Economic Evaluation of CHP Units Installation in Residential Buildings of Iran in case of Energy Subsides Removal

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Abstract: Increasing development of Combined Heat and Power (CHP) system applications in residential consumption has been resulted in a competitive market between generating power by these units and purchasing it from national grid. In Iran, on account of huge energy subsidies allocations, there has been no opportunity for the mentioned units to compete with the conventional practice of purchasing electricity from national grid up to now. Considering recent government policies, to remove the subsidy related to energy carriers, this paper intends to evaluate the applications of CHP units in residential buildings from economical point of view. For this, HOMER software has been utilized to evaluate the CHP unit placements as well as their utilization manner in order to minimize total energy costs for residential consumers. The results indicate that in the case of removing energy subsidies, the installation of such units will be economically quite cost-effective.

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1. Introduction

Various advantages of electrical energy production in distribution level (e.g. decreasing the costs associated with centralized production and energy transmission, reducing losses, controlling generation and consumption levels, power quality improvement and etc.) have resulted in increasing investment and development in utilization of dispersed production units with CHP capabilities. CHP units, with high efficiency, are considered one of main options for energy generation in residential regions throughout the world. In Iran, regarding to subsidy in energy sector and as a result of low price energy purchasing from the national grid, in comparison with generating by CHP units, for a long time there has been no opportunity to compete and these units' applications have been restricted to the regions where there was no access to the national grid. With regard to recent policies based on removing energy carrier subsidy and by taking the recent trends of Iran Power Generation and Transmission Company into consideration, which guarantees the purchase of generated power of CHP sources with the reasonable price, the competition between these units and other sources become more reasonable. In this paper, having compared final energy price of power generated by CHP units with buying energy from national grid, whether there is subsidy or not, installation of mentioned units for a residential consumer will be economically evaluated ([3], [4], [5] and [6]).

2. Modeling and input data

2.1 Modeling

In order to evaluate CHP units installation from economical point of view, in this paper HOMER software has been implemented [7]. The structure of investigated model has been illustrated in Fig. 1. As it is observed, subscribers are supplied by national grid and also a micro-turbine. Micro-turbine, as a CHP system, supplies thermal load as well. It should be noted that this thermal load is also connected to a boiler just in case when CHP unit is out of service or its heat generation is lower than heat consumption requirements.

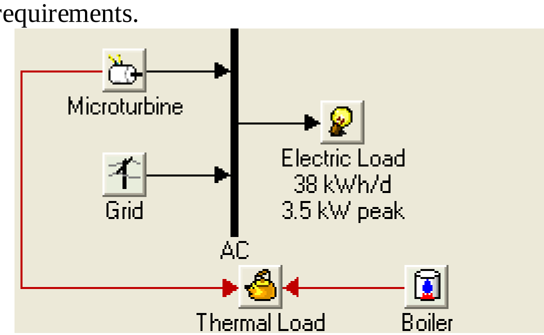


Fig. 1 Case study model

2.2 Input data

Input dada includes consumer load data, economical and technical data of CHP unit and economic data related to power and fuel costs with or without accounting subsidy. Maximum electric and thermal powers of residential consumer are considered 2 and 3.5 kW, respectively. Monthly load diagrams have been illustrated in Fig. 2 and Fig. 3. As it has been specified, maximum consumption loads have been occurred in summer and winter and its peak is about 3.5 kW. Average thermal load is also considered about 1 kW.

