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Design for Optimum Utilization of Integrated Energy Systems with Application to Rural Areas

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Abstract

This study uses multi objective linear programming (MOLP) as an optimization modeling tool to allocate various types of energy sources in rural areas. In Iran, about 99% of rural areas have access to grid connected electricity but access to thermal energy supply for heating and cooking is very difficult especially in impassable areas. So, the use of local renewable energy sources can be a suitable option for energy production in comparison with other sources of energy. This model can provide an Integrated Rural Energy Management System (IREMS) based on energy availability and demand with a minimum cost system and environmental protection configuration. Energy demand is divided in two categories; electrical and thermal. Electricity can be provided by a combination of wind, solar, small hydro power and electrical grid. Heat can be provided by oil, natural gas, gasoil, biogas, biomass, solar and geothermal district heating system. Six criterions were considered for determination of each energy sources in rural areas. These criterions can affect the selection of renewable and non-renewable energy sources. Easy access and very low emissions of green house gases are considered as main reasons for selecting renewable energies. The low price for providing energy and the easy to work nature of these equipments for the villagers are considered as existing priorities for selecting the fossil and wood fuels in rural areas. The model, as a case study, was applied for the village of kokhmamo on the Kordestan province located on the western part of Iran. The results were compared to a similar situation in a village in India and a good agreement was found between these two studies.

Keywords: *Integrated rural energy management system (IREMS), Multi Objective Linear Programming (MOLP), Renewable energy.*

1. Introduction

In the last decades, because of population growth and the limitation of fossil fuels resources, the world attention moved toward eco-friendly energy sources. In 1993, one of the initial motivation has been emerged after publication the energy report titled "Energy for Future" for the use of renewable energies. In this report, renewable energies considered as a suitable solution for providing a main part of energy demand in the world up to the year 2020[1]. In 1997, Regarding to the world focus on global warming caused by green house gases, the third session of the Conference of the Parties(COP3) was held in Kyoto. Based on this protocol, Annex A countries agreed to reduce their green house gas emission to the 1992 level. Therefore, promotion of utilization of renewable energy sources with a very low CO_2 emissions is inevitable [2]. Available statistics show that Iran despite of its rich potential for the use of fossil energy sources, will face with critical crises to meet its energy demand in next few decades. The total recoverable oil resources of the country is amounted to 136.99 billion barrels. The current oil production of the IRI (including export) is estimated about 2765.8 Million Barrels

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per Year(MBY). It is clear that the available sources can not meet the current consumption for more than 50 years[3,4]. ***Table 1*** shows estimated annual oil and gas resources and other energy potential resources of Iran reported for 2008.

TABLE 1. Estimated annual energy capacity report for 2008[3,4]

Type of energy	Estimated capacity
Oil	Liquid hydrocarbon reserves is equal to 136.99 milliard barrels(73.1 percent crude oil and 26.9 percent liquefied gases
Natural gas	Natural gas probable reserves is equal to 28.17 trillion cubic meters (32.8 percent terrestrial fields and 67.2 percent marine fields)
Electricity	41 GW as a nominal capacity of the power plants(37.9 percent gas and hybrid plant, 14.7 percent hydro plant, 1.3 percent diesel, wind and solar plants that can be produced electricity as a 178.1 TWh/year
Biomass	11 milliard tons coal reserves
Renewable energies	- Utilization of 36 hydro power plants with the capacity of 6043.9 MWh and the production of 16139.2 GWh hydro electricity - Utilization of 92 wind turbines with the capacity of 47.6 MW and the production of 70.9 GWh of electricity - Production of 53 MWh photovoltaic electricity
Nuclear energy	- Annually 7000 MWh probable energy production of Boshehr power plant

Fortunately, Many parts of Iran due to its geographical location has a vast potential for the utilization of the renewable energies such as solar, wind, hydro, biomass and geothermal [3]. The suitable areas for utilization of renewable energies in Iran, is given on ***Table 2***.[7]

TABLE 2. Suitable areas for application of renewable energy through the country[7]

