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Article

Renewable Energy Use in Smallholder Farming Systems: A Case Study in Tafresh Township of Iran

Hossein Shabanali Fami [1,*], Javad Ghasemi [2], Rahil Malekipoor [3], Parinaz Rashidi [4], Saeede Nazari [2] and Arezoo Mirzaee [5]

[1] Department of Agricultural Management and Development, Faculty of Agricultural Economics and Development, University of Tehran, 16 Azar Street, Enghelab Ave., Tehran, Iran

[2] Agricultural Education, Faculty of Agricultural Economics and Development, University of Tehran, 16 Azar Street, Enghelab Ave., Tehran, Iran; E-Mails: javadghasemi710@gmail.com (J.G.); snazari86@gmail.com (S.N.)

[3] Rural Development, Islamic Azad University, Science and Research Branch, Hesarak, Poonak, Tehran, Iran; E-Mail: malekipoor_rahil@yahoo.com

[4] Environmental Science, University of Tehran; 16 Azar Street, Enghelab Ave., Tehran, Iran; E-Mail: parinazrashidi@yahoo.com

[5] Agricultural Extension and Education, Islamic Azad University, Science and Research Branch, Hesarak, Poonak, Tehran, Iran; E-Mail: arezoo_agri@yahoo.com

* Author to whom correspondence should be addressed; E-Mail: hfami@ut.ac.ir; Tel.: +98-261-2247783; Fax: +98-261-2818709.

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Abstract: This study was conducted to investigate use of renewable energy and materials in smallholder farming system of the Tafresh township of Iran. The population of the study consisted of 2,400 small farmers working in the smallholder farming systems of the area, in which 133 people were selected as sample using Cochran formula and simple random sampling technique. In order to gather the information, a questionnaire was developed for the study and validated by the judgment of the experts in agricultural development and extension. The reliability of the main scales of the questionnaire was examined by Cronbach Alpha coefficients, which ranged from 0.7 to 0.93, indicating the tool of study is reliable. The findings revealed that the majority of the respondents use renewable energy and materials directly in its traditional forms without enabling technologies, and they lack the access to renewable technologies to improve the efficiency of energy use. They preferred fossil energy for many activities due to its lower cost and ease of access. The overall conclusion is that there are potentials and capacities for using renewable energies and materials in the farming systems of the Tafresh township. The government has to support and encourage the adoption of renewable technologies and abandon fossil fuels wherever possible.

Keywords: renewable energy; sustainable agriculture; smallholder farming; Tafresh

1. Introduction

Having about 13 million hectares of land suitable for agriculture, the agricultural sector is one of the major contributors to Iran's economy. It accounts for almost 13% of Iran's GDP, 20% of the employed population, 23% of non-oil exports, 82% of domestically consumed foodstuffs and 90% of raw materials used in the food processing industry. Key data reflecting the potential of Iran's agricultural industry include access to 37 million hectares of productive land, 130 billion cubic meters of renewable water, wide spectrum of climatic conditions, 102.4 million hectares of forests and grasslands, 2,700 kilometers of water border, and diverse genetic reserves, which have led to the sector's considerable growth. Due to its climatic diversity, Iran produces a wide range of agricultural products, from cereals and pulses to citrus fruits and sugar cane. Moreover, both irrigation and rainfed farming are used in Iran [1].

Although land cultivation is still done in traditional ways in some little portion of the smallholder farming systems, new technologies such as tractor and related implements have been introduced to the majority of smallholder farming systems throughout the country. For example, land tillage is done by using both old-fashioned instruments and technology, *i.e.*, wooden plows drawn by donkeys, mules, oxen as well as tractor. Tractor is becoming a popular technology in seeding, threshing and winnowing as well. Rearing livestock along with land cultivation is another major feature of smallholder farming system in Iran. In many villages one can witness sheep, goats and cattle using the stubble fields close to the farmer's residential areas. During the winter they are kept in (sometimes subsurface) stables [2]. However, a common feature in small holder farming systems is their dependence on renewable technology and resources in their production processes.

Nowadays, agriculture sector in developing countries such as Iran needs to be reformed because its trends worldwide lead to monoculture, specialization and increasing dependence on inputs of distance origins which are mostly non-renewable. It is globally believed that unless agriculture is practiced in a sustainable fashion, vital natural and cultural resources and qualities will be lost [3]. Hence, it will be essential for governments to establish a range of public policies to encourage proper incentives to reduce the social and environmental costs of economic growth, sustainable and efficient management of agricultural and natural resources [4]. Iran's latest five year plan, started in March 2005, has laid emphasis on the measures to ensure sustainability of the agricultural development process not only in economic terms but also on social and environmental factors to drive the country towards sustainable development [5]. However, sustainable agriculture experiences many problems now. One of the challenges faced by sustainable agriculture is that the majority of farms still rely on fossil energy for traction and electricity and energy self-reliance does not seem to be a major concern in practice [6]. Fossil energy for mechanized agriculture has been an important driver of the "Green Revolution" of increasing farm productivity. Today, three energy inputs (diesel fuel, fertilizer and electricity) account for more than three-quarters of farm energy use [7]. Each year, agriculture emits 10 to 12 percent of the global total of estimated greenhouse gas (GHG) emissions. In that context, productive and ecologically sustainable agriculture as well as organic farming represents a multi-targeted and multifunctional strategy to reduce the trade-offs among food security, climate change and ecosystem degradation; it offers an interesting concept that is being implemented quite successfully by a growing number of pioneer farms and food chains. Some researchers have proposed mitigation options for GHG emissions that include: improved crop, grazing, livestock and manure management; conservation of organic soils; restoration of degraded lands; and the use of agro-energy crops. These mitigation options challenge farmers and policy-makers to change practices and, among others, to improve the development of no-till cropping, agro-forestry and integrated crop and animal farming, and to decrease use of external inputs in food and agriculture [8-10].

