costs and, ultimately, higher profits, which is the driving force for producers motivation to adopt new techniques.

Return to scale

The analysis shows that only three DMUs numbered 15, 18 and 24 have best practice and actually are operating at the most productive scale size where CCR apply and scale efficiency equals one. The return to scale (RTS) indicated that all efficient units (based on technical efficiency) were operating at CCR, whereas all inefficient ones were at Increasing Return to Scale (IRS), which indicates that for considerable changes in yield, technological change is required. Increasing returns to scale indicates that an increase in input resources produces more than proportionate increase in outputs. The average SE score of greenhouses is far from the optimal size (0.88), which indicates that if inefficient producers utilize their inputs efficiently, some savings in the different sources is possible without any change in technological practices. By contrast, Omid et al [1] reported a higher (0.9) scale efficiency for cucumber greenhouses in Tehran province. An additional 12% productivity gain would be feasible - assuming no other constraining factors - provided they adjusted their greenhouse operation to an optimal scale. In the present dataset, no producer was found to operate at Decreasing Return to Scale (DRS). Pahlavan et al [27] examined the optimization of energy consumption for rose production in Iran. The results of DEA application revealed that the average pure technical, technical and scale efficiencies of farmers were 0.83, 0.68 and 0.79, respectively.

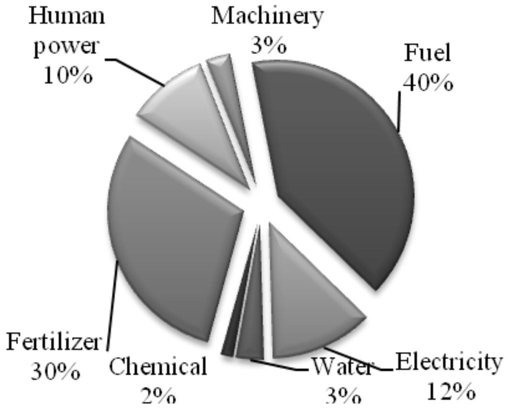

Figure.1. The anthropogenic energy input ratios in the production of tomato.

Table 3. Technical, scale efficiency and return to scale

DMU	TE	PTE	SE	RTS
GH1[a]	0.75	1.00	0.75	Increasing
GH2	0.72	0.87	0.82	Increasing
GH3	0.63	0.89	0.70	Increasing
GH4	0.78	0.83	0.93	Increasing
GH5	0.85	1.00	0.85	Increasing
GH6	0.92	0.98	0.93	Increasing
GH7	0.69	0.89	0.77	Increasing
GH8	0.70	0.85	0.82	Increasing
GH9	0.82	0.92	0.89	Increasing
GH10	0.68	0.76	0.89	Increasing
GH11	0.79	0.84	0.94	Increasing
GH12	0.74	0.86	0.86	Increasing
GH13	0.63	0.79	0.79	Increasing
GH14	0.98	1.00	1.00	constant
GH15	1.00	1.00	1.00	constant
GH16	0.95	1.00	0.95	Increasing
GH17	0.76	0.87	0.87	Increasing
GH18	1.00	1.00	1.00	constant
GH19	0.89	0.92	0.96	Increasing
GH20	0.68	0.76	0.89	Increasing
GH21	0.92	0.95	0.96	Increasing
GH22	0.67	0.73	0.91	Increasing
GH23	0.57	0.65	0.87	Increasing
GH24	1.00	1.00	1.00	constant
GH25	0.88	0.92	0.95	Increasing
GH26	0.75	0.87	0.86	Increasing
GH27	0.96	1.00	0.96	Increasing
GH28	0.75	0.86	0.87	Increasing
GH29	0.63	0.83	0.75	Increasing
GH30	0.74	0.85	0.87	Increasing
Mean	0.79	0.89	0.88	-

Energy saving from different energy inputs

Table 4 shows the actual energy use, optimum energy requirement and saving energy for tomato production. Also, the percentage of ESTR is illustrated in the last column. As it is indicated, optimum energy requirement for electricity calculation showed that, 15.26% from electricity, 10.87% from diesel fuel, 15.01% from water for irrigation, 20.78 from human power, 11.12% from machinery and 9.71% from SFCM (seed, fertilizer, chemicals and manure) could be saved. The percentage of total saving energy in optimum requirement over total actual use of energy was calculated as 12.16%, indicating that by following the recommendations resulted from this study, on average, about 14194 MJ ha^{-1} of total input energy could be saved while holding the constant output level of tomato yield. Mousavi-Avval et al [17] reported that on an average, about 9.5% of the total input energy for canola production in Iran could be saved.

