Techno-economical evaluation of stand-alone hybrid renewable energy systems for urban area in Sanandaj (Iran)

S. Mohammadi, H. Bevrani, J. Moshtagh , S. Bahramara,

Published (to be published) in: Conference of Technology, Energy, and Data on Electrical and Computer Engineering, Kermanshah, Iran

(Expected) publication date: 2015

Techno-economical evaluation of stand-alone hybrid renewable energy systems for urban area in Sanandaj, Iran

Salah mohammadi, Hassan Bevrani, Jamal moshtagh , Salah Bahramara
Department of Electrical & Computer Engineering
University of Kurdistan
Iran, Sanandaj

***Abstract*—The aim of this paper is to model and design a hybrid renewable energy system to meet fulfill the primary load for an urban residential area located in Sanandaj in the western region of Iran. The hybrid system consists of Photovoltaic (PV) array, wind turbines, batteries and diesel generators. Different combination of wind turbines, PV, batteries and generators were evaluated in order to determine the optimal combination of them based on the minimum Net Present Cost (NPC) index. Sensitivity analysis is done to evaluate the impact of wind speed and fuel cost variations on the results. Finally, evaluating the economic of plan by payback period and grid extension analysis was performed. The proposed hybrid system is modeled, optimized and simulated using Hybrid Optimization Model for Electric Renewable (HOMER). The simulation and optimization results show that the optimal integrated renewable energy system configuration consists of 150kW PV array, 1 units Fuhrländer 30 wind turbine, 40 units Surrette 6CS25P battery cycle charging, and a 100 kWAC/DC converter so that the PV power can generate electricity at 264,815 kWh/year while the wind turbine system can generate electricity at 20,364 kWh/year, giving the total electrical generation of the system as 285179kWh/year. This would be suitable for deployment of clean energy for uninterruptable power performance in the residential area. The economics analysis result found that the integrated renewable system has total NPC of 972,762 US Dollar.**

Keywords*-(PV) array*; Techno-economic evaluation; Net present cost (NPC); Standalone renewable energy system; wind turbine

I. Introduction

Reduced pollution, stable supply, reduce energy transmission losses, environmental policies ,regional development and the growing trend need for electrical energy in Iran (Annual electricity production must increase by eight percent) are factors that justifies the use of renewable energies. Solar and wind energy systems are omnipresent, freely available, and environmental friendly, and they are considered as promising power generating sources due to their availability and topological advantages for local power generations[1,2]. In recent years, the use of hybrid renewable energy systems to supply the power demand of various regions has attracted some researchers attention. In [3,4,5,6,7], detailed feasibility study and techno-economic evaluation of a standalone hybrid solar–wind system with battery energy storage for a remote island was analyzed. Most studies have been done for rural and remote areas. Fewer studies for urban areas and areas with easy access to the distribution network have done [8,9]. The reason is that renewable energy sources it is not cost-effective for urban areas. The growing trend of energy consumption, the growing population and limitation of fossil energy sources will be the main factors that create the energy crisis in the coming years. The best possible solution is to reduce the world's dependence on non-renewable resources and move towards renewable resources**.** In this study the integration of stand-alone power generation with renewable energy is investigated to model and design a optimal hybrid renewable energy system for the urban area located in Sanandaj in Northwestern Iran. Moreover, optimization results, cost summary are analyzed. Finally, the sensitivity results and payback period are discussed.

II. Site description

The urban residential complex located in Sanandaj. Sanandaj is the capital of Kurdistan Province in Northwestern Iran. Sanandaj is located at 1480 meters above the sea level. Its geographical coordinates are 35° 19' 2" North, 46° 59' 56" East. Temperatures in Sanandaj range from -8.2 to 35.1 (Celsius). The average seasonal temperature in Sanandaj is 15.20 C in spring, 25.20 C in summer, 10.40 C in autumn and 1.60 C in winter. The maximum absolute temperature was found to be 44 C, the minimum absolute -31 C, and the average annual temperature 13.10 C. The average relative humidity was 69% at 06:30 hours and 38% at 12:30 hours. The maximum number of hours of sunshine over the entire year 2,786.

A. Electrical load data

This residential complex is consisting of 80 units. maximum demand for each unit is 5 KW. The complex has a maximum demand 128KW for feeding public Installations.