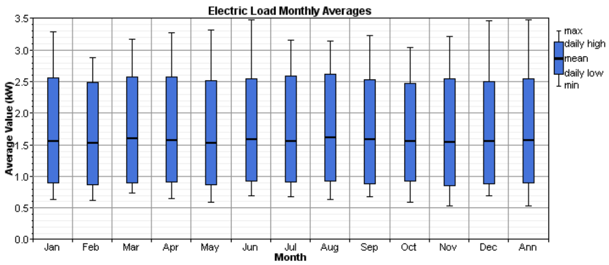


Fig. 2 Monthly electrical load diagram for consumer

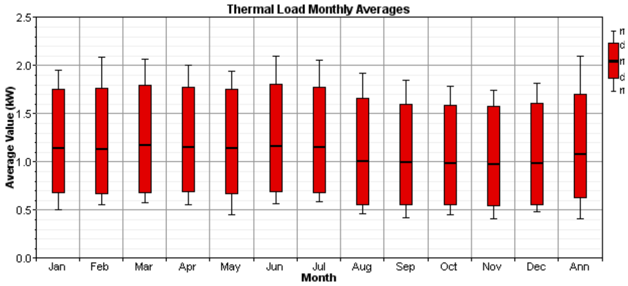


Fig. 3 Monthly thermal load diagram for consumer

CHP unit specifications have been provided in Table 1. Note that all prices are only applicable in Iran.

Table 1: CHP unit specification and costs

Description	Measure	Value
Installation costs	$/KW	1,200
Repair and maintenance costs	$/h	0.2
Consumed fuel value	m^3/ kWh	0.2
Lifetime	hr	45,000
Efficiency	%	65

In order to evaluate CHP installations economically, energy price in different states, with or without natural gas and power subsidy, have been applied. Energy purchasing price from national grid, with or without subsidy, is according to Table 2. Also, natural gas prices in different states have been presented in Table 3.

Table 2: Power price bought from national grid in different states, with or without subsidy ([1] and [2])

Description	$ /kWh
Power price with subsidy	0.0119
Power price without subsidy when fuel subsidy is applied	0.0457
Power price without subsidy with real price of fuel	0.1101

Table 3: Natural gas prices in different states with or without subsidy ([1] and [2])

Description	$/$m^3$
Natural gas with subsidy	0.00292
Natural gas without subsidy	0.069

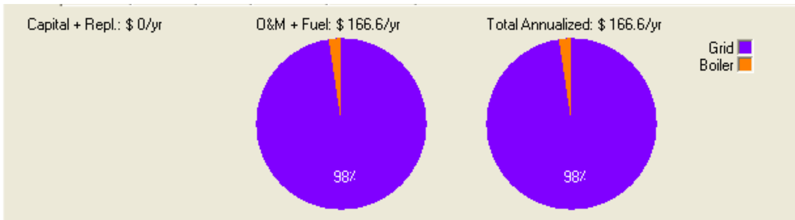
In the next part based on above estimated costs, the installation of CHP units in two cases, with or without energy subsidy, is examined.

3. Economic evaluation

As specified in Table 2, power purchasing price from national grid in case of subsidy allocation is about 0.0119 $/ kW.hr. It is the case where the gas price including subsidy is about 0.00292 $ / kWh. Considering these prices and also selecting the generation capacities of 2, 3 and 5kW for CHP unit, the results are calculated by Homer software and presented in Fig. 4. The results indicate that in optimum scenario with the minimum cost of energy of 0.012 $/ kWh, the total required power needs to be supplied by the national grid which yields the total annual cost of 166 $. Whereas in the last scenario, in which the whole power is supplied by CHP unit, the total price reaches to 0.124 $/kWh. The total costs together with each generation unit's contribution in the optimum case have been depicted in Fig. 5.

Fig 4. Different scenarios to supply required power for the consumer

		MT (kW)	Grid (kW)	Initial Capital	Total NPC	COE ($/kWh)	Ren. Frac.	Natural gas (m3)	MT (hrs)
			5	$ 0	$ 1,778	0.012	0.00	1,131	
		2	5	$ 2,400	$ 3,922	0.027	0.00	1,131	0
		3	5	$ 3,600	$ 4,994	0.034	0.00	1,131	0
		5	5	$ 6,000	$ 7,138	0.049	0.00	1,131	0
		5	0	$ 6,000	$ 18,220	0.124	0.00	8,323	8,760



Component	Initial Capital ($)	Annualized Capital ($/yr)	Annualized Replacement ($/yr)	Annual O&M ($/yr)	Annual Fuel ($/yr)	Total Annualized ($/yr)
Grid	0	0	0	163.3	0.00	163.3
Boiler	0	0	0	0.0	3.31	3.3
Totals	0	0	0	163.3	3.31	166.6

Fig. 5: Total costs as well as share of each power production supplies in optimum case

In this part four different scenarios for removing subsidy will be assessed. First, it has been assumed that total subsidy is suddenly removed. In next scenario, it is assumed that total subsidy paid by the government is removed in three stages. In the last scenario, it is assumed that fuel subsidy is not removed from energy production sector, power plants and residential buildings. Power and natural gas prices in different scenarios are provided in Table 5.

