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The evaluation of effective criteria on site selection for energy production units from cellulosic biomass in Iran

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Abstract: Both Analytical Hierarchy Process (AHP) and benefits, opportunities, costs and risks (BOCR) techniques were used successfully to evaluate the effective criteria on site selection for energy production unit development from cellulosic biomass in Iran. The results showed that the benefits criteria was at the first level while the initial cellulosic raw materials and opportunities with the aim of the local economy had the second position as the most important indices on site selection. In addition, third criterion has been introduced for the costs criteria (transportation cost) and social barriers by the experts. However, risks criteria which referred to instability of providing cellulosic raw materials is one of the less important effective indices on site selection to make energy production unit. The results illustrated that the economy and politics as two environmental effective factors affected on the site selection process generally.

Keywords: cellulosic biomass, natural resources Analytical Hierarchy Process, energy, Iran.

1. Introduction

The amount of energy consumption is considered as an important indicator of the human activities and society's development in the world (Sayin et al, 2005). Many researchers have been investigated that the demand of human being to energy as an important factor of the application of

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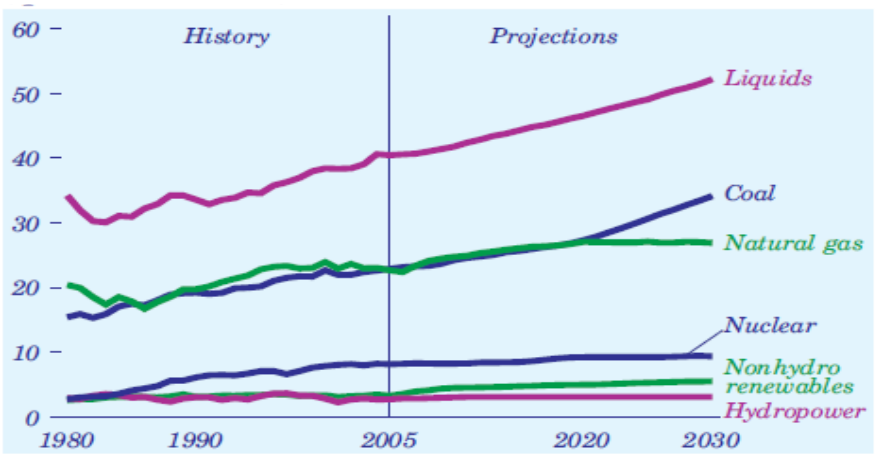
environmental changes and resources (Kanagawa and Nakata, 2006). The experts believe that by clean energies such as solar, wind power, geothermal, hydrogen and biomass instead of the fossil fuels energy, the environmental pollution and the risks are avoided (Jacobson, 2009). Fossil fuel energy resources such as oil, gas and coal will be finished finally and this fact caused to an increase worldwide interest to find the non-petroleum-based alternative sources for energy.

According to the statistics in the past 30 years, the energy demands of the world are increased considerably. In 1960, the energy consumption of the world was Gt 3/3 and it increased to Gt 8/8 in 1990(Sun, 1998). Nowday, the annual consumption of energy is about 13Gt/yr and it can increase to 14Gt/yr IN 2020(IEA, 2007). Figure 1 shows the energy consumption growth during 1980-2030 (Tomaseli, 2007). As seen from Figure 1, the energy consumption will increase in future and the use of other renewable energy resources is felt in developing countries including Iran (Shahla et al., 2009). The present cycle of energy is mostly based on using fossil fuels and creates complex problems ecologically. Due to the industrial developments, growth of population, and the environmental pollution, the energy utilization from renewable resources has received much attention during the last decade in most of European, American and Asian countries (Dovetail News, 2009).

Figure1: Consumption growth of various energy in non-renewable and renewable in the world from 1980 to 2030 (EIA, 2007), X: year, Y: Quadrillion Btu



The resources of renewable energies are various including solar, wind power, geothermal, sea wave, water, hydrogen and biomass. Today, biomass is considered as a renewable resource with high potential for energy production. Biomass is the fourth largest primary energy resource in the world after coal and crude oil, and meets about 14% of the world energy demand (FAO, 2004). With respect to the conversion technologies for energy use, biomass can be converted to the various forms of materials such as gas (biogas) or liquid (methanol, ethanol and biodiesel) being applied to produce electricity and heat (Shahla et al., 2009). The cellulosic biomass can be used as a potential source of renewable energy based on both benefits of energy recovery and environmental adaptation. Furthermore, cellulosic biomass is economical with the best CO_2 absorption and they can be traded and transferred at global level and is more reliable compared to other resources. Therefore, the countries with a wide cultivation area and various cellulosic biomass resources had high potential to use the these materials in several applications

According to the Iran agriculture statistics, there are wide range of cultivation and various resources of cellulosic waste in Iran (Zavare & Alizade, 2011). Thus, the used of cellulosic biomass as sources for energy production must be evaluated. For this purpose, the main goal of this study was to identify the effective criteria on site selection to develop the energy production units from cellulosic biomass resources in Iran using AHP and BOCR techniques.

1.1. Chemical composition of biomass

The chemical compositions of biomass dependent upon the ingredients are varied. Indeed, all the biomass resources are consisting of organic materials and are combustible with a computable heating value (Pazuki, 2008). Table 1 shows the heating value of most of the biomass ingredients (Klass, 1997). The information of the Table 1 showed that all the existing ingredients in biomass sources had the potential of energy production being of great importance in terms of converting it to consumable energy.