According to the data of the electricity distribution companies and Coincidence factor load profile is as Fig. 1. The estimated load is as follows: first a unit load is estimated. Then using the following equation the electrical load of the units is obtained:

$$P_t = (0.15 + \frac{0.85}{\sqrt{N}})\text{N.P} \qquad (1)$$

where P_t = whole apartments electrical load with the exception of public Installations load, P = Electric load of a unit and N=The number of units. Next apartments public load including public lighting and lifts load is calculated as follows: 1. In high-traffic hours,the total load(48KW) is calculated. 2. In average-traffic hours,Half of load is calculated. 3. In light -traffic hours, A fourth of load is calculated. 4. In very light traffic one-eighth of load is calculated.

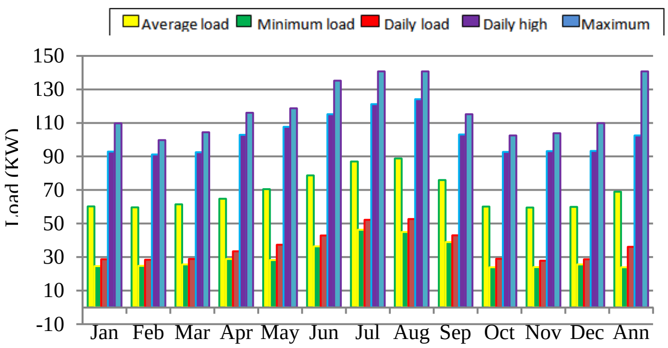

Figure 1. monthly load Profile for residential complex

B. *Wind data*

The most important wind source data is the wind speed which should be provided as monthly average. Another necessary parameter to design the wind system is known as “Weibull shape factor”. This parameter is a measure of the distribution of wind speeds over the year. In fact, this factor shows how windy a location is. The third parameter is called “autocorrelation factor”. This measure shows how strongly the wind speed in 1h tends to depend on the wind speed in the preceding hour. The fourth factor is defined as “diurnal pattern strength”. This factor shows how strongly the wind speed tends to depend on the time of the day. The other factor, hour of peak, is the hour of the day that tends to be windiest. Elevation of the site above the sea is also another parameter required to calculate the density of the air needed in wind turbine output power calculations. The last necessary parameter is anemometer height, showing the heights above the ground where the wind speed data are measured. Fig. 2 shows monthly average wind speed at sanandaj .The average wind speeds are not high enough for wind farm.

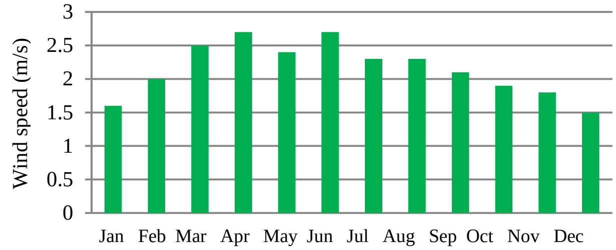

Figure 2. monthly average wind speed at sanandaj site

The wind speed data are measured at 10m anemometer height above the ground, Data are recorded from 1960 to 2010. The data is taken from the source[10].

C. *Solar data*

Monthly average values of solar data related to the case study location are shown in Fig. 3. As can be seen from this figure, the solar radiation in this rural area reaches its minimum of 2.392 kWh/m2/day in December and its maximum of 8.272kWh/m2/day in June. So, the average of daily radiation in the whole year is 5.42 kWh/m2/day. The average values of solar data are high enough to install the photovoltaic arrays.

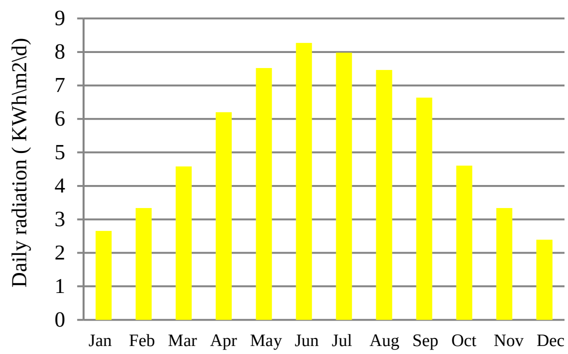

Figure 3. Daily radiation at sanandaj site

III. System Configuration

The block diagram for a typical stand-alone PV/wind generating system is shown in Fig. 4. The system consists of PV panels, wind turbine generator,storage batteries, and diesel generator. The main renewable sources for generating power at are Photovoltaic arrays and wind turbines. Diesel generator is used as dispatchable energy at this study to compensate power in the lack of renewable source. The batteries can feed electricity into the system in the lack of renewable sources and can store excess energy when the power from the renewable sources is extra. Explanation and details of the hybrid system components are given in the following sections.