Table 5: Power and natural gas prices in different cases of subsidy removal

scenarios	Description	Power price $ /kWh	Natural gas price $ /m^3
1	Total subsidy removal	0.11016	0.0690
2	One third subsidy removal	0.4467	0.024934
3	Two third subsidy removal	0.77416	0.046941
4	Power subsidy removal and gas subsidy application	0.04577	0.002928

With regard to the prices mentioned in table 5, various scenarios considering three different sizes of CHP units (2, 3 and 5 KW) have been examined by Homer software. The results are presented in Fig 6.

Natural gas ($/m3)	Rate 1 Price ($/kWh)	MT (kW)	Grid (kW)	Initial Capital	Total NPC	COE ($/kWh)	Ren. Frac.	Natural gas (m3)	MT (hrs)
0.003	0.012		5	$ 0	$ 1,778	0.012	0.00	1,131	
0.003	0.045		5	$ 0	$ 6,610	0.045	0.00	1,131	
0.003	0.077	2	5	$ 2,400	$ 7,721	0.053	0.00	3,809	8,658
0.003	0.110	2	5	$ 2,400	$ 7,902	0.054	0.00	3,840	8,759
0.003	0.046		5	$ 0	$ 6,756	0.046	0.00	1,131	
0.025	0.012		5	$ 0	$ 2,044	0.012	0.00	1,131	
0.025	0.045		5	$ 0	$ 6,876	0.045	0.00	1,131	
0.025	0.077	2	5	$ 2,400	$ 8,612	0.057	0.00	3,761	8,500
0.025	0.110	2	5	$ 2,400	$ 8,805	0.058	0.00	3,839	8,755
0.025	0.046		5	$ 0	$ 7,022	0.046	0.00	1,131	
0.047	0.012		5	$ 0	$ 2,310	0.012	0.00	1,131	
0.047	0.045		5	$ 0	$ 7,142	0.045	0.00	1,131	
0.047	0.077	2	5	$ 2,400	$ 9,486	0.061	0.00	3,675	8,211
0.047	0.110	2	5	$ 2,400	$ 9,707	0.063	0.00	3,835	8,744
0.047	0.046		5	$ 0	$ 7,288	0.046	0.00	1,131	
0.069	0.012		5	$ 0	$ 2,576	0.012	0.00	1,131	
0.069	0.045		5	$ 0	$ 7,408	0.045	0.00	1,131	
0.069	0.077	2	5	$ 2,400	$ 10,333	0.065	0.00	3,559	7,813
0.069	0.110	2	5	$ 2,400	$ 10,608	0.067	0.00	3,824	8,709
0.069	0.046		5	$ 0	$ 7,554	0.046	0.00	1,131	

Fig 6: Various scenarios for supplying the required power in different cases of subsidy removal

As it has been specified, in two cases supplying power by CHP unit has been economically justified. First, the case in which the total subsidy has been removed and the other case in which two third of subsidy has been removed. Significant point obtained from these results is that increasing fuel gas price and totally removing subsidy have no effect on the optimum scenario and just increase the total price from 0.0530 $/kwh, where the subsidy is included in gas price, to 0.0650 $/kWh. The results also indicate that with regard to consumption load, installing a unit by capacity 2 kW is the most cost effective comparing to othe capacities.

The results for the case in which subsidies are totally removed is illustrated in Fig. 7. As it can be seen, in case of totally removing subsidies, the optimum scenario is the one in which installing a unit with 2kW capacity has been proposed. But the importance of installing mentioned unit is revealed in comparison with third scenario in which total power is supplied by national grid. It is observed that in optimum scenario the total energy price is 0.0670 $/kWh, while in third scenario this cost is equal to 0.11 $/kWh. The average monthly total energy price for the customer in optimum scenario is about 83$ while in case no CHP unit installation, it is about 132$.