It seems that a basic solution to cope with the problem is to substitute renewable energy with the fossil fuels in agriculture. According to the U.S. Department of Energy, renewable energy can also help to reduce pollution, global warming and dependence on imported fuels. It offers several health and environmental benefits relative to petroleum-based diesel. It offers the broader public greater access to cleaner air and water, safer fuels, and a lower risk of cancer, respiratory, and other health problems associated with air and water pollution, ozone depletion, and climate change [11]. Renewable energy can address many concerns related to fossil energy use. It produces little or no environmental emissions and does not rely on imported fuels. Renewable resources are not finite (whereas fossil fuels are) and many are available throughout the country. Price competitiveness has been a concern, but costs have decreased significantly since the initial wave of interest in renewable energy in the 1970s. Research is also being conducted to reduce the cost of solar water heating systems through the use of materials like plastics instead of metals and glass [12].

Therefore, application of renewable energy and related technologies has a great potential to contribute to the objectives of sustainable agriculture and are being used in a variety of applications on farms and ranches, and there are many opportunities to expand their use in the future [12,13]. Farmers can make a significant contribution to energy supply and climate change mitigation, regionally and nationally [14]. In fact, renewable energy and farming are a winning combination. Wind, solar, and biomass energy can be harvested forever, providing farmers with a long-term source of income [15]. Agriculture can play an important role in the production and consumption of different renewable energies [12]. In the United States, one policy response has been to provide financial incentives for supplying 25% of energy use from renewable resources by 2025 [16].

Therefore, improving energy efficiency by better managing agricultural and food inputs can effectively cut agricultural greenhouse gas emissions as well as the cost of production particularly in resource poor smallholder farming systems. For example, organic agriculture reduces energy requirements for production systems by 25 to 50 percent compared to conventional chemical-based agriculture [9]. At one installation in Switzerland, a farmer added a dark metal roof to a hay barn to serve as a solar collector, with a fan to draw the hot air through the barn. This eliminated the need for an oil or electric heater, saving $4,100 per year in reduced energy and maintenance costs. Moreover, since the farmer did the work himself, the up-front cost was only one-eighth of what an oil heater would have cost [17].

Farmers are generally unable to pass price increases for energy or fertilizer onto the consumer, and therefore receive a lower return for their products when prices rise [18]. Nevertheless, over the long term, renewable energy systems are typically less expensive than conventional systems. Operations and maintenance requirements of renewable systems takes less time, thus allowing ranchers farmers to engage in more productive activities [19]. In general, fossil-fuel-based energy is less expensive to produce and use than energy from renewable sources [11]. Accordingly, renewable agriculture which is a specific type of farming with emphasis on the use of renewable energies, materials and technologies is expanding throughout the world. Over time the principles for organic and sustainable agriculture has included specific references to the question of the reducing the use of non-renewable energy. The international fertilizer society concluded in a study of organic and conventional diets that "Organic farming requires less energy but more land than conventional farming" [6].

Accordingly, this is obvious that the energy management is the key factor in any sustainable development program. All aspects of agriculture development, power generation, social welfare and industry in Iran are crucially related to the energy and its revenue. The growing number of people predicates a rapid growth in the demand for energy in the coming years. In order to ensure a sustainable path of development, it is necessary to find a way to reconcile production and consumption with its impact on natural resources. The emphasis should be placed on the development, implementation and transfer of cleaner, more efficient technologies. Iran is on the rising energy intensity curve and is going to take necessary steps in transition towards sustainable management of natural resources, particularly for renewable energy along with reducing mission of greenhouse gases [20,21].

Some researchers believe that renewable agriculture may face some institutional problems. Most of the projects of rural electrification and renewable energy are developed by the power sector without involving other sectors, and are mostly supply-oriented; most agricultural and rural development projects do not take into account explicitly the energy requirements, which are viewed as a "black box" to be provided by others. Rarely do the energy and agricultural sectors join their efforts to effectively promote energy systems to support sustainable agriculture and rural development [13]. This problem is solved in Iran; according to the report of Iran Renewable Energy Organization [22], there is good collaboration between this organization and the Ministry of Agriculture (Known as Jihade-Keshavarzi in Iran) for promoting the use of renewable energies in agriculture, although analysis of energy consumption pattern over last decades indicates inefficient usage [21]. At the same time, an analysis shows a great potential for renewable energies especially, solar energy in Iran. In long term development program around 1,000 MW Solar thermal power plant is to be installed [23].