Table 1: Heating value of biomass ingredients

Biomass Ingredients	CO_2 percentage	Heating value (MJ/Kg)
Monosaccharaides	40	15.6
Disaccharides	42	16.7
Polysaccharides	44	17.5
Lignin	63	25.1
Protein	73	24
Fat	75	39.8
Carbohydrates	41 - 44	16.7 – 17.7
Fiber	47 - 50	18.8 – 19.8

1.2. Different kinds of biomass raw materials applied in energy production in Iran

1.2.1 The existing wood and waste in the forest

Iran approximately has 14.3 million hectare forest which is covering 8.83% of total country. Based on the Iran population, the share of each Iranian person of the forest are 0.2% hectare and the Figure based on global per capita of the forest with 0.8% hectare showed Iran poverty in terms of forest per capita. Among 56 countries with forest in the world, Iran ranked 45th in the world and this statistics showed low vegetation and low waste. Based on the reduction of forest harvesting in the north of Iran, the direct energy production of forest resources is impossible (Ministry of Jihad e agriculture, 2009).

1.2.2. Wood and the wastes of highly growing trees plantation

Based on the ignorance of the government planners about wood cultivation and not providing the required infrastructures to implement this approach in Iran, the projects of wood cultivation only can provide a small part of cellulosic industries demands being financed from the existing cellulosic industries. Nowadays, wood cultivation projects are followed as limited in Northern provinces of Iran (Modir Rahmati, 2008). Although in most of the developed countries, wood cultivation system is conducted to provide a great part of the applied raw materials in cellulosic industries and energy production, despite the high potential in Iran, a great step is not taken in this field.

1.2.3 Agricultural bio-residue

All agricultural and related industries produced another by-product which obtained during their process. According to the existing statistics in Iran, half of the agriculture products are destroyed in various stages without being consumed and the processing of the industries in Iran is not developed enough to apply all the components of agriculture products (Zavare & Alizade, 2011). According to the statistics of the agriculture waste in Iran, in case of having an organized plan and suitable mechanism, obtaining the required technology, the agriculture waste leading into the environmental problems, can be applied to provide a part of the required energy of the industries and the reduction of using fossil fuels (Mahdavi, 2001).The investigations results showed that the Bagasse, wheat, barley and rice straw, and the corn stem are the wastes with high potential in energy production (Golestan, 2005). The major of waste products, which involved of the cane, wheat, barley, rice and corn can be reached to the 24827 thousands ton per year in Iran (Zavare & Alizade, 2011) but, most of these bio-residue have been burnt (Rahimikia et al., 2011). The production of five major cultivation products in Iran and respect obtainable waste in agriculture year 2007-2008 are presented in Table 2(Ministry of Jihad e agriculture, 2009).

Table 2- The cultivation waste production in Iran during 2007-2008

Cultivated product type	Waste type	Cultivation area (Hectare)	Product (1000 ton)	Accessible amount of waste (thousands ton)
Wheat	Stem and straw	7222311	15886	17900
Barley	Stem and straw	1641829	3104	3497
Rice (husk)	Stem and straw	630561	26120	2220
Corn	Stem	307015	2361	578
Cane	Bagasse	61178	5315	632
Sum	**-**	**9862894**	**52876**	**24827**

1.3. Review of literature

Although the research on renewable energy has been started in 2006 in Iran and several works have been focused on the evaluation of the generalities of using renewable energy and the feasibility of this type of energy (Abdoli et al., 2006), the considerable studies have not been conducted on using biomass resources and specifically cellulosic materials for the energy production. Such studies are considerably carried out in developed countries for a long time and it is also grown in the developing countries. For more than one decade, Analytic Hierarchy Process technique is used mostly in the process of ranking the factors and directing different kinds of strategic decision making as separately or with BOCR model (Saaty, 2006). The reliability of the results of AHP technique and its developed model Analytic Network Process changed this technique to an effective tool in all issues affected by varied variables. The issues of the identification of new energy resources and the effective factors are not exception and using AHP technique is mostly common in recent years (Saaty, 2006). The studies conducted by Onut et al. (2008), on the effective indicators in priority of the common energy sources, applied in manufacturing industries of Turkey in 2008 by developed AHP technique, ANP with BOCR model. The recent study aimed to select a good source of energy in manufacturing industries of Turkey and the results analysis and collection showed that electricity energy among the five choices is the highest priority In another study performed for the priority of renewable energy applied in Turkey, AHP method was applied (Saaty, 2006). The indices in this study were including economical, social, political and technology. The parameters of this study were biomass energy, water, geothermal, wind and sun. The results of 4 indices, 17 subscales and 5 effective choices showed that the best choice to use renewable energy in Turkey is wind, solar and biomass (Kahraman.C.et al., 2009). In this case, the economical, social and political indicators have the highest priority. Kaya et al. (2010) applied the best type of renewable energy in Turkey as AHP method. The results showed 4 indices, 29 subscales and 5 scales. The wind energy was the best choice among the different types of renewable energy, while, the best choice for the establishment of wind power plant was Catalca site. In a similar study to evaluate and prioritize the most important renewable energy in Taiwan, AHP method was applied. The results of 3 indicators and 14 effective subscales showed that environmental factors had the maximum influence on the mentioned indices. Thus, by comparison of 6 common renewable energy, it was found that hydroelectric energy, solar and wind power were the best item to use renewable energies in this country respectively (Shen & Yuan, 2010).