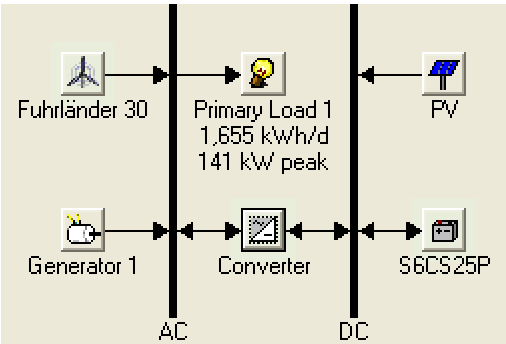

Figure 4. block diagram for a typical stand-alone system

A. PV panels

The output power of an array can be calculated using equations and manufacturer specifications. It can be assumed that array's power output is linearly related to the amount of the solar radiation reaching the panels. The capital costs of all the system components used for the study were gotten from PVsystem suppliers in Iran [12]. The proposed PV module is rated at 250 W. The initial cost of the modules is $275, and its operation and maintenance cost(O&M) is $5/yr.The lifetime of the modules will last the project. Another important factor affecting the performance of the PV array is the ground reflectance. The ground reflectance for this number is assumed to be 20% . To allow the simulation program to find an optimum solution, seven options were fed into search space for analysis(0,50,75, 100,125,150,175KW).

B. Wind turbine

The Fuhrländer 30 wind turbine has a capacity of 30 KW. Its initial cost is $20,000, and its operation and maintenance cost is $100/yr. The lifetime of turbine is estimated to last the project.To allow the simulation program to find an optimum solution, seven options were fed into search space for analysis: 0-6 (turbines). It should be noted that all prices of componens is based on wholesale price. Prices of renewable energy elements is highly dependent on the amount of power and by increasing the power prices will be reduced.

C. Battery

For the purpose of energy storage, lead acid batteries are included in this analysis for economic considerations. The use of hydrogen as another possible storage alternative is not currently economically viable given the prohibitive costs of electrolyzers and fuel cells and the low efficiency resulting from the electricity–hydrogen–electricity conversion cycle [13]. The Surrette 6CS25P battery is rated at 6V and has a capacity 1,156Ah. Its initial cost is $1000 and the replacement cost and the operation and maintenance cost add a further $1000 and $2/yr/1,respectively. To allow the simulation program to find an optimum solution, six options were fed into search space for analysis(0,10,20,30,40,50) strings. Each string is consists of 4 battery.

D. Power converter

A power electronic converter is needed to maintain the flow of energy between the AC and DC buses. For a 1 kW system the installation and replacement costs were taken as $800[12]. To allow the simulation program to find an optimum solution, six options were fed into search space for analysis(0,25,50,75,100,125KW). The Lifetime of a unit was assumed to be 25 years with an efficiency of 90%.

E. Diesel generator

In this study, a diesel generator with a capacity of 125 KVA was selected. Diesel generator model is Lovol 1006TAG14.The operating reserve was set as 5% of the hourly load. The initial capital cost of the diesel generator was assumed $12000[11]. Considering the cost of other components such as diesel generator location cost, Installation costs and etc,the net capital cost of the diesel generator was assumed $20000. Replacement and operational costs were assumed $12000/KW and $1/h, respectively. Operating lifetime was also considered 15,000 h. The fuel cost with considering penalties for air pollution is assumed 0.35$/L. The generator fuel curve intercept coefficient and slope can be found from engine performance data and fuel consumption diagram. In this study this coefficient is as below: Generator fuel curve intercept coefficient: 0.0133 L/h/kW and rated generator fuel curve intercept slope: 0.2304 L/h/KW [11]. Component costs is summarized in Table 1. To allow the simulation program to find an optimum solution, four options were fed into search space for analysis : (0,75,100,125KW).

IV. Results and discussion

In this study, the selection and sizing/dimensioning of components of the hybrid energy system have been done using HOMER software. In order to design hybrid system, HOMER simulates thousands of possible integrated components, discards infeasible configurations and puts all feasible systems in order based on total net present cost [14]. The simulation was done with a project's lifetime of 25 yr. Moreover, an annual interest rate of 6% was used in the economic calculations. Operating reserve as percentage of hourly load is 5%. This means that the system should keep spare capacity operating to meet the demand during sudden increasing of load to 5%. In this study operating reserve as percentage of solar power output is 50% and operating reserve as percentage of wind power output is 50%. The results are displayed, an overall form in which the top-ranked system configurations

TABLE 1.Component cost.

