Applicability of Trigeneration Systems in the Hotel Buildings: The North Cyprus Case

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Abstract: - In North Cyprus (N. Cyprus), the installed power capacity fails to meet the demand in severe winter and summer conditions thus; new power capacities are needed to supply the required demand. One way of dealing with the deficiencies resulting from the inadequacy of installed power capacity is to make the distributed power widespread, especially the trigeneration systems which exploit energy in the fuel in the most efficient way by producing heat, electricity and cooling simultaneously. The objective of the present work is to propose a methodology through which the decision makers can assess the applicability of trigeneration systems for the hotel sector. The power demand of a representative hotel in N. Cyprus was monitored and segregated into base and cooling components for typical days of summer. On the other hand, five hotels were selected for conducting surveys on their electricity and heat demands. Correlations were obtained for the representative hotel for two different scenarios of capacity sizing; in scenario 1, it was aimed to meet the maximum value of the base electrical load of the hotels and in scenario 2 the aim was to meet the minimum base electrical load. The experimental correlations were used in determining the capacities of the trigeneration systems for the other five hotels. An economical feasibility analysis is carried out for both scenarios. The results showed that the application of trigeneration systems to the hotel sector in N. Cyprus can be feasible. It is found that application of scenario 2 is more feasible than application of scenario 1. For the representative hotel the simple payback period and savings to investment ratio of the trigeneration application based on scenario 2 is found to be 3.3 years and 1.8 respectively, which are acceptable. Other hotels investigated in this work also have similar results when the scenario 2 is applied. In addition to this, it is found that further benefit is achieved if the excess electricity is sold to the utility. By the application of scenario 2 to the hotels considered in this work; total annual electricity production by the systems would be 16.7 GWh. Considering the electricity production by the utility via gas turbines was 4 GWh in the year 2007, the application of the trigeneration systems would not only erase the running and maintenance costs of these old and inefficient units but also reduce the load coming to the power plants.

Key-Words: - Trigeneration, absorption chiller, economical analysis, energy, power demand, hotels.

1 Introduction

Carbon emissions released from combusted fossil fuels cause a serious threat to the sustainability of our earth as CO_2 is a greenhouse gas causing global warming. UN announced that climate changes are taking place due to global warming and urgent action needed to be taken. World Energy reserves are expected to last in 40-230 years [1]. As the world fossil fuel resources, depleting the unit price of the fossil fuel based energies would maintain today's increasing trend. These issues have forced the countries to be more conscious while using the fossil-based fuels. Thus, there is an increasing tendency to use renewable energy resources as well as high efficient energy producing systems.

Trigeneration is a method among the high efficient energy producing systems, which produces electrical, heat, and cooling energy simultaneously using single stream of fuel. Production of there kinds of energy by single fuel stream not only provides high efficiency but also reduces the emissions released to the atmosphere. A well-designed trigeneration plant can reach up to 90 % efficiency based on low-grade heat. Trigeneration systems have wide range of applications spanning from single residential applications to regional applications.

In this paper application of trigeneration systems to the hotel industry investigated from the economical point of view. In N. Cyprus, hotel buildings constitute the largest portion of the electricity demand of the commercial sector. The electricity use in the tourism sector was 66.2 million kWh in 2006, constituting 26.4 % of the commercial sector [2]. Considering that, the average occupancy rate was 33.5 % in 2006 the electricity use could rise to 197.6 million kWh at full occupancy. Electricity use by the hotel businesses would then constitute 51.7 % of the commercial sector.

Application of trigeneration systems in N. Cyprus could provide benefits to the hotel businesses in energy, economic and environmental point of view. The objective of the present work is to asses the application of trigeneration systems to the hotel buildings in N. Cyprus and estimate the potential benefits by this applications. It is also aimed to investigate the possible contributions of the trigeneration system applications to the solution of the power problems in N. Cyprus.

2 Energy Scene in N. Cyprus

N. Cyprus is located in the Mediterranean Sea and has not any fossil fuel sources. The country relies entirely on imported fossil fuels in order to meet its electricity demand. Furthermore, most of the thermal energy is supplied from the imported fossil fuels. On the other hand, solar energy is widely utilized in water heating in the residential sector and in some commercial and industrial applications.