2. Materials and methods

The main source of the data collection of the current study was the academic and industrial experts active in various sectors. The sectors were including the agriculture, forest, cellulosic industries, Renewable Energy Organization of Iran, and scientific groups in universities. The data of the study were listed as follow: The statistics of formal cellulosic resources of Iran and the collected comments of the experts. Thus, the selection of a good and reliable technique to obtain the expert views was the first step of the methodology followed by the Analytical Hierarchy Process (AHP) as one of the most applied multi-criteria decision making instruments. Feglar (2005) in his studies expressed that in the current complex world, there are various solutions for each problem and each of the recommendations require taking various resources and include special results and each of the results include low or more desirability, low or more certainty and short or long time. Thus, an expert to take organized decisions should prioritize the solutions based on the required resources of each one of them and consider the benefits, costs, risks and opportunities of each decision. In

such a complex environment, the decision maker requires a logical method to classify and consider various criteria affecting the valid goals and the stability of his judgments and AHP technique is valuable. Therefore, AHP and Expert Choice software as its appropriate instrument was selected as a most successful theory of multi-criteria decision making which introduced by Saaty (1996).

2.1. BOCR analysis

In order to evaluate the effective indices on the selection of a suitable place for creating the energy production unit using cellulosic resources, , the network evaluation model of the benefits, opportunities, costs and risks (BOCR) has been considered (Liang and Li, 2008). The BOCR was applied as a symmetric model to evaluate the collected indicators in the study. During the decision making process, the BOCR method allowed the researcher to deal with the benefits, opportunities, costs and risks and could help them to take the best choice (Saaty, 1996; Alig et al., 2004).

To provide the questionnaire, comprehensive studies on the factories which produce the energy from the biomass waste in developed countries as well as the biomass potential for energy production in Iran have been conducted. The resulted questionnaire was distributed among 13 different domain experts of Public and Private Organization (industries, environment activists, wood industries experts, agriculture, forest and the specialized lecturers of University). In particular, the numbers of experts which participated in current study were 2, 7, 2, and 2 for environment, wood industries, agriculture and forest, specialized in energy production, and new energy organization experts respectively. By summing them up, the benefits, costs, opportunities and risks of energy production industry of cellulosic materials in Iran were extracted. The results were including the benefit, opportunities, costs and risks of energy production industry from cellulosic materials and the effective factors on site selection of the factories in Iran were presented in Tables 3, 4, 5, 6.

2.2. Overall factors

Since the indicators of benefits, costs, opportunities, and risks can be affected by Overall factors; another questionnaire was provided by considering the effective overall factors impact on the site selection indicators for energy production unit from biomass. Then, the questionnaire was given to four macro view experts (specialized in cellulosic materials) in energy field. The results of effective overall factors on the site selection indicators are illustrated in Table 7.

In the next stage, the weight of each of the indicators of benefit, costs, opportunities and risks were affected by overall factors and was obtained by Expert Choice2000 software.

Table 3: The main criterion of the benefits for site selection of new energy production from cellulosic materials

Entrepreneurship	The increase of the absorption of local skillful labor force	
	The increase of the local income	
Raw materials	The development of agriculture fields	The increase of wood cultivation
		The development of the cultivation of agriculture products
	Using low valued outputs of the forests	Cleaning the forest fields
		The increase of the woods sale with low value
	The increase of the income of the factories of wood industries	Selling waste
		The reduction of waste destruction costs
Providers	Waste	Agriculture waste
		Wood industries waste
	The trees of Agroforestry	
	The condition of forests	
Infrastructure	Infrastructure	

Table 4: The main criterion of the costs for site selection of new energies production from cellulosic materials

Economical	Land costs	
	Transportation costs	
	Road construction costs	
	Operationalized costs	Human resources
		Raw materials
Social and cultural	Social and cultural	

Table 5: The main criterion of the opportunities for site selection of new energies production from cellulosic materials

Development	Cultivation fields
	Local economy
	Wood industries in the region
The production and selling of heat, electricity and fuel	The production and selling of heat, electricity and fuel
Future investment	Future investment
The improvement of management systems of forest	The improvement of management systems of forest
State supports	Granting Rial and foreign exchange loan
	Tax exemption

Table 6: The main criterion of the risks for site selection of new energies production from cellulosic materials

Unreliability of continuance providing of raw materials	The lack of assurance of continuance providing of raw materials	
The government problems and related organizations	The lack of financial supports	
	The lack of stability of state rules	Tax rules
		The reduction of obtaining forest resources
Environmental issues	The reduction of land use	
	The change of forest management regimes	
	Forest damage	

Table 7: Overall factors structure

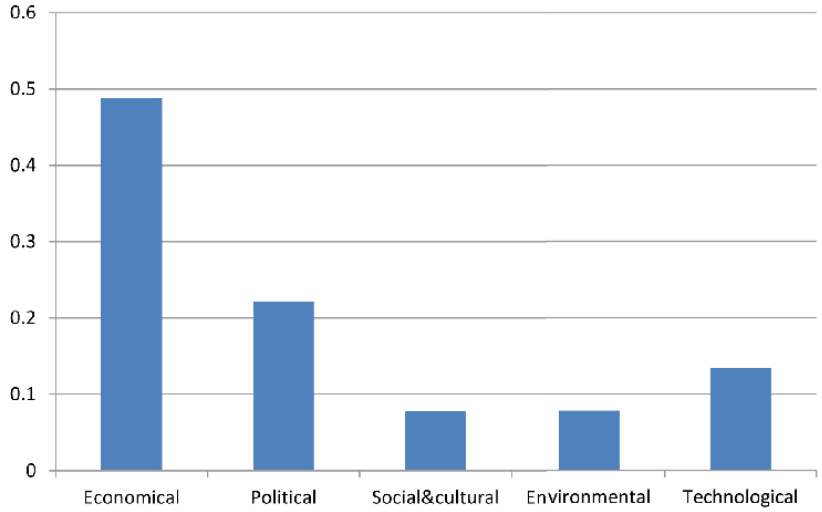
Economical factors	Economical factors
Political factors	Passive defense
	State rules
Social-cultural factors	Population growth
	Educational and culture condition
Technological factors	Technological factors
Environmental factors	Wood cultivation
	Environmental pollution
	Forest protection

3. Results and discussion

3.1. Overall factors

As mentioned above, the effective overall factors on the BOCR were consisting of economical, political, social - cultural, technological and environmental factors. The priority results of the factors from the view of the experts are present in Fig. 2. As seen in Fig 2, the economy factor with the weight (0.488) had the highest priority and the second position was for political factor with the weight (0.222). The, technology with the weight (0.134) was in the third priority while the social, cultural and environmental factors with the weight (0.078) were in the final rank.