In other countries such as USA, increased concerns about energy security, greenhouse gas emission, pollution, as well as the desire to support farm incomes have led to an increase in renewable, agriculture-based fuels or biofuels (including ethanol and biodiesel). Agricultural households and rural communities have responded to these government incentives and have expanded their production of renewable energy, primarily in the form of biofuels and wind power, every year since 1996 [11,24]. Today, the increased consumption of energy in modern industrial societies has, in addition to the risk of quick exhaustion of fossil resources, brought about irreversible and threatening environmental changes to the world [22]. In conjuncture with the stable global development, special role has been assigned to renewable resources of energy in international plans and policies. The European Union, for example, has determined to generate 12% of the required electric energy for the year 2010 from renewable resources of energy. In Iran, further to policies made by the Ministry of Energy's Deputy Directorate for Energy, Iran Renewable Energy Organization (SUNA) has taken this matter into account since 1995 and is going to expand this type of energy as one of the national priority to reduce consumption of fossil energy [22].

Keeping this in view, the present study was conducted to investigate renewable energy consumption and use by the farmers of Tafresh township working in smallholder farming systems. These farmers are mostly resource-poor and need more support by the government. In spite of easy access to fossil energy they still use renewable energy and materials in traditional forms. This study was conducted to identify the areas in which they use renewable energy and where they need modern technologies to facilitate and improve the use of renewable energy. It is hypothesized that smallholder farming systems are an appropriate ground for expanding renewable agriculture. The present study addresses the question whether is this ground still available and to what extent small farmers use renewable energy and materials. The existing ground is highly important to expand adoption of this farming approach with low cost and energy.

2. Materials and Methods

The study was conducted in the Tafresh township of Iran to investigate application of renewable energy and materials in the smallholder farming systems. Tafresh is a city of Markazi Province in Iran. It is located amidst high mountains; 222 kilometer southwest of Tehran. It has two distinct districts, *i.e.*, Markazi and Farahan. The farming systems located in Markazi district of Tafresh are mostly small-scale. The basic source of income of the people living in this area is agriculture and related jobs. Majority of the farmers carry out crop farming, animal husbandry and horticulture in their agroforestry farms. The farmers use both indigenous and modern technologies. An initial investigation showed that they have a good record of renewable energy and material use in their farming systems, despite their lack of appropriate access to new modern renewable technologies to enhance the efficiency of renewable energies in agriculture. However, this area needs to adopt an effective model of using renewable energies in agricultural operations. This study was an attempt to analyze the area with respect to this issue.

Therefore this study was conducted in Tafresh to investigate how renewable agriculture can be infused into this type of farming system. This was a correlational-descriptive research conducted in 2009. The population of the study consisted of 2,400 small farmers working in the smallholder farming system of Markazi district of the area of study, in which 133 people were selected as sample using Cochran formula and simple random sampling technique. In order to gather the information, a questionnaire was developed for the study and validated by the judgment of experts in agricultural development and extension. The reliability of the main scales of the questionnaire was examined by Cronbach Alpha coefficients, which ranged from 0.7 to 0.93, indicating the tool of study is reliable. The data were analyzed by SPSS for Windowd-16. Appropriate statistical procedures such as frequency, percentage, mean, standard deviation and correlation coefficient were applied to analyze the data. In order to measure the extent of renewable energy use by the farmers, different appropriate scales were developed and included in the final format of the questionnaire. The responses to each item of the scales were obtained on a six-point continuum viz., not at all, very low, low, medium, high and very high with the scores of zero, one, two, three, four and five, respectively. Then a total score was calculated for different scales by summing up the item's assigned scores, which indicated overall score for renewable energy use by each subject of study. Along with, the overall score of renewable material use was calculated by summing up the items included in a scale which had been developed for this purpose. These two overall scores of different renewable energy and material use by the farmers were applied in correlation analysis.

3. Results and Discussion

3.1. Personal Characteristics of the Farmers

The majority of the respondent was male farmers (91.7%), while only 8.3 percent of the farms were headed by women. The mean of the farmer's age was equal to about 60 years old with a standard deviation of about 19 years old. Similarly, the age mean of the farmer's spouse was about 54 years with the standard deviation of 11.54 years old. Table 1 shows the education levels of the farmers. The results indicate that 18.8 percent of the farmers were illiterate, while only 14.3 percent had a higher education degree. The average numbers of girls and boys in the families of farmers were 2.3 and 2.6 respectively. The experience of farmers in crop farming and animal husbandry were 36.8 and 28.3 years. The average numbers of training courses in which the respondents actively participated was equal to 3.63. About 70 percent of the farmers had no knowledge of computer; the rest was a little aware of this technology.