The KIB-TEK, which is the state owned company, has the monopoly in power generation and distribution. At present, the overall demand for electrical power in N. Cyprus is supplied by two steam power plants, gas turbine units and diesel generator units with total output capacity of 375 MW. From this capacity, 120 MW are generated by fuel oil # 6 driven steam turbine units and 175 MW are generated by fuel oil # 6 driven diesel generator units and the rest 80 MW is generated by diesel fuel driven gas turbine units which are primarily used to cover peak demand. The annual electricity productions from 1997 to 2007 by the power plants are given in Table 1 [3]. The increase of total annual electricity production for this period of time is 108.3 %. The diesel generators are installed after 2002, therefore the electricity production by diesel generators has begun after 2002.

Table 1- Electricity production by power plants [3].

Years	Steam turbines (MWh)	Gas turbines (MWh)	Diesel generators (MWh)	Total (MWh)
1997	549919	19843	0	569762
1998	617003	13268	0	630271
1999	663736	16882	0	680618
2000	707413	21591	0	729004
2001	681924	19709	0	701633
2002	688687	21959	0	710646
2003	673719	39598	50152	763469
2004	649198	18836	215836	883870
2005	676677	19408	302816	998901
2006	683752	16746	381053	1081551
2007	645593	4021	537222	1186836

The electricity consumptions of various sectors in 2006 are shown in Table 2 [2]. The dwellings have highest demand for electricity, whereas the industrial sector has the lowest demand. The space heating and cooling in the dwellings are predominantly supplied by electricity driven heat pumps and air conditioners, thus; the percentage of electricity consumption in dwellings is the highest. The commercial sector constitutes 32.5 % of the total electricity consumption. The electricity consumption in tourism sector is included in the commercial sector and constitutes 26.4% of commercial sector electricity usage.

Table 2- Electricity consumption of various sectors in 2006 [2].

Sector	Electricity consumption (x 1000 kWh)	Percentage
Dwellings	335830	43.6
Commercial	250270	32.5
Industrial	97580	12.7
Other	87170	11.2
Total	770850	100.0

Table 3 shows the energy consumption in N. Cyprus in 2006 in terms of type of fuel [2]. The major portions of the gasoline and diesel fuel are used in transportation. LPG is used as primary energy source for space heating and cooking requirements whereas Jet A-1 and kerosene are aviation fuels for use in aircraft engines. Fuel oil # 6 is used in the steam power plants and in the diesel generator units for electricity production as the primary energy source. The amount of fuel oil # 6 used in the steam power plant and in the diesel generator units for the year 2006 was approximately 273 million tons.

Table 3- Fuel consumption in N. Cyprus by fuel type in 2006 [2].

Type of the fuel	Consumption (Tons)
Gasoline (Super)	2250
Gasoline (Unleaded)	57627
Diesel fuel	148023
Kerosene	1025
Fuel Oil #6 (For the steam power plants)	273296675
LPG	17784
Jet A-1	21409

3 Methodology

A methodology is developed in order to size the trigeneration systems for the hotels. This methodology is based on the collected data during a research, which is conducted in 2008.

The developed methodology consists of three phases. First phase is the field study phase which includes the collection of energy end-use data of the hotels (six hotels were investigated). A survey is designed and conducted for hotels in which questions were asked about the energy consumptions and installed capacities of heating and cooling systems as well as their occupancy rates. Furthermore electrical power monitoring of a representative hotel and its chiller is carried out in order to visualize the trends in power demand and observe the peaks as well as to build up the electrical power demand curves for a typical summer day.

In the second phase, collected information and monitored data during the field study are used to propose appropriate size of prime movers for the trigeneration systems. Primarily the power demand curves of the representative hotel are built by using the monitored data. These curves are used to propose an appropriate size of prime mover for the trigeneration system of the representative hotel. Subsequently some correlations are derived from the demand curves of the representative hotel and incorporated with the collected information obtained from the surveying for estimating the size of the prime movers of the trigeneration systems for the other hotels.

Third phase includes the economical analysis of the selected trigeneration systems by employing economical measure methods like simple payback, net present value (NPV), savings-to-investment ratio (SIR) and internal rate of return (IRR)

The developed methodology is illustrated in Fig.1 as a flowchart [4].