Type of energy	Suitable areas
Oil	- Liquid hydrocarbon reserves is equal to 136.99 milliard barrels(73.1 percent crude oil and 26.9 percent liquefied gases
Solar energy	- Yazd, Kerman, Sistan & Baluchestan, Fars, Hormozgan provinces, slopes of mid and southern Zagros area
Wind energy	- Gilan province (Manjil and Rodbar) - Khorasan province- four areas of Khaf, Nehbandan, Sabzevar and Dizbad - Kohak, Deh Siahposh, Firozkoh, Harzvil and Binalod areas - Zahedan and Zabol
Geothermal energy	- Taftan-Bazman, Naiband, Birjand-Ferdows, Takab-Hashtrod, Khor-Biabanak, Esfahan-Mahalat, Ramsar, Bandar Abbas-Minab, Boshshr-Kazeron, Lar-Bestak areas
Biogas energy	- Khorasan, Golestan, Markazi, Mazandaran, Gilan, Ghazvin and Lorestan provinces

2. Energy consumption profile in a rural areas of the country

During last decades, Iran is facing with a major problem of deforestation due to wood smuggling and fire wood used by villagers. That cause an irreversible damages on the ecosystem. Also, harmful consequences of the use of traditional energy systems in rural areas are an important issues that should be considered carefully. For example, respiratory and pulmonary diseases due to the wood burning or the use of fossil fuels with a very low efficiency which have divert consequences on the health of the villagers. A present statistics show that about 98.5 to 99.5 percent of rural areas access to the electrical grid[4]. However, it causes a very high costs for providing electrical energy in an impassable and far from grid rural areas [5]. Based on the last report published by the National Iranian Gas Company (NIGC), about 7.18 percent of rural areas just have access to the gas pipeline and about 4500 villages connected to this grid[4]. So, in other parts of rural areas, thermal energy should be provided by other types of fossil and wood fuels [6].

It should be noticed that about 30 percent of the national energy consumption (including electricity, kerosene and natural gas resources) allocated to the rural areas. The statistics illustrate that in spite of low energy consumption in rural areas, the amount of the energy consumption intensity by rural households is higher than urban households. This situation occurs because of the variety of available energy consumption in rural areas, like inefficient energy equipments and the lack of sensitivity toward energy saving issues [8].

Generally, four sources are available for providing energy in rural areas:

1- Biomass energy sources including wood, charcoal, dung, agricultural waste, shrub and herb (annually the amount of 768.2 tons dung and 499.9 tons shrub and herb is available) [14].

2- Fossil fuels consist of the kerosene, Gasoil and natural gas for providing heating, cooking and agricultural activities.

3- Electricity for providing lighting.

4- Renewable energies such as wind, solar, biogas for providing energy for lighting and heating[9].

3. Modelling of Integrated Rural Energy Management System (IREMS)

3-1- IREMS Model description

This model provides a method for optimum use of integrated renewable and non-renewable energy sources in rural areas based on a Multi Objective linear programming (MOLP). These energy resources include: electricity, gas, kerosene, gasoil, hydro power, wind, solar, biogas, biomass and geothermal. Six criterions were selected for development of model as follow: Production Cost (investment and operation cost) of Indicated Energy(PCIE), Local Employment Opportunities (LEO), External Cost(EC) for determination of the level of Greenhouse Gas Emissions, Degree of Access to Indicated Sources of Energy (DAISE), Degree of Assurance on Safe Operation of System (DASOS) and Degree of Security on Indicated Energy Supply (DSIES). The PCIE and EC can be calculated as quantitative values but other criterions are qualitative. For calculation of the quantitative values of these criterions, each qualitative criterion is indicated as the fuzzy triangulated number(m, α, β) based on *Figure (1)*. These fuzzy numbers convert to quantitative values based on Chen-Hwang method shown in ***relation (1)***.

$$\mu_T = \frac{m+\beta}{2(1+\beta)} + \frac{m}{2(1+\alpha)} \qquad (1)$$

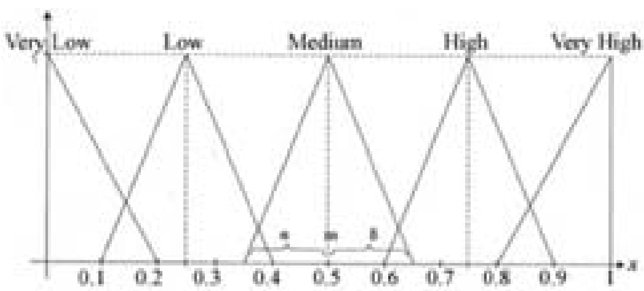


Figure 1. *The fuzzy triangulated numbers equal to qualitative numbers.*

In this equation μ_T is a quantitative number equal to the triangulated fuzzy number that is shown in terms of m, α, β. These items are respectively the average, left tolerance and right tolerance values which are given in ***Table (3)***.