Table 1. Frequency distribution of the farmers based on their educational level.

Education level	Frequency	Percent
Illiterate	25	18.8
Primary school	40	30.1
Junior high school	19	14.3
Senior high school	3	2.3
Diploma	27	20.3
Post diploma	10	7.5
Bachelor of science	9	6.8
Total	133	100

3.2. Use of Solar Energy

The amount of energy from the sun that reaches earth each day is enormous. All the energy stored in Earth's reserves of coal, oil, and natural gas is equal to the energy from only 20 days of sunshine [17]. In order to efficiently use this energy, solar technologies have been developed to produce electrical or thermal energy. In agriculture, photovoltaic applications can economically provide electricity where the distance is too great to justify new power lines [12,17]. Solar electric systems are also used to provide electricity for lighting, battery charging, small motors, water pumping, electric fences, steady supply of fresh air for confinement operations, drying crops and heating homes, livestock buildings and greenhouses. It can also provide hot water for dairy operations, pen cleaning, and homes. Regardless of the specific solar energy application (drying crops, heating buildings or powering a water pump), it makes the farm more economical and efficient [17]. For example, heating water and cooling milk can account for up to 40 percent of the energy used on a dairy farm [25,26]. Using the sun to dry crops and grain is one of the oldest and most widely used applications of solar energy. The simplest and least expensive technique is to allow crops to dry naturally in the field, or to spread the grain and fruit out in the sun after harvesting. The disadvantage of these methods is that the crops and grain are subject to damage by birds, rodents, wind, rain, and contamination by windblown dust and dirt. More sophisticated solar dryers protect grain and fruit, reduce losses, dry faster and more uniformly, and produce a better quality product than open-air methods [25].

Solar energy has been one of the basic sources of energy available to the farmers of Tafresh township to operate some agricultural practices. The information listed in Table 2 indicates that the extent of using solar energy to dry agricultural products is high in the cases of drying fodder, husked nuts, sliced dried fruits, garlic and onion, legumes, cherries and plums, and low in drying edible seeds, vegetable's seeds, whey and medicinal plant. An overall conclusion is that the farmers still use the sun to dry various agricultural products.

Table 2. Use of solar energy to dry agricultural products.

Types of crop	**Extent of use (Percentage of farmers)**						**Mean Score***	**Standard deviation of score**	**Rank**
	Not at all	**Very low**	**Low**	**Medium**	**High**	**Very high**			
Fodder (Alfalfa, Clover)	15	0.8	0.8	5.3	23.3	54.9	3.85	1.76302	1
Husked Nuts (Walnut, Almond)	10.5	0.8	3.0	10.5	42.1	33.1	3.72	1.49926	2
Vegetables	13.5	5.3	8.3	21.8	29.3	21.8	3.13	1.63662	3
Sliced dried fruits (Apricot, Peach and apple)	24.1	0.8	5.3	12.0	33.1	24.8	3.03	1.89659	4
Garlic and Onion	24.1	3.8	7.5	19.5	28.6	16.5	2.74	1.81598	5
Legumes (Beans…)	28.6	4.5	3.0	17.3	30.1	16.5	2.65	1.91107	6
Dried cherries and plums	27.8	4.5	8.3	13.5	26.3	19.5	2.64	1.92746	7
Edible Seeds (Pumpkin, Sunflower…)	30.8	2.3	10.5	20.3	18.0	18.0	2.46	1.90115	8
Vegetable's seeds	33.8	3.8	3.8	19.5	22.6	16.5	2.42	1.95512	9
Dried Whey	44.4	2.3	2.3	12.8	21.1	17.3	2.15	2.08109	10
Medicinal plants (bugloss, Mints…)	54.1	1.5	3.8	15.0	20.3	5.3	1.61	1.86970	11

* Scoring pattern: not at all = 0, very low = 1, low = 2, medium = 3, high = 4 and very high = 5.

3.3. Use of Wind Energy

Wind technologies as another type of renewable energy can provide mechanical and electrical energy [12]. It can provide an important economic boost to farmers. Large wind turbines typically use less than half an acre of land, including access roads, so farmers can continue to plant crops and graze livestock right up to the base of the turbines. The U.S. Department of Energy's (DOE) "Wind Powering America" initiative has set a goal of producing five percent of the nation's electricity from wind by 2020 [27]. With technological improvement (e.g., hybrid energy systems), the economic efficiency of wind energy continues to increase. Agricultural producers are likely to increase their use of wind power to reduce energy costs and become more energy self-sufficient [12,28].

This energy has been directly used in smallholder farming system of Tafresh township in Iran. Farmers can benefit from wind energy in many ways, including generating their own power, leasing land to wind developers, and becoming wind developers themselves. The information in Table 3 indicates that the extent of using wind energy to dry agricultural products is about medium in the cases of drying husked nuts, leafy vegetables and animal manure, and low in separating beans seeds from chaff, separating fodder seeds from chaff and separating wheat and barley seeds from chaff. An overall conclusion is that the farmer's use of wind energy in post harvesting activities ranges from low to medium levels.