4 Proposed Trigeneration Systems

The collected and monitored data are processed to generate two scenarios of trigeneration applications for the hotels. In the first scenario (scenario 1) the trigeneration systems are sized to meet the hotels' maximum electricity base load demand (MaxBD) whereas in the second scenario (scenario 2) the trigeneration systems are sized to meet the hotels' minimum electricity base load demand (MinBD). These scenarios will be referred to as scenario 1 and scenario 2 from this point forward.

Base load demand of the hotel is the electricity demand of the hotel, which is independent from the climatic conditions. The base load demand of the hotel can be obtained by taking demand recordings of the hotel during the seasons that there is no need for air conditioning or subtracting the chiller's demand values from the hotel's demand values for a typical summer day. Due to the recording was done in summer time in this work the chiller's demand values are subtracted from hotel's demand values in order to evaluate the base load demand of the representative hotel.

If the trigeneration systems are sized according to the minimum base load demand of the hotels there will be need to purchase for extra electricity to meet the rest of the electricity demand. However, when the trigeneration systems are sized to meet the hotels' maximum base load demand, the amount of the purchase for extra electricity will be less. Moreover, there may be excess electricity production by the systems. Schematic drawing of the demand curves and the electricity coverage by the trigeneration systems for both of the scenarios are given in Fig.2 and Fig.3.

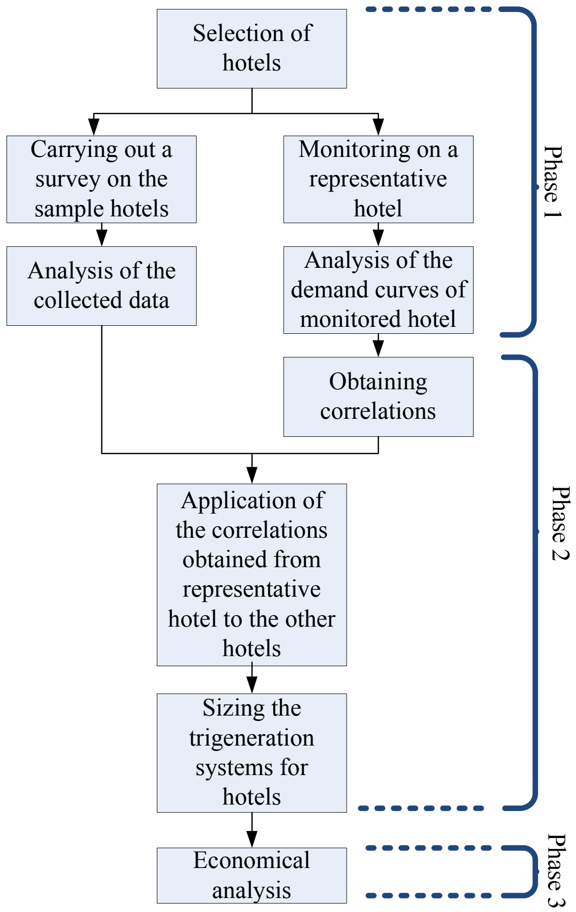

Fig.1 [4]- Developed methodology for sizing the trigeneration systems.

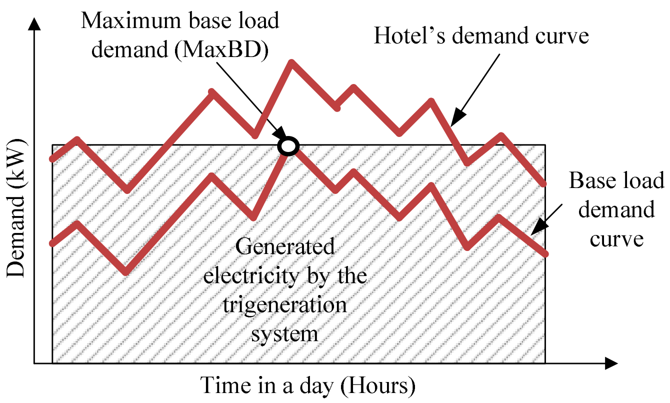

Fig.2- Schematic demand curves and electricity coverage by trigeneration system for scenario 1.