TABLE 3. Quantitative numbers(μ_T) for equivalent of fuzzy triangulated numbers(m, α, β) at different level

Very Low=(0,0, 0.2)	$\mu_T = 0.08$
Low= (0.25, 0.15, 0.15)	$\mu_T = 0.28$
Medium= (0.5, 0.2, 0.2)	$\mu_T = 0.5$
High= (0.75, 0.15, 0.15)	$\mu_T = 0.71$
Very high= (1, 0.2, 0)	$\mu_T = 0.91$

The importance of each criterions for the selection of energy resources was scored by a group of experts as shown in ***Table (4)***.

For description of this table, it should be noted that main reasons for selecting electricity as an energy resource are respectively very high subside for PCIE, DSIES, DASOS and EC but the main factors for the selection of renewable energy are the lack of gas emissions and easy access to sources of Energy. Productivity, inflation and exchange rate are the important factors that can effect calculation of production cost while other factors like the method of calculating environmental effects, consideration of technological barriers and production deficiencies are factors which effect the social cost calculations. ***Table (5)*** shows the electricity production cost and external cost of energy resources per kWh.

The amount of other criterions based on fuzzy logic method are illustrated as ***Table (6)***.

In this model, variables are defined as energy production in terms of kWh of energy resources from x_1 to x_{11}. ***Table (7)*** shows energy production in terms of kWh of energy resources. In order to be able to compare different energy resources consumptions, all units were converted to kWh. The potential of

TABLE 4. Scoring table for the selection of energy criterions importance(Weighted values)

Criterions / Energy resources	(PCIE) α_1	(DSIES) α_2	(DASOS) α_3	(LEO) α_4	(EC) α_5	(DAISE) α_6	Total
Electricity	45	25	15	-	10	5	**100**
Kerosene	40	25	-	5	-	30	**100**
Natural Gas	40	25	5	5	-	25	**100**
Gasoil	40	25	-	5	-	30	**100**
Hydro power	30	25	5	-	5	35	**100**
Biogas	30	5	5	5	20	35	**100**
Biomass	45	20	-	-	-	35	**100**
Wind	-	5	5	5	45	40	**100**
Solar	-	5	5	5	45	40	**100**
Geothermal district heating	-	10	5	5	40	40	**100**
Average	**27**	**17**	**4.5**	**3.5**	**16.5**	**31.5**	**100**

TABLE 5. Electricity production and external costs of energy resources per kWh

Financial criterions \ Resources	Electricity	kerosene	Natural gas	Gasoil	Hydro	Biogas	Biomass	Wind	PV	Collector	Geothermal
Production Cost($)	0.035-0.04	0.02-0.025	0.015	0.02-0.025	0.03	0.02	0.025	0.03-0.04	0.12-0.14	0.02	0.02-0.04
External cost(Euro cent)	2.5-7	5.5	2.5	6	0.05	1.5	1.7	0.09	0.28	0.28	0.3

TABLE 6. Quantitative values of qualitative criterions

Qualitative criterions \ Resources	Electricity	kerosene	Natural gas	Gasoil	Hydro	Biogas	Biomass	Wind	PV	Collector	Geothermal
DSIES	0.71	0.71	0.71	0.71	0.91	0.28	0.71	0.5	0.5	0.5	0.5
DASOS	0.71	0.5	0.5	0.5	0.71	0.71	0.71	0.71	0.71	0.5	0.71
LEO	0.08	0.28	0.28	0.28	0.28	0.5	0.5	0.71	0.71	0.71	0.71
DAISE	0.28	0.5	0.5	0.5	0.91	0.71	0.91	0.91	0.91	0.91	0.91