Table 3. Use of wind energy in post harvesting agricultural activities.

Types of crop	Extent of use (Percentage of farmers)						Mean Score*	Standard deviation of score	Rank
	Not at all	Very low	Low	Medium	High	Very high			
Drying Husked Nuts (Walnut, Almond)	17.7	7.3	4.2	24.0	27.1	19.8	2.94	1.73	1
Drying leafy vegetables	17.6	10.8	5.9	20.6	24.5	20.6	2.85	1.77	2
Drying animal manure	25.3	11.0	4.4	18.7	26.4	14.3	2.52	1.84	3
Separating beans seeds from chaff	44.6	14.9	4.0	13.9	16.8	5.9	1.61	1.77	4
Separating fodder seeds from chaff	58.9	9.3	4.7	15.9	10.3	0.9	1.12	1.53	5
Separating wheat and barley seeds from chaff	62.3	11.3	5.7	15.1	5.7	0	0.90	1.34	6

* Scoring pattern: not at all = 0, very low = 1, low = 2, medium = 3, high = 4 and very high = 5.

3.4. Use of Biomass Energy

Biomass energy is another type of renewable energy which can potentially be produced from plants and organic wastes—everything from crops, trees, and crop residues to manure. Crops grown for energy purpose can be produced in large quantities, just as food crops are. Crops and biomass wastes can be converted to energy on the farm or sold to energy companies that produce vehicular fuel or heat and power for homes and businesses. According to the U.S. Department of Energy, tripling U.S. use of biomass energy could provide as much as $20 billion in new income for farmers and rural communities and reduce global warming emissions by the same amount as taking 70 million cars off the road. New incentives are available from the federal government and a number of states to help capture these benefits [29]. Agricultural activities generate large amounts of biomass residues. While most crop residues are left in the field to reduce erosion and recycle nutrients back into the soil, some could be used to produce energy without harming the soil. Other wastes such as whey from cheese production and manure from livestock operations can also be profitably used to produce energy while reducing disposal costs and pollution [30].

The farmers of Tafresh township use some sorts of this energy directly without any intermediate technologies. Biomass energy is used in smallholder farming systems of the area in its traditional form without any artificial processing. Table 4 shows that the smallholder farmers of Tafresh use different types of biomass wastes for making direct or indirect profits without applying new technologies. Mixing crop residues with soil for increasing the fertility as well as composting biomass (such as leaves, crop residues after harvesting, overripe fruits), using crop residues for feeding animals, and setting them into fire for heating and cooking purposes are three main areas of waste biomass management. While some parts of them are still not used, the parts sold to the market are used in the traditional form for heating houses or processing them into coals. At present, there is no power plant in the area using biomass to generate energy. The major use of biomass is in improving sustainability of farming systems.

Table 4. Use of different types of biomass wastes in the farming systems of Tafresh.

Types	Use	Frequency	Percent
Vegetable residues	Composting biomass or mixing with soil for enhancing fertility	30	22.4
	Using as animal fodder	60	45.2
	Use to set fire for heating or cooking	17	12.9
	Selling to the market	3	2.3
	Preparing processed foods	0	0
	Not use it at all	23	17.2
Cereal residues	Composting biomass or mixing with soil for enhancing fertility	8	6.3
	Using as animal fodder	76	57
	Use to set fire for heating or cooking	27	20.3
	Selling to the market	14	10.1
	Preparing processed foods	0	0
	Not use it at all	8	6.3
Autumnal leaves	Composting biomass or mixing with soil for enhancing fertility	44	32.9
	Using as animal fodder	53	40.5
	Use to set fire for heating or cooking	19	13.9
	Selling to the market	0	0
	Preparing processed foods	0	0
	Not use it at all	17	12.7

Table 4. *Cont.*

Types	Use	Frequency	Percent
Slashed foliages	Composting biomass or mixing with soil for enhancing fertility	0	0
	Using as animal fodder	20	14.9
	Use to set fire for heating or cooking	102	77.1
	Selling to the market	2	1.2
	Preparing processed foods	0	0
	Not use it at all	9	6.8
Fallen fruits	Composting biomass or mixing with soil for enhancing fertility	35	26.5
	Using as animal fodder	37	27.9
	Use to set fire for heating or cooking	31	23.5
	Selling to the market	0	0
	Preparing processed foods	16	11.8
	Not use it at all	14	10.3

Given the availability, accessibility and low price of fossil fuel, farmer's use of renewable fuels are decreasing in the area of study. As indicated in Table 5, the use of different types of firewood is placed at the highest priority among renewable fuels, followed by hay, leaves, straws, animal manure and dung.

Table 5. Use of renewable fuels to heat the house.

Types of renewable fuel	Extent of use (percent)						Mean Score*	Standard deviation of score	Rank
	Not at all	Very low	Low	Medium	High	Very high			
Different types of firewood	53.4	16.9	5.1	12.7	11.0	0.8	1.13	1.49	1
Hay, leaves and straws	60.0	31.3	3.5	3.5	0.9	0.9	0.56	0.89	2
Animal manure, dung	87.9	7.8	0.9	1.7	1.7	0	0.21	0.70	3

* Scoring pattern: not at all = 0, very low = 1, low = 2, medium = 3, high = 4 and very high = 5.