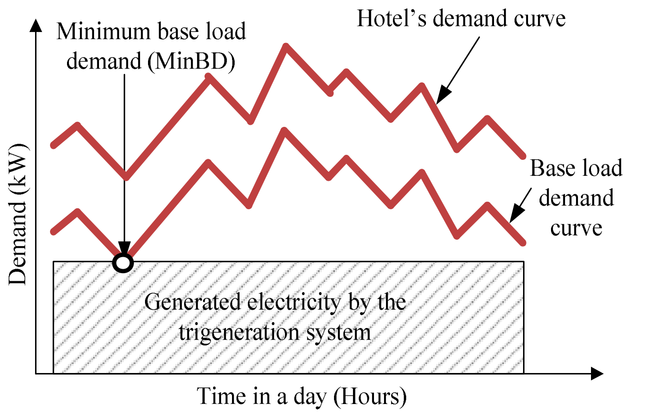

Fig.3- Schematic demand curves and electricity coverage by trigeneration system for scenario 2.

4.1 Sizing Trigeneration for the Representative Hotel

Power demand curves of the representative hotel based on full occupancy for a typical summer day is shown in Fig.4 [4]. Hotel's MaxBD and MinBD values for a typical summer day based on full occupancy rate are recorded to be 279 kW and 197 kW respectively. Size of the prime movers for the trigeneration systems for scenario 1 and scenario 2 are evaluated by substituting foregoing values into following expressions:

$$P_1 = (MaxBD) \times 1.1 \qquad (1)$$

$$P_2 = (MinBD) \times 1.1 \qquad (2)$$

where, *P1* and *P2* are the size of the prime movers for scenario 1 and scenario 2 respectively and 1.1 is a margin factor, which is included to avoid any possible contingences. A 307-kWe trigeneration prime mover for scenario 1 and a 217-kWe trigeneration prime mover for scenario 2 resulted in from equation 1 and 2.

Amount of heat produced by the systems is found by using the following expression:

$$Q = P \times HPR \qquad (3)$$

where, Q is the heat produced by the system, P is the electrical output of the prime mover and *HPR* is the heat to power ratio of the system. In this work, reciprocating internal combustion engine is selected as the prime mover due to its higher efficiency, possibility to use broad variety of fuels (in this work lpg is thought to be used as fuel), high availability and well-proven technology. *HPR* value of a reciprocating internal combustion engine based trigeneration system is accepted to be 1.25 for low-grade heat [1]. Then the total heat produced by the systems would be 384 kW_t and 271 kW_t for scenario 1 and scenario 2 respectively.

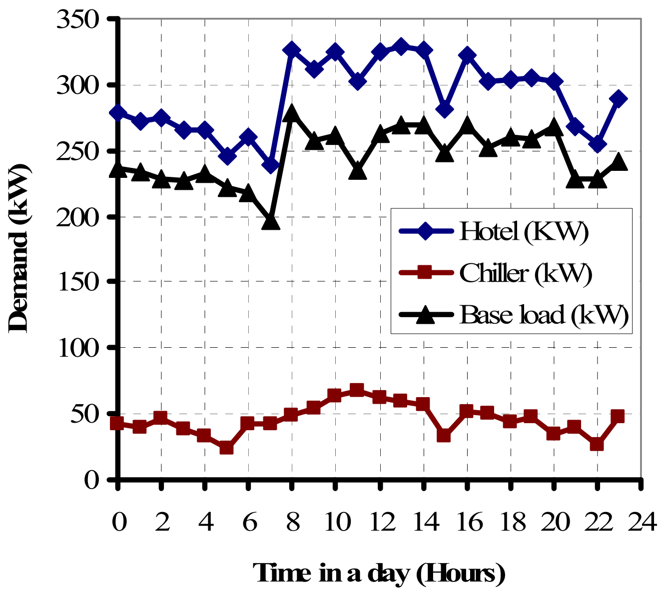

Fig.4 [4]: Hotel, chiller and base load demand curves for a typical summer day based on full occupancy.

Considering that the total installed boiler capacity of the hotel is 928 kW_t, heat produced by the trigeneration systems is not sufficient to supply the entire heating demand. Therefore, for scenario 1 a 544 kW_t and for scenario 2 a 657 kW_t supplementary boilers should be installed to meet the rest of the demand.