TABLE 7. Energy production per kWh of energy resources

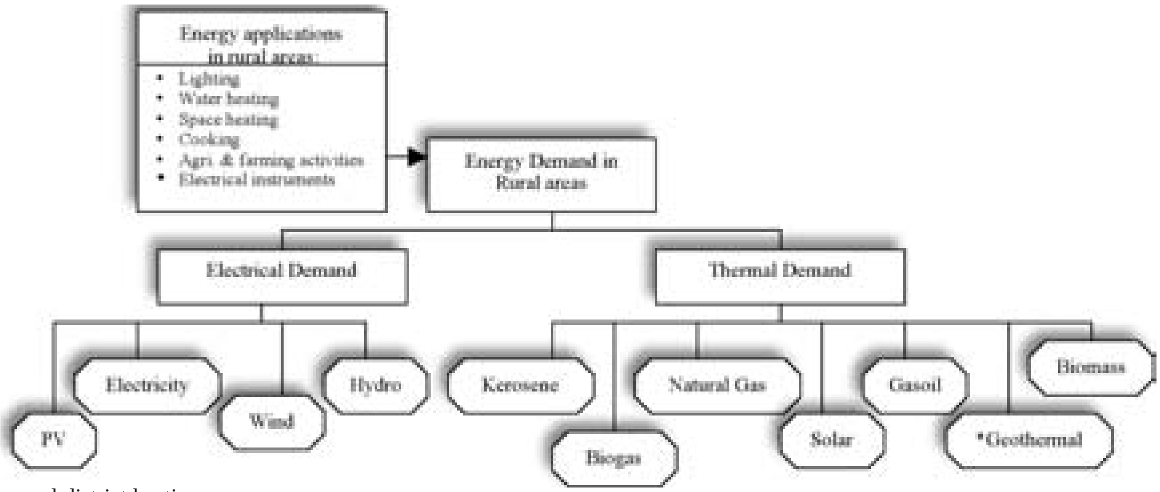
Unit of Energy resources	x_1	Electrical Energy	Water Heating Energy	Space Heating Energy	Cooking Energy	Capacity (kWh)
Electricity	x_1	1	0	0	0	102,000
kerosene	x_2	0	0.5	0.5	0	847,814
Natural gas	x_3	0	0	0	1	34,980
Gasoil	x_4	0.5	0	0.5	0	0
Hydro	x_5	1	0	0	0	0
Biogas	x_6	0	0	0	1	22,142
Biomass	x_7	0	0	0	1	215,698
Wind	x_5	1	0	0	0	∞+
PV	x_9	1	0	0	0	∞+
Solar collector	x_{10}	0	1	0	0	∞+
Geothermal	x_{11}	0	0	1	0	∞+
Energy Demand(kWh)	-	102,000	423,907	423,907	244,562	102,000

wind and solar energies in selected area were calculated by RETScreen software based on financial analysis. In estimating of wind energy capacity, a 660 kW unit was considered for simulation of annual energy production. The PV is considered as a grid connected system with an annual potential of energy equal to 53 MWh. In solar heating system, the annual energy production of a solar water heater is considered equal to 7100 kWh based on a each household water heating demand.

As explained, since 11 energy sources provide 4 types of energy demand with 6 types of criterions, therefore a problem can be made with 11 decision variables, 4 constraints and 6 criterions as follows:

$$OP\{f_1(x),\ldots,f_6(x)\} \qquad (2)$$
$$s.t.\ g_k(x) \geq d_k \qquad k = 1,\ldots,4$$
$$0 \leq x_j \leq a_j \qquad j = 1,\ldots,11$$

In this relation, x_j is the decision variable indicated as energy sources of j^{th} ($j=1,\ldots,11$), f_i is criterion function ($i=1,\ldots,6$), d_k is the energy demand and g_k are constraints of k^{th} type($t=1,\ldots,4$) and a_j is the energy potential of j^{th} type ($j=1,\ldots,11$). Formulation of this model is based on relations (3) to (7) and GAMS software was used for this purpose. ***Figure (2)*** shows the structure of integrated rural energy system.



* Geothermal district heating

Figure 2. *The structure of integrated rural energy system*

Electrical constraint:

$$s.t.: (1\times x_1)+(0\times x_2)+(0\times x_3)+(1\times x_4)+(1\times x_5)+(0\times x_6)+ (0\times x_7)+(1\times x_8)+(1\times x_9)+(0\times x_{10})+(0\times x_{11})\geq 102{,}000 \quad (3)$$

Thermal constraint (Water heating):

$$s.t.: (0\times x_1)+(0.5\times x_2)+(0\times x_3)+(0\times x_4)+(0\times x_5)+(0\times x_6)+ (0\times x_7)+(0\times x_8)+(0\times x_9)+(1\times x_{10})+(0\times x_{11})\geq 423{,}907 \quad (4)$$

Thermal constraint (Space heating):

$$s.t.: (0\times x_1)+(0.5\times x_2)+(0\times x_3)+(0\times x_4)+(0\times x_5)+(0\times x_6)+ (0\times x_7)+(0\times x_8)+(0\times x_9)+(1\times x_{10})+(1\times x_{11})\geq 423{,}907 \quad (5)$$