Figure 2: The priority of overall factors (inconsistency rate, 0.01), X: Criteria, Y: Weighing value



3.2. BOCR

According to the experts comment about the results and the comparison of overall factors , BOCR of the new energy production industry of cellulosic materials are affected by overall factors. Therefore benefits, opportunities, costs and risks are ranked by using the results of BOCR analysis in Expert choice 2000 software and the results are presented in Table 8. As can be seen from Table 8, among four main indicators, the benefits with the highest weight (0.364) was located on the top while the opportunities index with the less weight (0.316) was in the second level, and the costs with the weight of 0.192 can be observed in the third rank and the last location was belong to the risks index with score 0.128.

Table 8: The ranking of BOCR indicators by E.C software very high (1), high (0.51), medium (0.252), low (0.124), very low (0.065)

Distributive mode	**Rating**	**Rating**	**Rating**
Alternatives	**Environmental, Wood cultivation (0.540)**	**Environmental, pollution (0.163)**	**Environmental, forest preservation (0.297)**
Benefits	medium	medium	medium
Costs	Very low	low	medium
Opportunities	low	low	low
Risks	Very low	medium	medium
Alternatives	**Social, population growth (0.500)**	**Social, Educational and culture condition (0.500)**	**Technology, Technological (0.134)**
Benefits	high	Very high	Very high
Costs	medium	Very high	high
Opportunities	medium	high	Very high
Risks	medium	medium	high

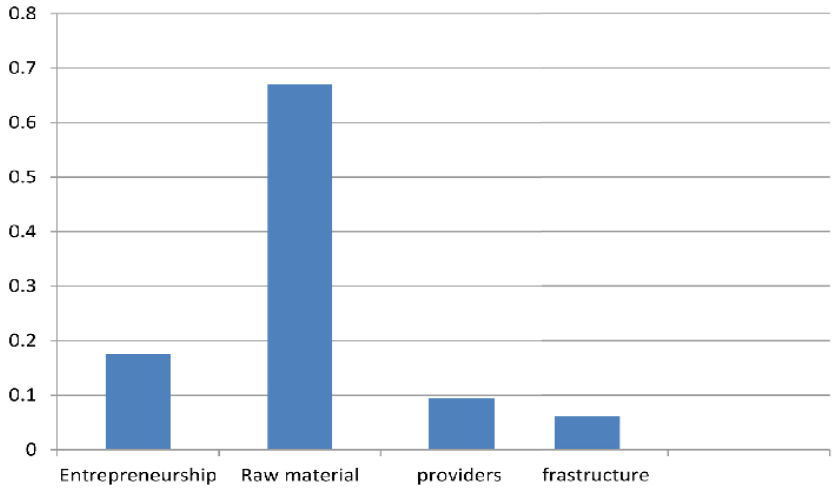
Distributive mode		**Rating**	**Rating**	**Rating**
Alternatives	Total	**Economical (0.488)**	**Politic, passive defense (0.75)**	**Politic, state rules (0.25)**
Benefits	0.364	Very high	high	medium
Costs	0.192	high	medium	medium
Opportunities	0.316	Very high	medium	Very high
Risks	0.128	low	medium	Very high

3.3. Benefits

As shown in Figure 3, the benefits with four indicators which include the entrepreneurship, raw material, providers and infrastructure are evaluated. The results showed that raw material

index with weight (0.67) had the highest priority, while the entrepreneurship index with weight 0.175 showed the second priority, providers' index with weight 0.094 was placed at the third priority then followed by infrastructure indicator.

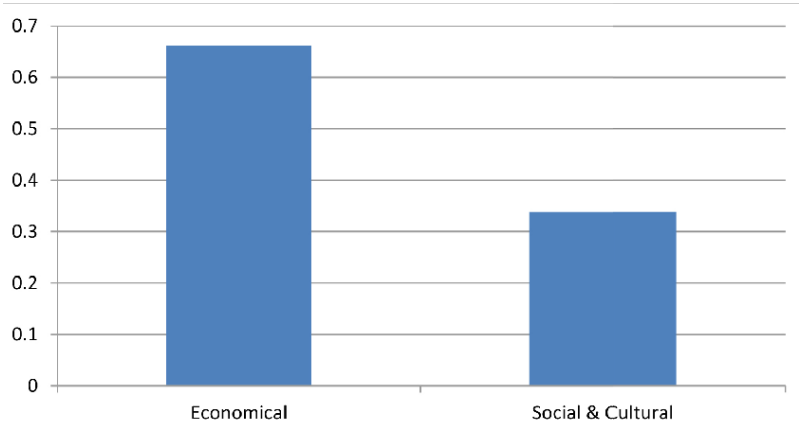
Figure 3: The priority of benefits in first level (inconsistency rate 0.05), X: Criteria, Y: Weighing value



3.4. Costs

The costs were evaluated with economical and social-cultural indices. The results of the priority of the indices are shown in Fig. 4. The results showed that the economical index and the social-cultural index had the first and second priority respectively.