As Table 6 shows, considerable numbers of farmers uses different types of firewood for cooking at home or in the farm, while few of them use other renewable fuels, *i.e.*, hay, leaves and straws, animal manure and dung for the same purpose.

Table 6. Use of renewable fuels for cooking at home or in the farm.

Types of crop	Extent of use(Percent)						Mean Score*	Standard deviation of score	Rank
	Not at all	Very low	Low	Medium	High	Very high			
Different types of firewood	12.5	15.8	17.5	15.8	22.5	15.8	2.67	1.64	1
Hay, leaves and straws	23.5	26.9	19.3	13.4	5.9	10.9	1.84	1.59	2
Animal manure, dung	63.2	12.3	8.8	4.4	1.8	9.6	0.98	1.61	3

* Scoring pattern: not at all = 0, very low = 1, low = 2, medium = 3, high = 4 and very high = 5.

Some parts of biomass-based materials are used in building construction in the Tafresh area. It helps to mitigate the use of non-renewable construction materials that are produced by fossil energy. Table 7 shows the different construction materials used in house, barn and farm house in the area of the study. As indicated by the data, about 50 percent of farmers use renewable construction material to roof their houses. In the case of barn and farm house roofing, 59 and 76.5 percent of farmers use renewable materials, respectively. Although the majority of farmers use non-renewable materials in wall construction, the percentage of those using renewable materials is still considerable. In the case of covering floor, the majority of farmers use non-renewable materials. An overall conclusion is that the farmers use renewable construction material in establishing different buildings in notable extent.

Table 7. Comparison of renewable and non-renewable construction materials used in house, barn and farmhouse (Percentage).

Type of material	Construction's operation	Materials used	House	Barn	Farmhouse
Renewable	Roofing	Woods	14	21.5	33
Renewable	Roofing	post and board	35	37.5	43.5
Non-renewable	Roofing	Iron beam and brick	51	41	23.5
Renewable	wall construction	Mud brick	38	50	46
Non-renewable	wall construction	Brick	62	50	54
Renewable	Covering floor	Soil	22.5	36	36
Non-renewable	Covering floor	Cement-made	38.5	47	43
Non-renewable	Covering floor	Mosaic tile	39	17	21

3.5. Use of Water Energy

Energy in water (in the form of kinetic energy, temperature differences or salinity gradients) can be harnessed and used in different forms. Hydropower has been used for hundreds of years in Iran. Watermills have been popular and common technologies used in Tafresh to generate mechanical energy to grind the grains and turn wheat into flour. Although this technology has not produced any harmful environmental gas emissions, it has been withdrawn from area now. Given the available experience and infrastructure, this technology can be vitalized and used with trivial changes.

3.6. Correlation between Extents of Renewable Energy Use by the Respondents with Some Selected Variables

As indicated in Table 8, there were positive significant relationships between some random variables viz., farmer's age, age of farmer's wife, working experience and family size with the use of renewable energy and materials by farmers. In fact, in the smallholder farming households, farmers and their wives who have higher age, more experience and larger family size are more dependent on renewable energy and materials. This is because they are mostly resource-poor and unable to pay the cost of non-renewable energy and materials. In contrast, there were negative significant relationships between educational level as well as farmer's knowledge in computer with their use of renewable energy and material use. The negative correlation coefficients indicate that farmers with higher level of education level and computer literacy use less renewable energy and materials. It might be due to lack of sufficient financial and information resources of peasant farmers to cope with the cost and complexity of non-renewable energy sources. Lack of access to many of non-renewable energy technologies at the farm and even at house might be another reason for the higher use of renewable energy and material use by small peasant farmers. They cannot use modern machines, tools and devices to perform their farming operations due to traditional structure of their farming systems. Some of the new technologies such as tractors are not applicable for solving peasant farming problems. They sometimes use animals for transportation of inputs and outputs as well as for plowing in small plots of lands. They do not have access to portable gas stove for cooking at farm and have to use firewood for this purpose. In addition, electricity is accessible only in the farms located nearby the city. Therefore, they inevitably use renewable energy and material in considerable extent due to both the lack of availability of non-renewable energy, technology and materials as well as the farmer's poverty to bear the costs.

Table 8. Correlation between extents of renewable energy and material use* by the respondents with some selected variables.

Sl. No.	Selected variables	Renewable energy use		Renewable material use	
		"r" value	Sig.	"r" value	Sig.
1	Age	0.214*	0.015	0.156	0.072
2	Age of wife	0.186*	0.035	0.177*	0.042
3	Educational level	–0.348**	0.000	–0.243**	0.005
4	Working experience	0.264**	0.002	0.281**	0.001
5	Family size	0.222*	0.012	0.005	0.957
6	Knowledge on computer	–0.227**	0.010	–0.193*	0.026

* The overall score of energy and material use entered the correlation analysis.