Thermal constraint (Cooking):

$$s.t.: (0\times x_1)+(0\times x_2)+(1\times x_3)+(0\times x_4)+(0\times x_5)+(1\times x_6)+ (1\times x_7)+(0\times x_8)+(0\times x_9)+(1\times x_{10})+(0\times x_{11})\geq 244{,}562 \quad (6)$$

$0 \leq x_1 \leq 102{,}000$

$0 \leq x_2 \leq 874{,}814$

$0 \leq x_3 \leq 34{,}980$

$0 \leq x_4 \leq 0$

$0 \leq x_5 \leq 0$

$0 \leq x_6 \leq 22{,}142$

$0 \leq x_7 \leq 215{,}698$

$0 \leq x_8 \leq \infty$

$0 \leq x_9 \leq \infty$

$0 \leq x_{10} \leq \infty$

$0 \leq x_{11} \leq 0$

It should be noticed that since 6 criterions have been selected for the selection of the type of energy resources, therefore an criterion function should be made for each criterions. Therefore a multi criterion problem is formed. Considering ***Tables (5)*** and ***(6)***, the criterions can be presented as follows:

(7)

$f_1(x)$ = min $0.0375x_1 + 0.0225x_2 + 0.015x_3 + 0.0225x_4 + 0.03x_5 + 0.02x_6 + 0.025x_7 + 0.4x_8 + 0.12x_9 + 0.02x_{10} + 0.025x_{11}$

$f_2(x)$= max $0.71x_1 + 0.71x_2 + 0.71x_3 + 0.91x_5 + 0.28x_6 + 0.71x_7 + 0.5x_8 + 0.5x_9 + 0.5x_{10} + 0.5x_{11}$

$f_3(x)$= max $0.71x_1 + 0.5x_2 + 0.5x_3 + 0.5x_4 + 0.71x_5 + 0.71x_6 + 0.71x_7 + 0.71x_8 + 0.71x_9 + 0.5x_{10} + 0.71x_{11}$

$f_4(x)$= max $0.08x_1 + 0.28x_2 + 0.28x_3 + 0.28x_4 +0.28x_5 + 0.5x_6 + 0.5x_7 + 0.71x_8 + 0.71x_9 + 0.71x_{10} + 0.71x_{11}$

$f_5(x)$= min $4.75x_1 + 5.5x_2 + 2.5x_3 + 6x_4 +0.05x_5 + 1.5x_6 + 1.7x_7 + 0.09x_8 + 0.28x_9 + 0.28x_{10} + 0.71x_{11}$

$f_6(x)$= max $0.28x_1 + 0.5x_2 + 0.5x_3 + 0.5x_4 +0.91x_5 + 0.71x_6 + 0.91x_7 + 0.91x_8 + 0.91x_9 + 0.91x_{10} + 0.71x_{11}$

It should be noticed that for fuzzy numbers, μ_T have been considered as approximate values. For selection of this problem which has 6 criterion functions; the method of weighted summation of criterion functions is applied. The weighted values are given in ***Table (4)***. At the end the resulting criterion function is given as follows:

$$OP.\sum_{i=1}^{6}\alpha_i f_i(x)] \quad (8)$$

Where α_i is important criterion of f_i, i= 1,…,6

3-2-Case Study

In this study, the village of Kokhmamo in west of the country was selected for field study. The main reasons include:

- Destruction of the surrounding forest areas especially chestnut trees by the villagers for providing firewood
- The lack of suitable connection road (this village is located on the boundary areas between Iran and Iraq)
- High energy price in comparison to low villagers income
- Very low energy ration per capita

- Closure of available connecting roads in cold seasons
- Very low energy systems efficiency

There are four resources of energy available for this area:

- Kerosene for providing space and water heating (the monthly ration per capita is about 20 liters)
- 11 kg Liquid gas cylinder for cooking (the number of required cylinder depends on the number of persons in each household but the ration is about one cylinder for each two months)
- Firewood (it plays a main role for thermal energy consumption with almost 50% share)
- Electricity energy for lighting

Kokhmamo's current population is 310 with a 53 households. The major industry is agriculture and laboring. The annual electricity demand is 102000 KWh(87,720,000 Kcal). The annual mean temperature is 9.3°C.The total annual demand for heating is estimated to be 9,326,696,800 kcal. Over the year, the daily mean global solar radiation is about 4.94 KWh/m^2. The mean wind speed is about 6.11 m/s at a height of 50m. The amount of manure from livestock is not very high with an annual amount equal to 20988 kg. Using fermentation, this can be turned into methane as a biogas. The amount of methane reaches 4051.5m^3(19,042,050 kcal). Energy production and demand in Kokhmamo village is shown in ***Table (8)***.