	MT (kW)	Grid (kW)	Initial Capital	Total NPC	COE ($/kWh)	Ren. Frac.	Natural gas (m3)	MT (hrs)
	2	5	$ 2,400	$ 10,608	0.067	0.00	3,824	8,709
	3	5	$ 3,600	$ 14,278	0.092	0.00	4,449	7,361
		5	$ 0	$ 16,905	0.110	0.00	1,131	
	5	5	$ 6,000	$ 20,161	0.132	0.00	2,712	1,905
	5	0	$ 6,000	$ 24,090	0.159	0.00	8,323	8,760

Fig. 7: The results for the state of totally removing subsidies

The results corresponding to sensitivity analysis in different scenarios of removing subsidies are provided in Fig. 8.

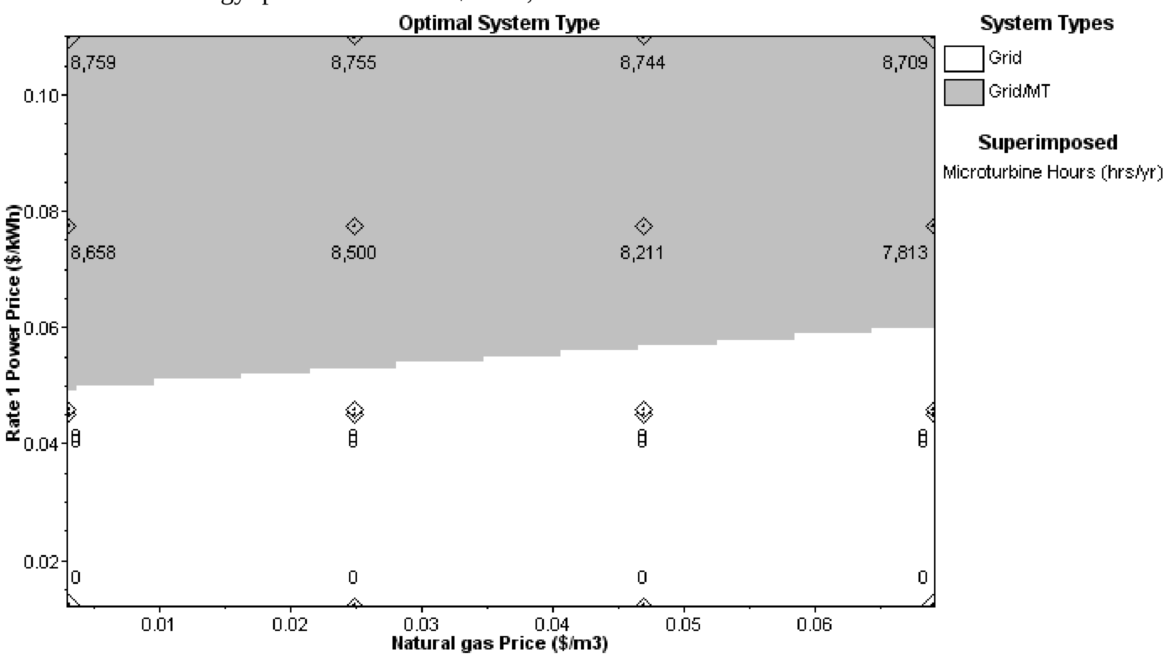


Fig. 8: The results corresponding to sensitivity analysis in different states of removing subsidies

As it is obvious from the results of Fig. 8, having increased energy price from 0.04 $/kWh, the contribution of CHP unit in production will be increased. Also, even with increase in fuel price, the contribution of CHP unit in production has been increased because of the severe impact of purchasing power from national grid on total energy price.

5. Conclusions

As it was specified from the results in these studies, with regard to recent government policies based on removing subsidies for energy carriers, installing CHP units is totally economic and cost effective. The results indicated that by totally removing subsidies or removing two third of them, installing CHP units for residential consumers has economic justification. In addition, optimal capacity of this unit for residential consumer by about 3.5 kW peak load and the specifications presented in Table 1, was calculated as 2 kW. Also it was determined that if all subsidies are removed and CHP units are installed, then nearly 60% of residential consumers' expenditures will be saved.

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