Fig. 2 shows the share of the various energy inputs in the total input saving energy. It is evident that, the highest contribution to the total saving energy is 36 % from diesel fuel followed by SFCM (25%), Human power (16%), electricity (15%), water for irrigation (4%) and machinery (2%) energy inputs.

In Table 5 the pure technical efficiency, actual energy use and optimum energy requirement from different energy inputs for 22 individual inefficient farmers are presented. Using this information, it is possible to advise a producer regarding the better operating practices by following his/her target energy requirement from different inputs to reduce the input energy levels to the target values while achieving the output level presently achieved by him. It gives the average energy usage in current and optimal condition (MJ ha^{-1}) and percent contribution of total saving energy over actual use [18]. Therefore, dissemination of these results will help to improve efficiency of farmers for tomato production in surveyed region.

Improvement of greenhouse gas emission by using DEA

In this research GHG emissions were the scope of this analysis and the corresponding amount was calculated. The diesel fuel combustion can be expressed as fossil CO_2 emissions with equivalent of 2764.2 gL^{-1}[28]. Also, the machinery and fertilizer supply terms can be expressed in terms of the fossil energy required to manufacture and transport them to the farm with CO_2 equivalents of 0.071 $TgPJ^{-1}$ and 0.058 $TgPJ^{-1}$ for machinery and chemical fertilizers, respectively [28-29].

Table 6 shows the CO_2 emission for tomato production in actual and optimum energy use. Results of this table indicated that tomato production is mostly depending on diesel fuel sources. Diesel fuel had the highest share (53.44%) followed by chemical fertilizer (41.85%) and machinery (4.71%). As it can be seen in Table 5, the total amount of CO_2 can be decreased to the value of 4.55 tones. As it can be seen, the total CO_2 emission from diesel fuel, chemical fertilizer and machinery could be decrease to 2.42, 1.92 and 0.21 ton, respectively. 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. Eady et al [30] applied the Life cycle assessment modeling of complex agricultural systems with multiple food and fibre co-products. They reported that amongst the crops, estimates of emissions for the cereal grains averaged 202 kg CO_2-*e*/tonne grain, canola 222 kg CO_2-*e*/tonne and lupins 510 kg CO_2-*e*/tonne, when modeled to include the benefits of the mixed farming system.

CONCLUSION

This paper describes the application of DEA to the study for improving the energy use in the tomato production in the Esfahan province of Iran. This technique allows the determination of the best practice farms and can also provide helpful insights for farm management. DEA has helped in segregating efficient farmers from inefficient farmers. It has also helped in finding the wasteful uses of energy by inefficient farmers, ranking efficient farmers by using the CCR and BCC models and ranking energy sources by using technical, pure technical and scale efficiency. The results revealed that tomato production depends mainly on diesel fuel, fertilizers and electricity energy inputs. On an average, the total input energy could be reduced by 12.16% without reducing the output energy from its present level by adopting the recommendations based on this study. Results of GHG emission showed that total amount of CO_2 in tomato production was calculated as 5.09 ton ha^{-1}. Diesel fuel had the highest share (53.44%) followed by chemical fertilizers (41.85%) and machinery (0.24%). Optimization of energy inputs can be decreases the CO_2 emission by 0.54 ton ha^{-1}. 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.