A typical trigeneration system includes an absorption chiller in order to provide space cooling. The heat produced by the system is utilized in absorption chiller as the absorption chiller's primary energy source. Cooling energy supplied by the absorption chiller depends on the amount of heat energy obtained from the system. Cooling capacity of the absorption chiller is calculated by using the COP definition. COP of an absorption refrigeration system is calculated by using following expression [5].

$$COP_{AC} = \frac{Q_L}{Q_{gen}} \quad (4)$$

where, Q_L is the cooling capacity of the absorption chiller and Q_{gen} is the heat energy supplied to the absorption chiller. COP of the absorption chiller is accepted to be 0.7 in this study [5]. When these values are substituted in equation 4, cooling capacity of the absorption chillers are evaluated to be 269 kW_t and 190 kW_t for scenario 1 and scenario 2 respectively.

These values should be compared with the hotel's cooling demand for a typical summer day in order to decide whether there is need for supplementary chillers. Cooling demand of the hotel for a typical summer day is calculated by:

$$CD = CMD \times COP \quad (5)$$

where, CD is the total cooling demand, CMD is the chiller's maximum electricity demand and COP is the COP value of the existing chiller. Maximum electricity demand of the hotel's chiller was recorded as 68 kWe for a typical summer day as seen in Fig.4. COP of the existing chiller is accepted to be 2.7 in this work. When these values are substituted in equation 5, cooling demand of the hotel is found out to be 184 kW_t. Cooling supplied by the absorption chillers are 269 kW_t and 190 kW_t for scenario 1 and scenario 2 respectively. It is seen that these values are enough to supply the entire cooling demand of the hotel so there is no need to install any other supplementary chillers. The summary of the results for the representative hotel for scenario 1 and scenario 2 can be seen in Fig.5 and Fig.6 respectively.

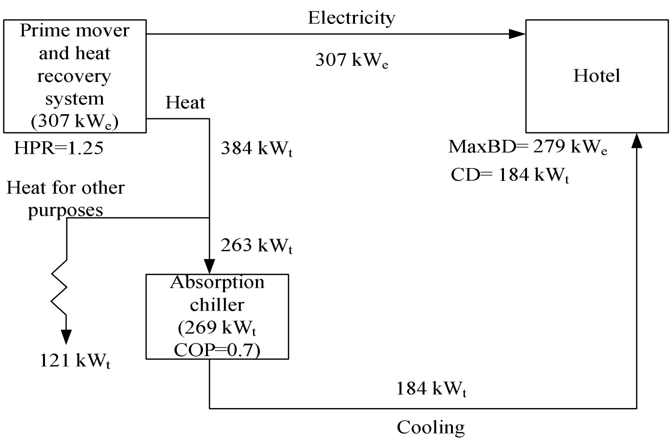

Fig .5- Summary of the application of trigeneration system to the representative hotel for scenario 1.

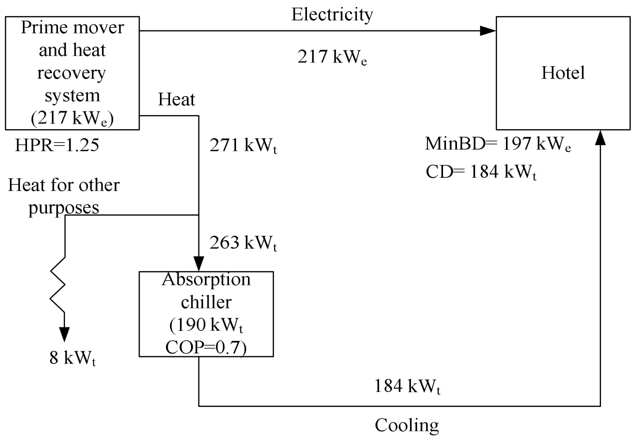

Fig.6- Summary of the application of trigeneration system to the representative hotel for scenario 2.

4.2 Sizing Trigeneration for the Other Hotels

Monitoring is carried out only in one hotel, which is called representative hotel. During the survey, electricity bills of the other five hotels were collected. The recordings and the electricity bills are used to develop some correlations for sizing the trigeneration systems for the other hotels. Those correlations are used to evaluate MaxBD, MinBD and CMD values of the other hotels.