4. Conclusions

The findings of the study indicated that the farmers working in the smallholder farming systems of Tafresh township use renewable energies and materials at the great extent. The results showed that they lack access to intermediate renewable energy technologies to benefit from the renewable energies and reduce the cost of the non-renewable option. In fact they have lost some of their traditional technologies being used to transform renewable energy into mechanical energy, e.g., watermills. Using the sun to dry crops and grains is one of the oldest applications of solar energy. Solar drying equipment can dry crops faster and more evenly than leaving them in the field after harvest, with the added advantage of avoiding damage by birds, pests, and weather [17]. The study shows that the farmers use solar energy directly; the ground is ready to promote and introduce solar drying technologies to the farmers. If a farm has a crop dryer already in place, it may make sense to install a low cost solar heater to supplement a propane or oil heater. The farmer would save on fuel costs while still being able to dry crops even in cloudy weather [17]. The need for electric energy is growing fast in the agricultural sector of Iran. In the Tafresh township some farms have access to electricity through power lines that are costly and difficult to maintain. Some of the farms are dispersed in vast areas and cannot have easy access to electricity. Some resource-poor farmers ignored to adopt new technologies as they are dependent to electricity unavailable to them. It seems that solar electric is a very good alternative to provide the energy needed in a cost-effective and feasible manner. It will reduce the dependence of rural and farming areas on costly remote electricity supply. Solar electric, or photovoltaic (PV), systems convert sunlight directly to electricity. They can power an electrical appliance directly, or store solar energy in a battery. PV systems may be much cheaper than installing power lines and step down transformers in applications such as electrical fencing, lighting, and water pumping [25].

According to the findings, the farmers have considerable contribution in producing biomass energy through cultivating different crops and trees. However, lack of access to renewable energy technologies reveals that the country needs to develop and apply appropriate and commercial renewable technologies to harness the potential and capacities of the renewable resources available in agricultural sector. At the same time a strong and growing private market for renewable energy technologies in the agricultural sector should be developed. In addition, the places with enough wind resources for small turbine use should be identified. Agricultural extensionists have to receive training in the appropriate use of renewable energy technologies for ranching and farming and empowering local people to make decisions related to their own energy and water use at a community level. Agriculture has been rapidly developing its renewable energy production capacities at the global level. Hence, the Iranian government has to enact a variety of incentives, regulations, and programs to encourage the production and use of agriculture-based renewable energy. In addition to these measures, it is recommended to revitalize and modernize indigenous knowledge and technologies of using renewable technologies. Before introducing fossil energy to the farming community of Tafresh, the firewood was a high value source of energy, but at present it is not used even at the farm level for heating or cooking purpose. The farmers need to be aware of the economic and ecological value in using their firewood instead of accumulating them in different parts of their farm. These collections are a basic ground for many pests to hide and live for a longer term. However, the promotion of renewable agriculture needs more attention by the government as a basic strategy to develop sustainable agriculture. It should be clearly reflected in the agricultural development plans. The universities and extension offices have to pay due attention to this issue to support renewable agriculture programs by educating the actors of agricultural development.

References

1. *Iran Agriculture Brief*; Atieh Bahar Consulting (ABC): Tehran, Iran, 2008; Available online: http://www.atiehbahar.com/Resource.aspx?n=1000013 (accessed on 20 October 2008).
2. Agriculture, 2009; Available online: http://www.iranica.com/newsite/articles/ v1f6/v1f6a056.html (accessed on 9 August 2009).
3. The Swedish Society for Nature Conservation (SSNC). *Policy for Sustainable Agriculture*; Birger Gustafson AB: Stockholm, Sweden, 1999.
4. Broadbent, J. *Environmental Politics in Japan: Networks of Power and Protest*; Cambridge University Press: Cambridge, UK, 1998.
5. *Agri-Food Country Profile, Statistical Overview—Iran*; Canadian Embassy in Tehran (CET): Tehran, Iran, 2004; Available online: http://atn-raiae.agr.ca/africa/3860_e.htm (accessed on 15 August 2005).
6. Corré, W.J.; Schröder, J.J.; Verhagen, A.; *Energy Use in Conventional and Organic Farming Systems*; International Fertiliser Society: York, UK, 2003.