Component	Size (kW) or Quantity	Capital cost ($)	Replacement	O&M	Lifetime
PV	1KW	1100	1000	$5/yr	25(years)
Fuhrlander 30	1	20000	17000	$100/yr	25(years)
converter	1KW	800	800	0	25(years)
Surrette 6CS25P	1	1000	1000	$2/yr /1	operating hours
Lovol 1006TAG14	125KVA	20000	12000	1($/hr)	15000 (operating hours)

TABLE 2. optimization results according to NPC

PV (kW)	FL30	disel (kW)	S6CS25P	Conv. (kW)	Initial Capital	Operating Cost ($/yr)	Total NPC	COE ($/kWh)	Ren. Frac.	Diesel (L)	disel (hrs)
150	1	100	40	100	$ 321,000	50,985	$ 972,762	0.126	0.42	114,765	6,413
150		100	40	100	$ 301,000	52,888	$ 977,085	0.127	0.39	119,539	6,642
		125			$ 20,000	79,235	$ 1,032,887	0.134	0.00	182,368	8,760
	1	125			$ 40,000	77,677	$ 1,032,978	0.134	0.03	177,632	8,760
	2	100	40	25	$ 116,000	72,155	$ 1,038,384	0.135	0.07	165,498	8,737
50		125		25	$ 95,000	73,820	$ 1,038,673	0.135	0.13	166,827	8,760
50	1	125		25	$ 115,000	72,676	$ 1,044,041	0.135	0.16	163,271	8,760
		100	80	25	$ 116,000	77,335	$ 1,104,600	0.143	0.00	175,803	8,760

are listed according to their NPC for possible system type. Table 2 shows a list of the possible combinations of system components in the overall form. The table has been generated based on inputs selected. According to this table, the Optimal choice is using 150KW PV,1 unit wind turbine ,100KW disel genmerator, 40 units battery and 100KW converter. The results of the simulation showed that this system had a total annual electrical energy production of 684,219KWh,which the total energy produced from a PV array is 264,815 KWh, the energy generated from wind turbine is 20,367KWh and the energy generated from disel generator is 399,037 KWh. All results related to the electric energy production, and electric energy consumption is summarized in Table 3.

TABLE 3. Electrical production for the PV,wind and disel energy system

Component	Production (kWh/yr)	Fraction
PV array	264,815	39%
Wind turbine	20,367	3%
Generator 1	399,037	58%
Total	684,219	100%

Monthly average electric production has been shown in Fig. 5. In this figure, the production of electric energy each component per month is specified. Most of the electricity generated by PV has been in July, June and August. Least of the electricity generated by PV has been In December. Most of the electricity generated by wind turbine has been In April and June. Least of the electricity generated by wind turbine has been In January and December.

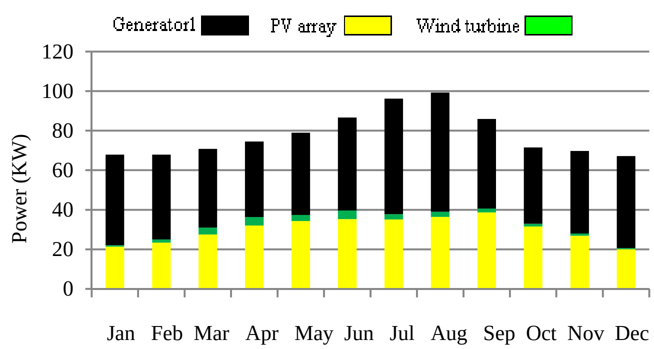

Figure 5. Contribution of the power units at load supply

The annualized cost of a component is equal to its annual operating cost plus its capital and replacement costs annualized over the project lifetime. The cost summary includes capital, replacement and operation costs of all components, fuel costs and salvage [4].The assessed values about total net present costs for each component of the energy system are presented in Table 4.

TABLE 4. Summarized total net present cost of the system components ($)

Component	Capital	Replacement	O&M	Fuel	Salvage	Total
PV	165,000	0	959	0	0	165,959
Fuhrländer 30	20,000	0	1,278	0	0	21,278
Generator 1	16,000	48,921	65,584	513,480	-697	643,287
Surrette 6CS25P	40,000	29,758	1,023	0	-8,543	62,237
Converter	80,000	0	0	0	0	80,000
System	321,000	78,679	68,844	513,480	-9,240	972,762

Table 5 shows Hourly data simulation in first of January for the urban residential complex load.The data show that from 1:00 to 2:00 the renewable energy cannot provide the electricity demand, so dispatch system selects batteries to meet Load. After 2:00 am till 8:00 am the diesel generator generates required energy of loads. After 8:00 am till 9:00 am wind speed increases as a result diesel generator and wind turbine generates required energy of loads. After 9:00 am till 18:00 diesel generator,PV and wind turbine generates required energy of loads. After 18:00 till 22:00 diesel generator and wind turbine generates required energy of loads. After 22:00 till 23:00 diesel generator generates required energy of loads. HOMER implements this hour-by-hour calculation for the entire year in order to find the optimal hybrid configurations.