First correlation is called MADR, which stands for maximum to average electricity demand ratio of the hotel. The MADR value of the representative hotel is found and applied to other hotels in order to estimate their maximum electricity demand values. MADR is expressed as:

$$MADR = \frac{MD}{AD} \quad (6)$$

where, MD is the maximum electricity demand of the hotel and AD is the average electricity demand of the hotel. Maximum demand is already known from the recordings (329 kW_e). AD value can be found by evaluating the area under the hotel's electricity demand curve, which is given in Fig.4, and dividing it to 24 (hours in a day). Area under the demand curve is evaluated by fitting a polynomial to the demand curve and integrating it over the 24 hours period. Eventually, AD value of the representative hotel came out to be 279 kW_e. Then MADR value is found to be 1.18.

AD values of the other hotels for a typical summer day can be evaluated by using the total electricity consumptions in July 2007 (monthly electricity and fuel consumptions are obtained during surveying). Due to the MADR value depends on the AD value which is calculated based on the recordings taken in July, total electricity consumptions in July are used to evaluate the AD values for the other hotels. When the total electricity consumptions based on full occupancy are divided to total hours in July, AD values of the other hotels are come out. Then AD values of the other hotels are substituted in equation 6 and their MD values are evaluated.

In order to evaluate the MaxBD and MinBD values for the other hotels other correlations are needed to be developed. The ratio of the MaxBD value to the MD value and the ratio of the MinBD value to the MD value of the representative hotel can be used to evaluate the MaxBD and MinBD values of the other hotels. The MaxBD to MD ratio is 0.85 whereas MinBD to MD ratio is 0.60 for the representative hotel. This means that 85% of the hotel's maximum electricity demand is equal to its maximum electricity base load demand and 60% of the hotel's maximum electricity demand is equal to its minimum electricity base load demand. When the MD values of the other hotels are multiplied with 0.85, their MaxBD values are estimated. On the other hand, when the MD values of the other hotels are multiplied with 0.60 their MinBD values are estimated. Then by using equation 1 and 2 size of the prime movers for the trigeneration systems for the other hotels for scenario 1 and scenario 2 are evaluated. Amount of produced heat by these prime movers are calculated by using equation 3. Heat output of the systems should compared with the heating demands of the other hotels (assumed to be total boiler capacity) in order to decide if there is need for supplementary boilers. The heating demands of the other hotels are given in Table 4.

Another relation is needed to be developed in order to evaluate the CMD values of the other hotels. The CMD values of the other hotels can be estimated by using the ratio of the CMD value to the MD value of the representative hotel. This ratio is 0.21. This means that 21% of the hotel's maximum electricity demand is equal to the chiller's maximum electricity demand. When this relation is applied to the other hotels their CMD values are estimated. In addition to this by using equation 5, their CD values can be evaluated. The CD values of the other hotels are given in Table 4. Cooling capacities of the absorption chillers can be calculated by substituting the values of heat produced by the systems and COP of the proposed absorption chillers (0.7) into equation 4. Cooling capacities of the absorption chillers should meet the entire cooling demand; otherwise supplementary chillers are needed to be installed.

The size of the prime movers and the absorption chillers as well as the needed supplementary boilers and supplementary chillers and amount of heat produced by the systems for the other hotels can be seen in Table 5. When the results are investigated it is seen that for all the hotels there are need for supplementary boilers for both of the scenarios in order to meet the heating demands. On the other hand, it is seen that the size of the absorption chillers are enough to meet the cooling demands of the all hotels for both of the scenarios

Table 4- Heating and cooling demands of the other hotels.

Hotel	Heating Demand (kW_t)	Cooling Demand (kW_t)
1	3480	553
2	812	193
3	2005	216
4	928	276
5	1392	191

Table 5- Size of the trigeneration systems and the supplementary boilers as well as chillers for the other hotels

Hotel	Scenario 1				
	Size of the prime movers (kW_e)	Size of the abs. chillers (kW_t)	Heat produced by the systems (kW_t)	Size of the supp. boilers (kW_t)	Size of the supp. Chillers (kW_t)
1	913	799	1141	2339	---
2	318	278	397	415	---
3	356	311	444	1561	---
4	455	398	569	359	---
5	314	275	393	999	---
Hotel	Scenario 2				
	Size of the prime movers (kW_e)	Size of the abs. chillers (kW_t)	Heat produced by the systems (kW_t)	Size of the supp. boilers (kW_t)	Size of the supp. Chillers (kW_t)
1	644	564	805	2675	---
2	224	196	280	532	---
3	251	220	314	1691	---
4	321	281	402	526	---
5	222	194	277	1115	---