Table. 4. Energy requirement in optimal condition and saving energy for tomato production

Input	Optimal energy requirement (MJ ha^{-1})	Actual energy requirement (MJ ha^{-1})	Saving energy (MJ ha^{-1})	ESTR (%)
Human power	9028	11397	2369	20.78
Machinery	3012	3389	377	11.12
Fuel	41982	47106	5124	10.87
Electricity	12131	14316	2185	15.26
Water	3221	3790	569	15.01
SFCM[a]	33198	36768	3570	9.71
Total	102572	116766	14194	12.16

Table. 5. The actual energy use and optimum energy requirements for individual inefficient tomato producers based on the results of BCC model

DMU No	PTE	Actual energy use (MJ ha^{-1})						Optimal energy requirement (MJ ha^{-1})					
		Water	Human power	Machinery	Fuel	Electricity	SFCM	Water	Human power	Machinery	Fuel	Electricity	SFCM
2	0.87	3986	11891	3780	49872	14990	37771	3753	11451	3451	48123	14579	37110
3	0.89	2970	12301	3467	51231	14880	37681	2970	11510	3390	48790	14512	37221
4	0.83	4590	12365	4536	56719	15674	36571	3896	11491	3657	49721	14781	36571
6	0.98	3971	12765	3201	44122	13890	34221	3781	11392	3201	44122	13890	34221
7	0.89	4250	12900	3241	49870	14675	37690	3890	11430	3241	48546	14431	37390
8	0.85	2980	11908	3450	48126	15778	38121	2980	11483	3312	47634	14667	36990
9	0.92	3671	13671	4568	47891	14660	30718	3671	11516	3970	47534	14460	30718
10	0.76	2854	13672	4789	54378	15643	39980	2854	11487	3876	49520	14990	37100
11	0.84	3781	12890	4120	50090	14356	39081	3781	11397	3980	48729	14356	37550
12	0.86	3324	14671	4981	49357	14770	38890	3324	11679	3751	48310	14500	36976
13	0.79	3120	14890	4782	57892	15670	39707	3120	12180	3519	49880	14669	36991
17	0.87	5620	10101	4100	54623	15180	38790	3780	10101	3829	48390	14459	37003
19	0.92	2856	10236	2901	49221	17432	37123	2856	10236	2901	47680	14220	36009
20	0.76	2354	15409	4579	60225	16350	38900	2354	12920	3669	50456	14789	37790
21	0.95	2781	12370	2764	46153	14523	37431	2781	11451	2764	46153	14471	34511
22	0.73	3981	15671	4789	61379	16822	40120	3790	12610	3986	51679	14993	37730
23	0.65	4561	17987	4765	67890	17451	42259	3821	11790	3943	53471	15119	38912
25	0.92	5412	12590	3781	45663	15227	38960	3796	11999	3412	45663	14668	36980
26	0.87	3491	14231	2789	54620	15539	37912	3491	12300	2789	49821	14771	36920
28	0.86	3401	13461	3901	53167	14591	38150	3401	12412	3613	48934	14591	37229
29	0.83	3188	11231	3213	55324	15991	38890	3188	11231	3213	48990	14881	37440
30	0.85	3899	12309	3571	51269	15570	37780	3800	12009	3429	48770	14990	36991

Table. 6. Amount of greenhouse gas emission for tomato production in actual and optimum energy use

Input	Equivalent (Tg (CO_2) PJ^{-1})	Quantity of CO_2 in energy actual use (ton)	Quantity of CO_2 in energy optimum use (ton)
Diesel fuel	0.0578	2.72 (53.44%)	2.42 (53.19%)
Machinery	0.071	0.24 (4.71%)	0.21(4.61%)
Chemical fertilizer	0.058	2.13 (41.85%)	1.92 (42.20%)
Total	-	5.09	4.55

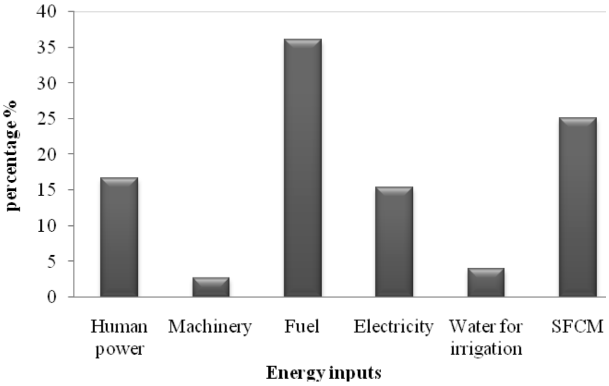

Fig. 2. Distribution of saving energy for tomato production in Iran

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