Table 5.Hourly data simulation in first of January for the urban residential area load

Date	End Time	Global Solar	Wind Speed	AC Primary Load	PV Power	Wind turbine power	Diesel Power	AC Prim. Served	Inverter Input Power	Inverter Output Power	Rectifier Output Power	Battery Input Power	Battery State of Charge
		kW/m2	m/s	kW	kW	kW	kW	kW	kW	kW	kW	kW	%
1-Jan	1:00	0	1.097	40.343	0	0	0	40.343	44.825	40.343	0	-44.825	81.915
1-Jan	2:00	0	1	35.041	0	0	46.617	35.041	0	0	9.84	9.84	85.091
1-Jan	3:00	0	0.637	33.017	0	0	44.593	33.017	0	0	9.84	9.84	88.267
1-Jan	4:00	0	0.756	35.167	0	0	46.743	35.167	0	0	9.84	9.84	91.443
1-Jan	5:00	0	1.034	35.214	0	0	40.721	35.214	0	0	4.681	4.681	92.954
1-Jan	6:00	0	0.513	40.603	0	0	43.35	40.603	0	0	2.334	2.334	93.707
1-Jan	7:00	0%	1	43	0	0	45.013	42.561	0	0	2.085	2.085	94.38
1-Jan	8:00	0%	1.343	63	0	0.158	65.231	63.199	0	0	1.862	1.862	94.981
1-Jan	9:00	4%	2	63.255	4	0.928	60.129	63.255	2.443	2.198	0	1.663	95.518
1-Jan	10:00	9%	2	66	10	1.06	57.058	65.778	8.511	7.66	0	1.485	95.997
1-Jan	11:00	0.013	2.33	67.574	1.478	1.551	65.886	67.574	0.152	0.137	0	1.326	96.425
1-Jan	12:00	0.007	2.691	77.941	0.761	2.596	75.726	77.941	0	0	0.324	1.085	96.775
1-Jan	13:00	0.093	2.305	77.03	10.49	1.478	67.128	77.03	9.36	8.424	0	1.13	97.14
1-Jan	14:00	0.081	2.041	80.993	9.097	0.997	72.661	80.993	8.15	7.335	0	0.947	97.446
1-Jan	15:00	0.03	2.415	79.087	3.401	1.798	74.99	79.087	2.555	2.299	0	0.846	97.719
1-Jan	16:00	0.014	2.085	57.141	1.595	1.071	55.315	57.141	0.839	0.755	0	0.756	97.963
1-Jan	17:00	0.022	2.237	69.404	2.54	1.325	66.4	69.404	1.865	1.679	0	0.675	98.181
1-Jan	18:00	0.004	1.907	70.625	0	0.772	70.562	70.625	0	0	0.603	0.603	98.375
1-Jan	19:00	0	1.934	89.849	0	0.817	89.664	89.849	0	0	0.538	0.538	98.549
1-Jan	20:00	0	1.991	96.577	0	0.913	96.229	96.577	0	0	0.481	0.481	98.704
1-Jan	21:00	0	1.21	98.634	0	0.056	99.083	98.634	0	0	0.429	0.429	98.843
1-Jan	22:00	0	0.873	88.85	0	0	89.301	88.85	0	0	0.383	0.383	98.967
1-Jan	23:00	0	0.961	81.769	0	0	82.171	81.769	0	0	0.342	0.342	99.077

V. Sensitivity analysis

In this study only one average wind speed at a certain height has examined. In practice the wind speed varies with altitude and place changes.In this analysis the effects of wind and fuel variations on the system will be analyzed**.** HOMER simulates 7056 simulations for every 6 different sensitivity cases are (average wind speed= 2.11, 3 , 4 (m/s) and disel fuel cost (0.35 and 0.45$/L)). Table 6 shows a list of the optimal combinations of system components in the overall form for average wind speed= 2.11, 3 , 4 (m/s) and disel fuel cost (0.35 and 0.45$/L)). According to this table, the optimal choice is using 6 units wind turbine ,100KW disel genmerator, 40 units battery and 50KW converter for average wind speed of 4 m/s and disel fuel cost of 0.35$/L. According to the obtained results wind speed affect on the some parameters including, diesel generator capacity, PV array capacity, converter capacity, wind turbine capacity, initial capital cost, opearating cost, total NPC, Cost of Energy (COE), and excess electricity fraction.