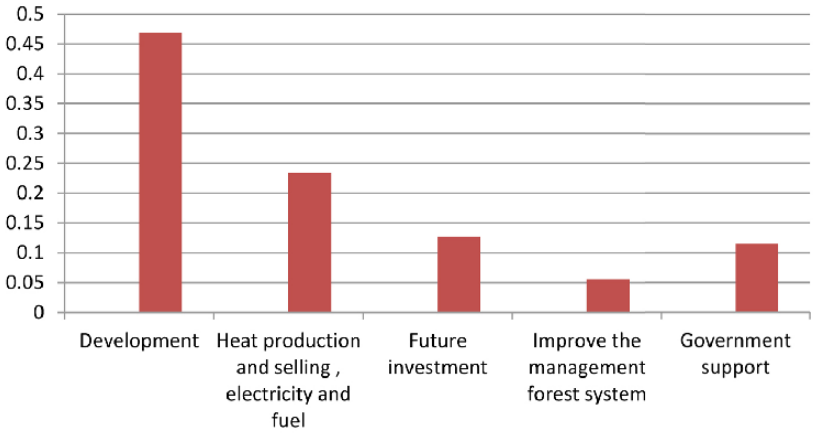
Figure 4: The priority of costs indices in first level (inconsistency rate 0.00), X: Criteria, Y: Weighing value



3.5. Opportunities

The opportunities were evaluated by five indicators include development, heat production and selling, electricity and fuel, future investment, improve the management of forest system and government supports. The ranking of the indicators are presented in Fig. 5. The results showed that the development index with weight 0.469, production and selling of heat, electricity and fuel with weight 0.234, future investment with weight 0.127, state support index with weight 0.115, and the improvement of management systems of the forest with weight 0.055 had the first, second, third, fourth, and last priority respectively.

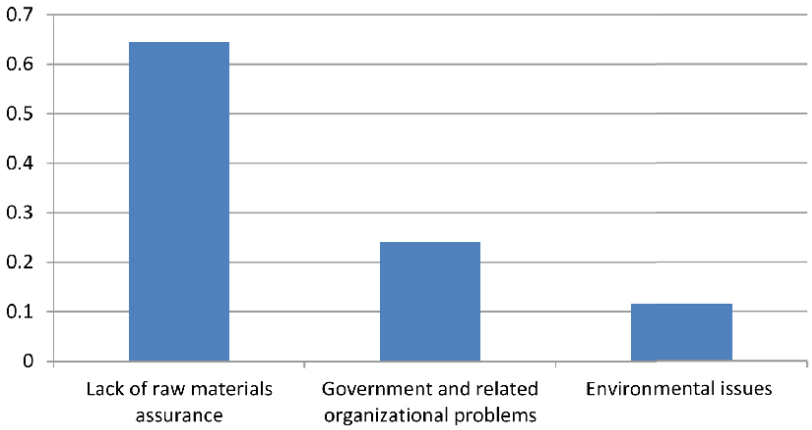
Figure 5: The priority of the opportunities indices in first level (inconsistency rate 0.02), X: Criteria, Y: Weighing value



3.6. Risks

Three indices that involved the lack of raw materials assurance, government and related organizational problems as well as the environmental issues were considered to evaluate the risks indicator. The results are presented in Fig. 6. As the results show, the lack of assurance to prepare raw materials with weight (0.645) had highest priority while the second and third priority were referred to the government and related organizations problems and also the environmental issues.

Figure 6: The priority of risks indices in first level (inconsistency rate 0.02), X: Criteria, Y: Weighing value



3.7. The analysis of the overall factors

The results demonstrated that the economical factor with weight (0.488) was found to be a most important factor on BOCR in order to establish the energy production industry from cellulosic materials in Iran. The distance between the economical factor with the next one (political factor) was two times higher and it showed that the economical factor was the most important parameter to evaluate the benefits, costs, opportunities and threats for site selection and the establishment of energy production unit. In addition, the results from the experts view technology, social-cultural, and environmental factors were located at the next level respectively.

3.8. Economic factors

In order to understand the efficiency of economy factor role on BOCR to produce energy from cellulosic materials, the evaluation of economical parameters on energy production in terms of environmental costs is essential. It is believed that the initial investment costs for creating the energy production unit is high and it can be an obstacle for factories constitution. In advanced units of energy production from cellulosic waste, the maintenance and personnel costs were equal to oil

and gas factories and so attraction of initial investment for the establishment of these units has been difficult .(Hearps & McConnell, 2011).

In addition, the pulp and paper, composite, and other cellulosic based industries can be serious adversary to the energy production unit in case of using the raw materials which lead to increase the price of these sources resulting in a serious repellent for development of the factories. The experience of the European and American countries showed that the increment of bio markets and the development of energy production factories (especially in short term) can increase the price of raw materials and put the related trading of the industries in risky competitive (Dovetail, 2009).

3.9. Political factors

The political circumstance can be considered as a second effective factor on BOCR for energy production from cellulosic materials in Iran. It is noticeable to say that the Iran economy structure is a subside structure and single-product (based on oil industry) and this industry is exclusively dedicated to state institutions. It is obvious that all the economical variables in Iran are affected by political approaches of the government or the rules proposed by the government and any change in the approaches leads into the major changes in economical condition. The development of the application of renewable energies by passive defense can help the long term stability and security of Iran economy. By the investigation of the next 20 years perspective, it is observed that the considerable part of GDP is provided via oil export. By the development of renewable energy, the fossil energy resources are maintained (oil and gas) in the future (Shahla et al., 2009).

3.10. Technological factors

For explaining the technology factor as the third factor of effective overall factors on BOCR of energy production of cellulosic materials in Iran, it should be considered that achieving update technology of energy production of cellulosic waste and it domestic nature is an important factor in reduction of production costs and increasing of productivity coefficient of energy production units of cellulosic materials (Shahla, 2009). Using the modern or old technology of energy production of cellulosic materials can affect all BOCR indices to establish the related factories.