4- Results

In the IREMS model designed in GAMS software media, for integrated rural energy system, two different scenarios were selected. In first scenario, the energy cost was evaluated on the basis of production cost and in the second scenario the external costs were added. The results of these scenarios are indicated in ***Table (9)***.

In the first scenario, best option for consumption of electricity is the grid connected electricity, and for the thermal energy consumption are solar water heater for water heating, kerosene for space and water heating, biogas, biomass and natural gas for cooking. It should be mentioned, that the consumption of grid connected electricity is always preferable in comparison to renewable energy sources, if the external cost were not brought into account. The total annual production cost for first scenario is equal to 27494.5 $, which in comparison with present situation, 31441.4 $/year, shows an annual saving equivalent to 3946.9$ i.e. 12.5 percent. Also, in first scenario, DSIES, DASAS and DAISE gain very high scores while LEO is at a medium level. In the second scenario, bringing the fossil fuel emissions and their related external

TABLE 8. Energy demand and capacity in Kokhmamo

Energy resources	Electrical energy	Thermal energy (kWh)			Calorific value (kcal/kg)	Efficiency
		Water heating	Space heating	Cooking		
Electricity	102,000 kwh	0	0	0	860	100%= 1
Kerosene	0	74,400 Litr. (729,120,000 kcal) 47,814kWh		0	9800	
Natural gas	0	0	0	3498 kg (30,082,800 kcal) 34,980 kWh	8600	60%
Gasoil	0	0	0	0	10000	30%
Hydro	0	0	0	0	860	85%
Biogas	0	0	0	4051.5 m^3 (19,042,050 kcal) 22,142 kWh	4700-6000	50%
Biomass	0	0	0	53000 kg (185,500,000 kcal) 215,698 kWh	3500	55%
Wind	+∞	0	0	0	860	100%= 1
Solar	+∞	0	+∞	0	860	100%= 1
Geothermal	0	0	0	0	860	100%= 1
Total energy demand	102,000 kWh	423,907 kWh	423,907 WKh	244,562kWh	-	-

costs into account a different outcome will be presented, and the consumption of renewable energy in form of electricity will become feasible. It should be noted, the external cost of fossil fuel electricity is about 4.75 € cents/kWh while the external cost of wind electricity is about 0.75 € cents/kWh. The total annual production cost for second scenario is equal to 34012.1 $, which in comparison with present situation, 46022.9$/year, shows an annual saving equivalent to 12010.8$ i.e. 26 percent. Also, in second scenario, DAISE and LEO gain higher scores than first scenario but DSIES and DASOS gain less scores. The percent share of each energy resources in second scenario is shown in ***Figure (3)***.