TABLE 6. Optimization results according to NPC for sensitivity analysis

PV (kW)	FL30	disel (kW)	S6CS25P	Conv. (kW)	Initial Capital	Operating Cost ($/yr)	Total NPC	COE ($/kWh)	Ren. Frac.	Diesel (L)	disel (hrs)
	6	100	40	50	$ 216,000	31,716	$ 621,439	0.080	0.71	68,058	4,117
50	6	100	40	75	$ 291,000	27,166	$ 638,279	0.083	0.77	57,369	3,545
	6	125			$ 140,000	59,174	$ 896,442	0.116	0.57	128,103	7,846
50	6	125		25	$ 215,000	55,542	$ 925,011	0.120	0.62	119,730	7,446
150		100	40	100	$ 301,000	52,888	$ 977,085	0.127	0.39	119,539	6,642
		125			$ 20,000	79,235	$ 1,032,887	0.134	0.00	182,368	8,760
50		125		25	$ 95,000	73,820	$ 1,038,673	0.135	0.13	166,827	8,760
		100	80	25	$ 116,000	77,335	$ 1,104,600	0.143	0.00	175,803	8,760

Fig. 6 shows the impact of wind speed variations on the capacity of diesel generators, wind turbine ,solar panels and converter. As can be seen from this figure that with increasing the wind speed,solar panel capacity is reduced, wind turbine capacity is Increased,converter capacity is reduced and diesel generator capacity is not varied.

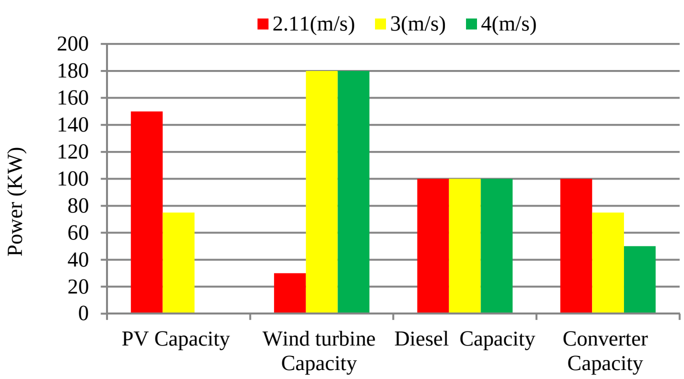

Figure 6. Diesel generator, conveter, wind turbine and solar panel capacity changes according on wind speed changes

Fig. 7 shows the impact of wind speed variations on the production of diesel generators, wind turbine ,solar panels and total production. As can be seen from this figure that with increasing the wind speed, solar panel production is reduced, wind turbine production is Increased, diesel generator capacity is reduced and total production is Increased.

Fig 8. shows the impact of wind variations on the total NPC ,total annualized cost, total capital cost and fuel cost. It can be seen that by increasing the wind speed, Total NPC, total annualized cost, total capital cost and fuel cost are. This means that by increasing the average wind speed all the costs are reduced.

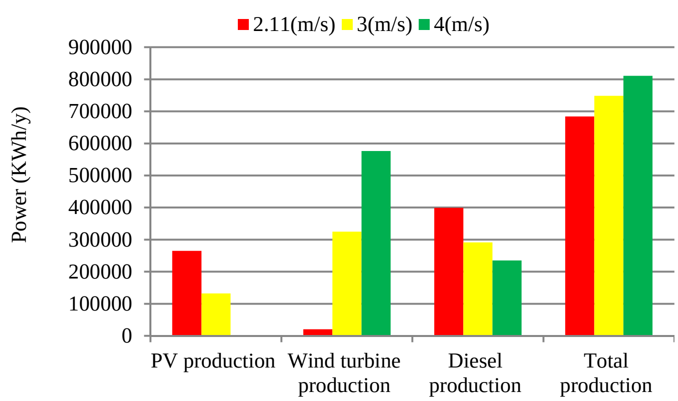

Figure 7. Diesel generator, wind turbine,solar panel and total production variations according on wind speed changes

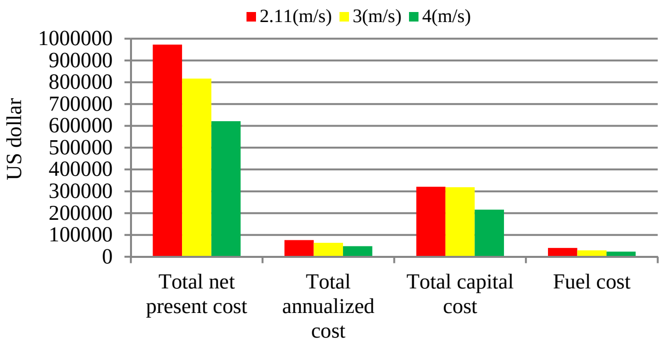

Figure 8. Total NPC ,total annualized cost, total capital cost

Fig. 9 shows the impact of wind variations on the air pollution. It can be seen that by increasing the wind speed, All air pollutant emissions are reduced.