7. Miranowski, J.A. Energy consumption in U.S. agriculture. In *Agriculture as a Producer and Consumer of Energy*; CABI Publishing: Oxfordshire, UK, 2004.
8. Bellarby, J.; Foereid, B.; Hastings, A.; Smith, P. Cool farming: Climate impacts of agriculture and mitigation potential. *Greenpeace International*, 7 January 2008.
9. Urs, N.; Andreas, F.B.; Hepperly, P. *Low Greenhouse Gas Agriculture: Mitigation and Adaptation Potential of Sustainable Farming Systems*; Food and Agriculture Organization of the United Nations (FAO): Rome, Italy, 2009.
10. Smith, P.; Martino, D.; Cai, Z.; Gwary, D.; Janzen, H.; Kumar, P.; McCarl, B.; Ogle, S.; O'Mara, F.; Rice, C.; Scholes, B.; Sirotenko, O. Agriculture. In *Mitigation of Climate Change*; The Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC); Metz, B., Davidson, O.R., Bosch, P.R., Dave, R., Meyer L.A., Eds.; Cambridge University Press: Cambridge, UK, 2007; Available online: http://www.mnp.nl/ipcc/pages_media/FAR4docs/final_pdfs_ar4/Chapter08.pdf (accessed on 11 June 2008).
11. Schnepf, R. *Biodiesel Fuel and U.S. Agriculture*; CRS Report for Congress, Order Code RS21563; Congressional Research Service: Washington, DC, USA, 2003.
12. Fischer, J.R.; Finnell, J.A.; Lavoie, B.D. Renewable energy in agriculture: Back to the future. *Choices*, 1st Quarter 2006.
13. Best, G.; Van Der Plas, B.; Van Campen, B.; Zepeda, R. Renewable energy for sustainable agriculture and rural development in Honduras; Available online: http://www.fao.org/sd/2001/EN0601a_en.htm (accessed on 28 June 2001).
14. Scurlock, J. *Biofuels, Agriculture and Climate Change, The Heat Is On*; Rowley Conference Centre: Newmarket, UK, 2008; Available online: www.nfuonline.com (accessed on 10 February 2008).
15. *Renewable Energy and Agriculture*; Union of Concerned Scientists (UCS): Cambridge, UK, 2009; Available online: http://www.ucsusa.org/clean_energy/coalvswind/gd_reandag.html (accessed on 18 May 2009).
16. Peskett, L.; Slater, R.; Stevens, C.; Dufey, A. Biofuels, agriculture and poverty reduction. In *Natural Resources Perspectives*; Overseas Development Institute: London, UK, 2007.
17. *Up with the Sun: Solar Energy and Agriculture*; Union of Concerned Scientists (UCS): Cambridge, UK, 2009; Available online: http://www.ucsusa.org/assets/documents/clean_energy/agfs_solar_2003.pdf (accessed on 5 July 2009).
18. Costantini, V.; Bracceva, F. *Social Costs of Energy Disruptions*; Center for European Policy Studies: Brussels, Belgium, 2004; Available online: http://www.ceps.be (accessed on 3 March 2004).
19. Ross, M.; Arango, J.M.; Rovero, Ch. *Renewable Energy for Agriculture*; *US Agency for International Development (USAID): Mexico, 2004*; Available online: http://www.pi.energy.gov/documents/EWSLmexico1.pdf (accessed on 11 June 2005).
20. Hessari, F.A. Sectoral energy consumption in Iran. *Renew. Sustain. Energ. Rev.* **2005**, *9*, 203-214.
21. Karbassi, A.R.; Abduli, M.A.; Mahin Abdollahzadeh, E. Sustainability of energy production and use in Iran. *Energ. Policy* **2007**, *35*, 5171-5180.

22. *History & Objectives of the Organization*; Iran Renewable Energy Organization (SUNA): Tehran, Iran, 2009; Available online: http://www.suna.org.ir/intro-history-en.html (accessed on 29 May 2009).
23. Kahrobaian, A. The role of renewable energy in Iran. *Renew. Energ.* **1999**, *16*, 1155-1159.
24. Schnepf, R. *Agriculture-Based Renewable Energy Production*; CRS Report for Congress, Order Code RL32712; Congressional Research Service: Washington, DC, USA, 2006.
25. *Agricultural Applications of Solar Energy*; Office of Energy Efficiency and Renewable Energy, US Department of Energy: Washington, DC, USA, 2009; Available online: http://www.p2pays.org/ref/24/23989.htm (accessed on 9 August 2009).
26. *Renewable Energy for Farmers and Ranchers*; National Renewable Energy Laboratory: Golden, CO, USA, 2009; Available online: http://www.nrel.gov/learning/ farmers_ranchers.html (accessed on 5 July 2009).
27. *Farming the Wind: Wind Power and Agriculture*; Union of Concerned Scientists (UCS): Cambridge, UK, 2009; Available online: http://www.ucsusa.org/assets/documents/clean_energy/agfs_wind_2003.pdf (accessed on 5 July 2009).
28. Bergey, M. Small wind systems for rural energy supply. In *Proceedings of the Village Power 2000*, Washington, DC, USA, 4–8 December 2000.
29. *Renewable Energy and Agriculture: A Natural Fit*; Union of Concerned Scientists (UCS): Cambridge, UK, 2009; Available online: http://www.ucsusa.org/assets/documents/clean_energy/agfs_overview_2003.pdf (accessed on 7 July 2009).
30. *Growing Energy on the Farm: Biomass Energy and Agriculture*; Union of Concerned Scientists (UCS): Cambridge, UK, 2009; Available online: http://www.ucsusa.org/assets/documents/clean_energy/agfs_biomass_2003.pdf (accessed on 7 July 2009).