3.11. Social-cultural factors

The evaluation of social-cultural factor showed that the population growth and educational-cultural conditions had equal weight and similar influence on BOCR for energy production from cellulosic materials in Iran. The increase of population in Iran needs to more energy consumption and it has direct influence on an increase in energy providing resources in Iran. Based on oil crisis and the reduction of fossil energy, it is necessary to use the resource that can be mixed or replaced with other energy resources. Ethanol is a kind of alcohol with zero pollutant capability and high combustion compared to other fuels and it can be obtained from cellulosic waste (Hall & Scrase, 1998). The increase of the education level and the improvement of the culture of the society have direct effect on the environment protection approaches and it can be considered as an effective factor on the evaluation of benefits, costs, opportunities and threats of industry development for energy production with high environment adaptability.

This is why social-cultural factor is less important than economical and political factors. With considerable fossil energy resources in Iran as the responding source to the needs of population growth and low indices of society and culture avoided the significant effect of the factors on new energy development process adaptable with environment in Iran.

3.12. Environmental factor

The evaluation of environmental factor as the least effective factor on BOCR for energy production from cellulosic materials in Iran showed that Sensitivity to the environment in Iran, not only from sociological approach in Iran society but also from the attempts of the government in the ratification of the environment protection rules is low.

3.13. The evaluation of BOCR analysis

As shown in Table8, the benefits index was the first important rank for creating the energy production units from cellulosic materials in Iran,. The results revealed that the benefits index is

mostly based on two subscales include raw materials and raw materials supplier. The results also showed that the resource of raw materials and the credible raw materials supplier would have very important role to make the energy production unit as well as on site selection process.

The opportunities index which located at second level was evaluated by infrastructure factors such as cultivation fields, forest or wood cultivation, state loan (loan and tax exception), local economy, etc. and it showed that the infrastructures and its potential in a region are the second concern of the authorities on site selection and the establishment of energy production. However, the costs and risks were the third and fourth important parameters on the site selection process respectively.

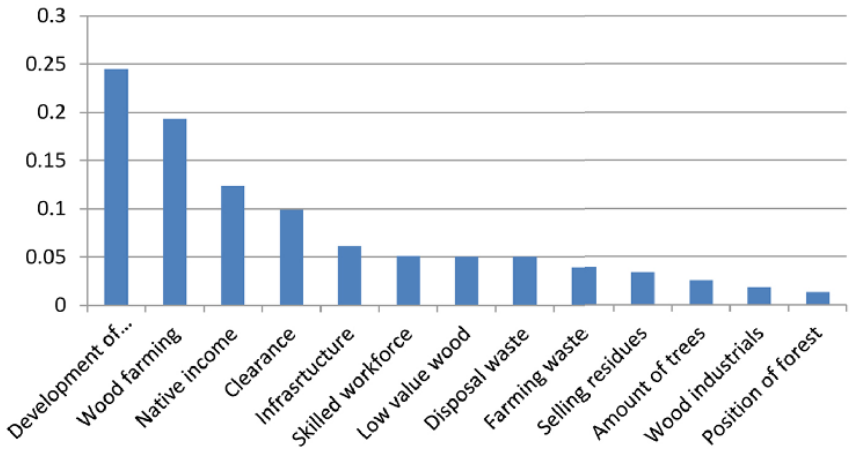
The results showed that the experts had more concern about the costs of energy production unit establishment compared to the risks or threats. These two results are evaluated as based on the wide dominance of fossil resources of energy on global economy are applied as powerful competitors of new energy. On the other hand, competition environment between the energy production units of cellulosic resources, with agricultural and wood based industry for seizing cellulosic resources make the necessity of considering the establishment costs of such units to achieve the economical justification and competitive advantage. However, the experts were less concerned about the risk of the lack of providing the raw material because of the agriculture infrastructures and the existence of wide cultivation area in Iran.

3.14. Benefits index analysis

The results of the benefit index analysis are presented in Fig. 7. The results showed that among four subscales include entrepreneurship, raw material, supplier and infrastructures, raw material had the highest score. The result was similar to the previously studies which have reported elsewhere (McKendry, 2001). The adequate and stable resource of cellulosic raw materials is the prerequisite of setting up each energy production unit. The agriculture bio residue, waste from wood industries, and wood cultivation are the resources that can be used for energy production. Traditionally, burning biomass such as wood waste, agriculture bio residue and animal fertilizer can destroy the environment (FAO, 2004) while using the chemical process to convert those bio residue to valuable products same as liquid flues is more friendly environment.

On the other hand, in the raw materials index analysis, cultivation area as subscale of the development of agriculture fields had the highest score. Among the waste materials, the agriculture bioresidue has very important role to produce new type of energy in developed countries (Mahdavi, 2001). In most of the European and American countries, agricultural waste is applied for energy production (ethanol and methanol, etc.) (Plieninger et al, 2009). Based on the existing statistics in Iran, almost half of the agriculture products are destroyed without being consumed and the process industries in Iran are not developed enough to use all components of agricultural product. Since the Iran is one of the poor countries in terms of forest resources and only 8.83% of its space is covered by forest (Ministry of Jihad e Agriculture, 2009) the importance of the agricultural wastes as the main cellulosic resource is more emphasized in Iran. Thus, the cultivation development subscale is the most important factor in providing raw materials for renewable energy production units. This is in appropriate with the studies performed in other countries and the exiting potentials in Iran (Mahdavi, 2001).