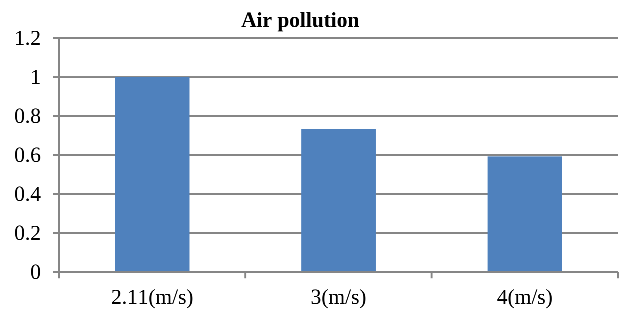

Figure 9. Air pollution variations according on wind speed changes

Impact of fuel cost variations on the air pollution, wind turbine capacity, grid extension, COE, total annualized cost, total capital cost and total NPC is summarized in Table 7.

TABLE 7. Impact of fuel cost variations on some Components (wind speed = 2.11(m/s))

	Air pollutant	**Wind turbine capacity**	**COE**	**Total annualized cost**	**Total capital cost**	**Total NPC**
Fuel cost	Normalized	KW	$/KWh	($)	($)	($)
0.35	1	30	0.12599	76096	321000	972762
0.45	0.906	120	0.14384	86886	381000	1110691

VI. Grid extension

HOMER will compare the cost of the grid extension with the cost of each stand-alone system configuration that you model. For each stand-alone system configuration, HOMER will calculate the breakeven grid extension distance, which is the distance from the grid at which the total net present cost of the grid extension is equal to the total net present cost of the stand-alone system.The cost of stand-alone hybrid renewable energy systems is compared with grid extension cost at this site. At the present time, the capital and operational costs of grid extension via 20KV voltage lines in Iran are $20,000/km and $150/year/km, respectively[7]. Grid power price is assumed $0.05/KW. Table 8 shows the break-even grid extension distance variations according on wind speed and fuel cost changes.These results show that by increasing the wind speed break-even grid extension distance is reduced. It can be obtained from the table that the breakeven grid extension distance is increased by increasing of fuel cost**.** These results mean that the system is not cost-effective in urban areas. This system is cost-effective in an urban environment which the break-even grid extension distance is less than the distance of the system from the grid. With increasing the wind speed to 4(m/s), break-even grid extension distance is 10.737Km. In this case,the use of this system will be cost-effective in some parts of the city of Sanandaj. But the use of renewable energy sources is not only the economic aspect. Reduce air pollution, reduce dependence on fossil fuels, reduce losses, the reliability of energy and energy security are benefits of renewables.

TABLE 8. Impact of fuel cost and wind speed variations on break-even grid extension distance

Wind Speed (m/s)	**2.11**		**3**		**4**	
Fuel cost($/L)	0.35	0.45	0.35	0.45	0.35	0.45
Grid extension(Km)	26.767	33.06	19.638	24.761	10.737	14.718

VII. Payback period

Payback is the number of years at which the cumulative cash flow of the difference between the current system and base case system switches from negative to positive. The payback is an indication of how long it would take to recover the difference in investment costs between the current system and the base case system.To calculate the payback period of a hybrid system, a conventional base case system as a control or reference is required[4]. Table 9 defines the capital and NPC for both systems.

Table 9.Hybrid and base case system costs for the urban residential complex load (wind speed = 2.11(m/s))

	PV (kW)	FL30	diesel (kW)	S6CS25P	Conv. (kW)	Initial Capital	Total NPC
Base case			125			$ 20,000	$ 1,032,887
Current system	150	1	100	40	100	$ 321,000	$ 972,762

Table 10 shows the results of payback calculations. In this study payback is compare a PV-wind-diesel hybrid system with a diesel-only base case system for an off-grid project to find the present worth of fuel saved by installing a hybrid system instead of a diesel-only system. The present worth is the difference between the net present costs of the base case system and the current system. The sign of the present worth indicates whether the current system compares favorably as an investment option with the base case system: A positive value indicates that the current system saves money over the project lifetime compared to the base case system. The annual worth is the present worth multiplied by the capital recovery factor. Internal rate of return (IRR) is the discount rate at which the base case and current system have the same net present cost. The simple payback is where the nominal cash flow difference line crosses zero. The discounted payback is where the discounted cash flow difference line crosses zero.