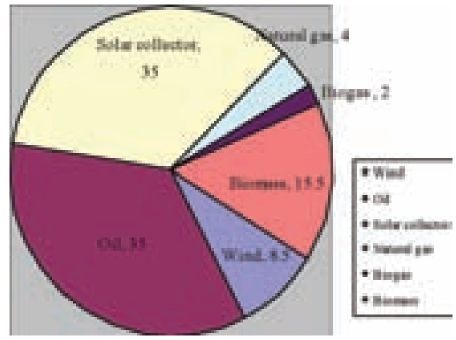


Figure 3. *The percent share of each energy resources in second scenario*

TABLE 9. The results of running IRES in two scenarios

Energy resources	Electrical energy (kWh)	Thermal energy (kWh): Water heating	Thermal energy (kWh): Space heating	Thermal energy (kWh): Cooking	PCIE ($)	DSIES	DASOS	LEO	EC ($)	DAISE
First scenario: IRES without consideration of EC										
Electricity	102,000	0	0	0	3825	72420	72420	8160	0	28560
Kerosene	0	0	423,907	0	9537.9	300974	211953.5	118694	0	211953.5
Natural gas	0	0	0	34,980	524.7	24835.8	17490	9794.4	0	17490
Gasoil	0	0	0	0	0	0	0	0	0	0
Hydro	0	0	0	0	0	0	0	0	0	0
Biogas	0	0	0	22,142	442.8	6199.76	15720.82	11071	0	15720.82
Biomass	0	0	0	187,440	4686	133082.4	133082.4	93720	0	170570.4
Wind	0	0	0	0	0	0	0	0	0	0
Solar (PV)	0	0	0	0	0	0	0	0	0	0
Solar (Collector)	0	423,907	0	0	8478.1	211953.5	300973.97	300974	0	385755.4
Geothermal	0	0	0	0	0	0	0	0	0	0
Total	102,000	423,907	423,907	244,562	27494.5	0.627495	0.62931664	0.45414	0	0.694965
Second scenario: IRES with consideration of EC										
Energy resources	**Electrical energy (kWh)**	**Thermal energy (kWh): Water heating**	**Thermal energy (kWh): Space heating**	**Thermal energy (kWh): Cooking**	**PCIE ($)**	**DSIES**	**DASOS**	**LEO**	**EC ($)**	**DAISE**
Electricity	0	0	0	0	0	0	0	0	0	0
Kerosene	0	0	423,907	0	9537.9	300974	211953.5	118694	5426	211953.5
Natural gas	0	0	0	34,980	524.7	24835.8	17490	9794.4	384	17490
Gasoil	0	0	0	0	0	0	0	0	0	0
Hydro	0	0	0	0	0	0	0	0	0	0
Biogas	0	0	0	22,142	442.8	6199.76	15720.82	11071	33.2	15720.82
Biomass	0	0	0	187,440	4686	133082.4	133082.4	93720	37.4	170570.4
Wind	102,000	0	0	0	4080	51000	72420	72420	76.5	92820
Solar (PV)	0	0	0	0	0	0	0	0	0	0
Solar (Collector)	0	423,907	0	0	8478.1	211953.5	300973.97	300974	36	385755.4
Geothermal	0	0	0	0	0	0	0	0	0	0
Total	102,000	423,907	423,907	244,562	27749.5	0.609561	0.62931664	0.507942	6262	0.748768

Conclusion

IREMS model is designed as a management tool for optimum utilization of integrated energy systems with application to rural areas, using environmental, social, and economical criterions. These criterions are the advantages of this model in comparison to other available models. However, in order to verify the validity of this model, a case study was carried out using this new model; and also Integrated Renewable Energy System based on LINDO software as an available model. The results were accredit and showed an excellent agreement with each other. This model designed as a multi objective linear programming in GAMS computer software. In this regard, the optimization method was used for minimization of PCIE, EC and maximization of DSIES, DASOS, LEO and DAISE. Finally, this model presents a view of existing energy situation in comparison with the present designed integrated energy system. Another advantage of this model is its ability to evaluate and clearly indicate the possibility of using renewable energy such as wind energy for generation of electricity, even in the presence of grid connected electricity. In this regards, if the existing and external cost of a grid electricity assumes about 0.0375 and 0.0097$/kWh, the total cost of electricity would be about 0.0472$/kWh while total cost of wind electricity with consideration of external cost would be about 0.035 and lower than the total cost of grid connected electricity. With comparison between the cost of these two sources of electricity, it should be mentioned that the threshold level of wind electricity utilization is in amount of 0.035 to 0.0472$/kWh. This illustrates that increasing the cost of wind energy up to this level, it still can be considered as an optimum choice. In other hand, whereas the existing purchase cost of renewable energy electricity in Iran is equal to 0.1$/kWh, the difference between the production and purchase cost would be about 0.065 $/kWh; which shows a promising benefit as an investment. Therefore in such cases the investment in wind farms for generation of electricity will be very attractive and provides local job opportunities even with presence of grid connected electricity. It should be added that the model is designed in a general and dynamic form that it can be applied for different location worldwide; by adjusting and changing the necessary input variables.

As an outcome of present research, the following recommendations may be added:

- The external cost of energy production of any kind should be considered in economical evaluations; as was indicated in IREMS model.
- This model should be used in order to create a management strategy for utilization of renewable energy at national level.
- This model can help the government to evaluate the possible amount of energy subsidies reduction, and using this amount for other development projects in the region.
- This model is designed in a dynamic form; i.e. by introducing the new form of available energy sources; variation of energy prices and geographical characteristics, the model can be used to deal with the new situation and provide information for making new policies.
- Presently; the research team are working to integrate the developed model, with a proper GIS model; which will enormously increase the capability of IREMS model.

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