Figure 7: Final synthesis of benefits indices (inconsistency rate 0.03), X: Criteria, Y: Weighing value



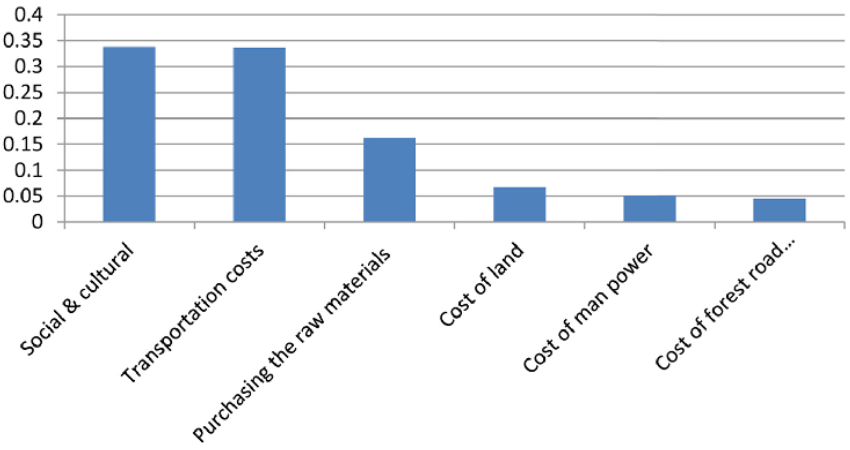
3.15. Costs index analysis

The results of the costs index analysis are illustrated in Figure4. The results showed that the economical index with weight (0.662) had the first priority compared to social and cultural index. The top level of the economical index which had two times more weight compared to social and cultural index showed the high importance of economical index in energy production from cellulosic materials.

In addition, the processing of costs index subscales are presented in Fig. 8. As seen from Figure 8, the social-cultural index with score (0.338) is in the first priority. Utilization the waste of forest management and agriculture considerably reduced the demand for land to produce bio fuel. However the recognition of suitable waste and proper utilization to protect the soil and ecosystem is vital. According to the UN-Energy organization information (2007), the uses of forest waste decrease the Nitrate absorption for trees. On the other hand, the extraction of the forest waste led to decrease the soil infertility and erosion. Thus, introducing the scientific suggestion to decrease the pressure on the mentioned sectors from the researchers and authorities can play an important role in reducing the concerns.

The transportation cost as subscales of the costs index with weight (0.337) was located in the second level in energy production. Based on the studies by MacDonald (2006), the most important barrier for providing the required raw materials is the transportation costs. The study showed that regarding the energy production from forest waste in developing countries, transportation costs are a barrier in using the resources compared to other effective factors such as waste density and roads quality. The costs index for purchasing the raw materials is another important index in the form of costs index with weight (0.162) dedicated the third priority. According to Perez et al., (2009), one of the most important issues making the projects of bio energy production challenging is the costs of purchasing the raw materials.

Figure 8: Final synthesis of costs indices (inconsistency rate 0.04), X: Criteria, Y: Weighing value



3.16. Opportunities index analysis

The results of the opportunities index analysis are presented in Fig. 5. The results showed that the development index with weight (0.469) was in the first priority and other constituent indices of opportunities index include the possibility of production and heat selling, electricity and fuel, future investment, improvement of forest management systems and state supports were in the next importance position respectively. But the ranking of the constituent subscales for development index are demonstrated in Figure 9. The results showed that from the view of the experts, the most important subscale of development index is local economy with weight (0.625).

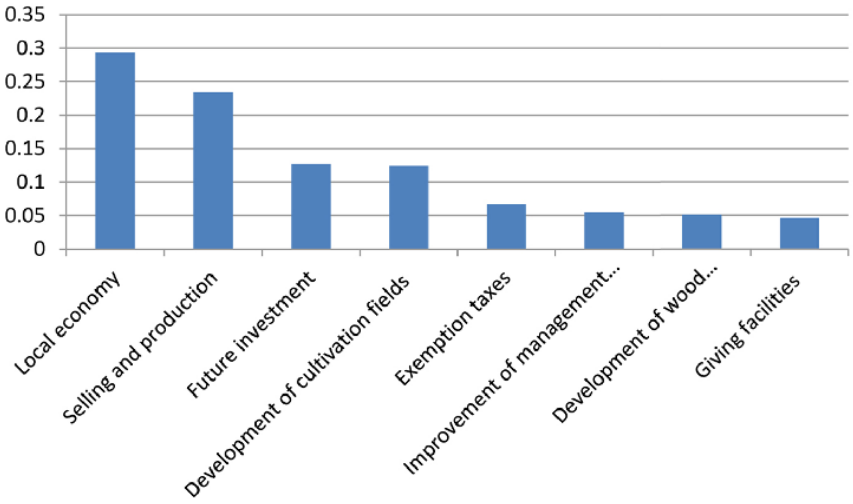
Dovetail, the renewable energy organization in USA (Dovetail, 2009) investigated the benefits and challenges of using biomass for energy production. They have stated that when the resources of biomass are maintained at local level, the transfer of waste is economical. For example, the economical scale in USA to transfer waste was mostly 50 mile or less and this figure is rather high for the wood and agriculture waste transfer which is reported as 70 mile. The use of wood waste and low-quality wood can increase the local income and the costs of burning and disposal of wood waste are reduced.

The use of existing biomass in a region which provided by the farmers and owners of local resources and industries caused to employ workers for transporting, crushing and transferring the fuel and energy. Furthermore, several jobs can create in the local society by using the biomass and the economical activity and development will be increased.

In order to explain the subscale of production and heat selling, electricity and fuel as the second rank of the subscale of development with weight (0.234); considering the unique nature of cellulosic materials as a resource for providing the fuel, thermal energies, and electricity is very important. The energy from cellulosic resources can be used as different types of energy such as electricity and heat and also as energy carriers same as gas and liquid fuels. This property of cellulosic resources provides specific opportunities for the production of the energy which can meet the demands of various parts in the society (Mc Kendry, 2001).