Table 10. Results of payback calculations(wind speed =2.11(m/s))

Metric	Value
Present worth	$ 60,125
Annual worth	$ 4,703/yr
Return on investment	9.34 %
Internal rate of return	8.06 %
Simple payback	10.2 yrs
Discounted payback	17.7 yrs

If the wind speed is changed to 4(m/s), results of payback calculations is change. Table 11 shows the results of payback calculations for this case. These results show that by increasing the wind speed present worth,annual worth and return on investment is increased. This result means that with increasing the wind speed, the system becomes more affordable.

Table 11. results of payback calculations(wind speed = 4(m/s))

Metric	Value
Present worth	$ 411,448
Annual worth	$ 32,186/yr
Return on investment	24.2 %
Internal rate of return	24.7 %
Simple payback	4.05 yrs
Discounted payback	4.83 yrs

VIII. Conclusion

In this study ,model and design a hybrid renewable energy systems for the urban residential complex in Sanandaj was examined. Sanandaj has a low average wind speed and the use of wind turbines in the city is not affordable. It should be noted that in some places near the city, there are places with more wind energy potential. Sanandaj is endowed with high solar potential which makes it a suitable region for use of PV arrays. The value of COE at average wind speed(2.11(m/s) and4(m/s))is equal to $0.126/KW and $0.08/KW,respectively. The average Grid power price is about $0.05/KW .Therefore if we consider only the economic aspects , in this case, system is not economical. Of course, the main reason which the system is not economic due to low energy prices in our country. With expected continuing rapid development in renewable energy industry, Increasing prices of energy and upgrades in storage technology, the system's cost will be reduced. Hence in the future, system is also can be economically affordable. Of course, in urban area, reduce air pollution is the most important advantage of renewable energy resources.

References

[1] TRANSCO, 2011 Seven year electricity planning statement (2012e2018) [online] available from <http://www.transco.ae/media/pdf/Seven%20Year%20Electricity%20 Planning%20Statement-Main-report.pdf> [18.08.12].

[2] Kazim A. Assessments of primary energy consumption and its environmental consequences in the United Arab Emirates. Renew Sustain Energy Rev 2007;11:426e46.

[3] Tao Ma, Hongxing Yang, Lin Lu. A feasibility study of a stand-alone hybrid solar–wind–battery system for a remote island. Applied Energy 121 (2014) 149–158.

[4] Golbarg Rohani, Mutasim Nour, Techno-economical analysis of stand-alone hybrid renewable power system for Ras Musherib in United Arab Emirates. Energy 64 (2014) 828-841.

[5] Ayong Hiendro, Rudi Kurnianto, Managam Rajagukguk, Yohannes M. Simanjuntak. Techno-economic analysis of photovoltaic/wind hybrid system for onshore/remote area in Indonesia. Energy 59 (2013) 652- 657

[6] U. Suresh Kumar , P.S. Manoharan. Economic analysis of hybrid power systems (PV/diesel) in different climatic zones of Tamil Nadu. Energy Conversion and Management 80 (2014) 469–476.

[7] Arash Asrari, Abolfazl Ghasemi, Mohammad Hossein Javidi. Economic evaluation of hybrid renewable energy systems for ruralelectrification in Iran—A case study. Renewable and Sustainable Energy Reviews 16 (2012) 3123– 3130

[8] Yaser Aagreh , Audai Al-Ghzawi. Feasibility of utilizing renewable energy systems for a small hotel in Ajloun city,Jordan. Applied Energy 103 (2013) 25–31.

[9] A. Shiroudi, R. Rashidi, G. B. Gharehpetian, S. A. Mousavifar, and A. Akbari Foroud. Case study: Simulation and optimization of photovoltaic-wind-battery hybrid energy system in Taleghan-Iran using homer software. JOURNAL OF RENEWABLE AND SUSTAINABLE ENERGY 4, 053111-1 -053111-11. (2012).

[10]http://www.chaharmahalmet.ir/stat/archive/iran/kor/Sanandaj/36.asp

[11]http://www.abyaran.com/diesel-generator/genset

[12]http://amitisenergy.com

[13] Bernal-Agustín JL, Dufo-López R. Simulation and optimization of stand-alone hybrid renewable energy systems. Renewable and Sustainable Energy Reviews 2009;13(8):2111

[14]. Hrayshat ES. Techno-economic analysis of autonomous hybrid photovoltaice- diesele -battery system. Energy Sustain Dev 2009;13:143e50.