5 Economical Analysis

In order to assess the applicability of the proposed trigeneration systems their life cycle cost analysis have been carried out for the N. Cyprus conditions. The economical performance measure parameters like simple payback, net present value (NPV), savings-to-investment ratio (SIR) and internal rate of return (IRR) are evaluated for both of the scenarios.

It is assumed that the prime mover of the trigeneration system will run continuously for the whole year. Amount of the energy generation (electricity and heat) by the proposed trigeneration systems are evaluated for one-year period for the all hotels. These values are compared with the annual amount of the energy consumption (for the year 2007) by the existing systems of the hotels. During a year in some months, there is excessive produced energy and in others, the produced energy is not enough by the trigeneration systems. In the case of excessive production the produced energy (electricity) could be sold to the utility (grid-connected case) whereas when the production is not enough electricity could be purchased from the utility and heat could be produced by supplementary boilers. The annual trigeneration coverage and the excessive electricity and heat generation for the hotels are given in Table 6. When the annual running and maintenance costs of the trigeneration systems are evaluated and substracted from the annual energy consumption costs of the existing systems, total annual savings come out. The annual savings for the hotels are given in Table 7. When the annual saving is negative, there is no need to do a feasibility analysis due to the fact that there is not any benefit by the application of the system. The annual savings and other parameters such as capital costs of trigeneration systems, life of the projects and salvage values of the trigeneration systems as well as the salvage values of the existing systems are incorporated in a spreadsheet program for the evaluation of the economical performance parameters. The parameters that are used in the spreadsheet program for the representative hotel are given in Table 8. The results of the feasibility analysis for the all hotels are given in Table 9.

6 Conclusion

When the results of the life cycle cost analysis of the proposed trigeneration scenarios given in Table 9 investigated, it is seen that the results achieved by the application of scenario 2 are more feasible than the results achieved by the application of scenario 1 in economical point of view. All of the economical measure parameters (simple payback, NPV, SIR, IRR) results with better values by the application of scenario 2. Therefore, it is decided to apply scenario 2 to the hotels due to its superior economical results over scenario 1. When scenario 2 is applied to the all hotels considered in this work, total installed capacity of the trigeneration systems would be 1.9 MW_e. In addition to this, total annual electricity production by the trigeneration systems would be 16680816 kWh. This means that there will be 16.7 GWh less electricity demand annually from the utility. This decrease in the electricity demand would reduce the load coming to the power plants. Furthermore, considering that, total electricity production by the utility using 80 MW old gas turbine units was approximately 4 GWh in 2007, running and maintenance costs of these units would be avoided by disposing of them. In addition to this, if the trigeneration systems are widespread among the hotel sector and reach total installed capacity of around 15 MW, the commissioning of new power plants by the utility could be deferred. If the excess electricity could be sold to the utility (grid-connected) further benefit would be obtained by the application of scenario 2. If the representative hotel is considered; the NPV value will increase 3.3 times, the SIR value will increase 2 times, the IRR value will be raised by 32 units and payback time will be approximately half if the excess electricity could sold to the utility. However, it should be noticed that for the time being there are not any appropriate infrastructure and legal rules and regulations that enable electricity sale to the utility in N. Cyprus. Therefore, it is strongly recommended that a demand side management program should be put into practice by the state. This program should include the development of the electrical transmission infrastructure in such a way that the electricity produced by the consumers could be sold to the utility.

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Table 6- Annual trigeneration coverage and energy generated (electricity and heat) by the trigeneration systems for the hotels for scenario 1and scenario 2.