More analysis on the subscales of the opportunities index analysis showed future investment subscale with weight 0.127 and the development of cultivation fields subscale with score 0.124 had the third and fourth priority. Tomaselli (2007) demonstrated that the investment on new energy production units is too risky. Therefore, it is necessary to render suitable plan for this sector by selection the reliable solutions leading into the creation of the maximum benefit in the industry and provide a good background for reliable investment in this sector. Based on the vital importance of providing the raw materials for the establishment of energy production units from cellulosic materials, it is obvious that the development of cultivation fields is providing the opportunity and concentration on the establishment of the units that considered by the experts.

Figure 9: Final synthesis of opportunities indices (inconsistency rate 0.02), X: Criteria, Y: Weighing value



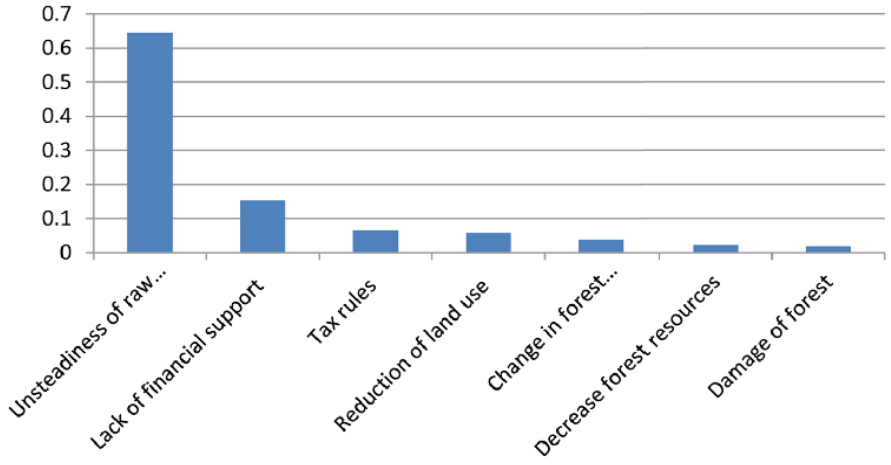
3.17. The comparison of the risks index

Based on the results presented in Fig. 6, the index of unsteadiness of raw material supplying, the problems from the government and the related organizations and environmental issues were the risk indices and had the highest weight, based on the priority. However, the results of the priority of the subscales of the three scales presented in Fig. 10 showed that the unsteadiness of continuous providing of raw materials with high difference from other subscales is in the first priority. The five times size ratio of the index with the next index, the lack of financial supports showed the high importance of the subscale and this result is consistent with the results of other studies. According to Wyman (2003), the most important factor in the continuance of the activities of energy production units of cellulosic materials is providing the raw material at high volume and continually. Coleman and Stanturf (2006) considered the most important condition to start the activity and sustainability of the energy production units of cellulosic materials as having suitable raw materials and considered any instability or the shortage in providing the materials the biggest risk of the units.

As the lack of financial support index with weight 0.153 is in the second rank and after the unsteadiness of continuous providing of the raw materials showed the importance of the subscale in formation of the risk for the energy production units of cellulosic materials. Solomon et al., (2007) considered the most important factor in the low growth of bio refinements and the investment risk on the units the lack of providing the required financial resources, high costs of new technologies and economical pressures.

After the two subscales, tax rules and the reduction of land use subscales with scores 0.065, 0.058, respectively were in the third and fourth priorities. This result is consistent with the results of the similar studies in other countries. According to Solomon et al., (2007) applying tax rules and not considering the underlying conditions and policies in the region for the establishment of such factories increased the investment risk.

Figure 10: Final synthesis of risks indices (inconsistency rate 0.01), X: Criteria, Y: Weighing value



4. Conclusion

The current study aimed to identify and prioritize the effective indicators in site selection of the energy production units of cellulosic resources (the waste of agriculture, forest management and wood industries) in Iran. The indices were identified and ranked by the conclusion of the experts in this field and by AHP method based on BOCR analysis of energy production units of cellulosic resources.

The results of the study based on BOCR analysis of energy production units of cellulosic resources showed that benefits index and its main factor, raw materials was the most important effective factor to select the site of the establishment of an energy production unit of cellulosic resources in Iran. However, the results of ranking of the constituent subscales of raw materials factor showed that agriculture waste compared to forest and wood industries waste was important to select the site of establishment of energy production unit of cellulosic resources in Iran. This result is consistent with the fact that limited resources of providing wood in Iran made various units of wood industries challenging with the crisis of providing wood raw materials.

The results of the study showed that opportunities index and the main constituent factor, development is in the second rank for the selection of the site of establishment of energy production unit of cellulosic resources in Iran. However, the results of ranking of the constituent subscales of development factor showed that the development of local economy is the main factor of decision making for site selection. The results of the study showed that costs index and its main constituent factor, economical costs are in the third rank for the selection of the site of the establishment of energy production unit of cellulosic resources in Iran. The costs of social barriers and transportation costs are main subscales considering the cellulosic resources in Iran in site selection process. Finally, the results of the final section of BOCR analysis in the current study emphasized that risk indices and the constituent main factor, the unsteadiness of continuous providing of raw materials in Iran is in the last rank of importance. This result is justified based on the dispersion of cultivation area of the products in Iran.

The results of the important part of the study, demonstrated that economy and politics are two main factors with mutual effects, which affect respectively and the generality on decision making and site selection of the establishment of energy production factories of cellulosic resources in Iran.

Appendix A. Supplementary material

Supplementary data associated with this article can be found, in the online version, at https://dx.doi.org/10.14254/jems.2017.2-2.11.

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