Hotel #	Electrical energy generated by trigeneation system (kWh)	Electrical energy consumption of the hotel (kWh)	Saved electrical energy by absorption chiller (kWh)	Excessive Electrical energy available (kWh)	Heat energy generated by trigeneration system (kWh)	Heat energy consumption of the hotel (kWh)	Heat energy consumption by absorption chiller (kW)	Excessive heat energy available (kWh)
Scenario 1								
Rep.	2696688	1942070	191729	946347	3370860	1039985	777384	1553491
1	8019792	7304176	579744	1295360	10024740	5612134	2235528	2177078
2	2793312	2835082	202032	160262	3491640	720050	781776	1989814
3	3127104	2569620	228384	785868	3908880	3183653	874008	-148781
4	3996720	3578664	289872	707928	4995900	962754	1119960	2913186
5	2758176	1983101	202032	977107	3447720	2081646	772992	593082
Scenario 2								
Rep.	1906128	1942070	191729	155787	2382660	1039985	777384	565291
1	5656896	7304176	579744	-1067536	7071120	5612134	2235528	-776542
2	2143296	2835082	202032	-489754	2679120	720050	781776	1177294
3	2204784	2569620	228384	-136452	2755980	3183653	874008	-1301681
4	2819664	3578664	289872	-469128	3524580	962754	1119960	1441866
5	1950048	1983101	202032	168979	2437560	2081646	772992	-417078

Table 7- Annual savings by the application of the trigeneration systems for the hotels.

Hotel #		Net annual savings (YTL)	
		Scenario 1	Scenario 2
Representative hotel	Stand-alone	-158555	76364
	Grid-connected	132163	154427
1	Stand-alone	257460	607411
	Grid-connected	776187	699126
2	Stand-alone	-57223	73839
	Grid-connected	76004	102028
3	Stand-alone	66852	204566
	Grid-connected	362020	288886
4	Stand-alone	-139530	113046
	Grid-connected	97764	144363
5	Stand-alone	-13508	146040
	Grid-connected	286660	233580

Note: YTL is the currency in N. Cyprus.

Table 8- Parameters needed for the feasibility analysis of the trigeneration system.

Parameter	Value				Unit
	Scenario 1		Scenario 2		
	Grid-connected	Stand-alone	Grid-connected	Stand-alone	
Net annual savings	132163	-158555	154427	76364	YTL
Running cost of the system	949550	949550	671098	671098	YTL
Maintenance cost	24270	24270	17155	17155	YTL
Total maintenance and running cost	973821	973821	688253	688253	YTL
Total capital cost	480355	480355	339500	339500	YTL
Capital cost of prime mover with heat recovery unit	1350				YTL/kW
Capital cost of absorption chiller unit	245				YTL/kW
Life of the project	10				Years
Salvage value	25				%
Discount rate	13				%
Salvage value of the existing electrical generator	88				YTL/kVA
Salvage value of the existing chiller	45				YTL/kW

Table 9- The results of the feasibility analysis for the hotels.

Hotel #	Parameter	Value				Unit
		Scenario 1		Scenario 2		
		Grid-connected	Stand-alone	Grid-connected	Stand-alone	
Rep. hotel	NPV	356290	--------	607582	183993	YTL
	SIR	2.0	--------	3.6	1.8	YTL/YTL
	IRR	32	--------	60	28	%
	Simp. payback	3.0	--------	1.7	3.3	Years
1	NPV	3186965	372226	3158553	2660885	YTL
	SIR	4.1	1.4	6.0	5.2	YTL/YTL
	IRR	68	20	99	86	%
	Simple payback	1.5	4.4	1.0	1.2	Years
2	NPV	22039	--------	299416	146456	YTL
	SIR	1.1	--------	2.2	1.6	YTL/YTL
	IRR	14	--------	35	24	%
	Simp. payback	5.6	--------	2.7	3.8	Years
3	NPV	1588910	-12743	1344031	886490	YTL
	SIR	5.2	1.0	7.0	5.0	YTL/YTL
	IRR	87	12	114	81	%
	Simp. payback	1.2	6.2	0.9	1.2	Years
4	NPV	-28300	--------	418689	248755	YTL
	SIR	0.9	--------	2.1	1.7	YTL/YTL
	IRR	12	--------	35	26	%
	Simp. payback	6.3	--------	2.8	3.6	Years
5	NPV	1175713	--------	1021124	546111	YTL
	SIR	4.1	--------	5.1	3.2	YTL/YTL
	IRR	69	--------	86	53	%
	Simp. payback	1.5	--------	1.2	1.9	Years