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Novel technical and economic analysis of water and power co-generation in coastal areas

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Abstract

Analysis of the current status of power plants and finding solutions to increase their efficiency is essential because of long-term rising fuel prices, environmental concerns and an ever-increasing demand for energy in the world. A basic approach to maintaining the existing units is to increase energy efficiency by using these units in the cogeneration cycle, based on technical and economic considerations. In this paper, the technical and economic evaluation of a gas power plant in central Iran is used with reference to a combined electricity and freshwater generation system on Iran's southern shores. Results show that the two gas turbines, a heat recovery boiler, condensing steam turbine and reverse osmosis unit at Chabahar is the most attractive scenario, because it has the highest net present value, internal rate of return, the quickest payback period and the lowest price in the studied scenarios.

Keywords: water production; cogeneration; technical analysis; economic approach

1. Introduction

Gas power plants are important components of the power industry. Given the increasing demand for electricity, it is expected that all these plants will be converted to high-efficiency combined cycle power plants in due course. To improve energy efficiency, technical and economic considerations should be explored for the use of these units in cogeneration systems. Many studies have been done in this area. Lozano et al. [1] proposed a methodology for disaggregating energy systems (productive and dissipative units). They disaggregated the exergy flows into thermal, mechanical and chemical concepts and applied the proposed methodology to the cogeneration system based on the gas turbine. Local optimization problem solving was one of their formulation results. Gomar et al. [2] performed a techno-economic analysis of the Asalouyeh combined cycle power plant to produce specifications for a suitable desalination unit. The MED desalination method was selected. Mohan et al. [3] presented a tri-generation (power, water, cooling) system at the Al-Hamra gas turbine power plant. Results showed cost savings and reduction in carbon emissions. Shnaiderman et al. [4] calculated the total expected initial setup and operational costs of a cogeneration system. They showed that implementation of a cogeneration system might outperform a conventional system in terms of return-on-investment time. Ferreira et al. [5] presented a numerical model to design an optimal cogeneration system based on a cost-benefit analysis. Shahzad et al. [6] presented a hybrid advanced desalination cycle as MEDAD. They presented a numerical model for the proposed cycle and found that the improved design permits the latter stages of MED to operate below the ambient temperature. Darwish et al. [7] analyzed a cogeneration power-desalting plant (combinations of the gas-steam turbine combined cycle (GTCC) with thermally driven desalination units). They performed energy and exergy analysis and presented the effect of using GTCC on several operating parameters. They found that the main exergy loss was calculated in the GT combustion chambers, and the desalinated water cost was strongly affected by the fuel type. Hanafi et al. [8] performed a thermo-economic analytical study of a combined cogeneration power plant for power and water production. They investigated some operating conditions to obtain the optimum point for maximum production of water and power with the best overall efficiency. Bade et al. [9] proposed a methodology, based on pinch analysis, to integrate a gas turbine and regenerator with a process plant to minimize fuel consumption. They presented the thermodynamic analysis of a gas turbine integrated CHP plant on the gas turbine pressure ratio versus the power to heat ratio diagram. Ng et al. [10] performed research on various aspects of AD and

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related hybrid MEDAD cycles (theoretical and experimental). They investigated fuel cost in cogeneration configurations. Shahzad et al. [11] presented experiments with regard to 3-stage MED and MEDAD plants. The performance ratio (PR) for all states was measured. The results show that the MEDAD cycle water production could be increased up to 2.5 to 3 fold with respect to a conventional MED of the same rating. Basha et al. [12] presented a computational economic feasibility study of retrofitting a given existing gas turbine power generation plant into a co-generation power plant. They found that for a decrease of inlet air temperature by 10°F, net plant efficiency increased from 33.3% (GT only) to 63.4% (cogeneration). Salvini et al. [13] investigated installing small size (up to 6 MWel) GT base CHP plants in Italy. They found that the specific plant investment costs and GT technical features affected economic performance and the economic result improved with the size of plant. Karaali et al. [14] applied some methods to improve gas turbine cogeneration cycles (such as preheating air, preheating air and fuel, inlet air cooling by using evaporative cooling and absorption cooling) on a simple cogeneration cycle. They evaluated energy and exergetic efficiency. They concluded that the most efficient cycle was the air-fuel preheated cycle for obtaining more electric power and less heat power. Arani et al. [15] presented a new approach for the economic analysis of thermal systems considering system availability variation during its lifetime. They analyzed a combined gas turbine cycle and desalination unit and for availability calculation used the state space method with time-varying failure rates and factored in servicing. Some economic indicators were compared with two cases of variable and constant availability, using the life cycle cost analysis method. Considering time-varying availability, the payback period was increased to 9 months, and the net present value reduced by about $18 million. Shahzad et al. [16] proposed a tri-hybrid system to enhance overall recovery by up to 81%. They used the RO & ME-AD hybrid cycle for desalination. Shahzad et al. [17] performed a state of the art review on energy, water, and environment interconnection and future energy-efficient desalination possibilities to save energy and protect the environment. Król et al. [18] reviewed the cost and energy efficiency of a heat and electricity production system. They calculated the energy balance in a one hour operation period. Shahzad et al. [19] analyzed a multi-effect distillation (MED) system operated with thermocline energy from the sea (called the ST-MED process). They showed that desalination efficiency could outperform existing methods by a factor of 2. Ng et al. [20] proposed a multi-effect desalination system operated with ocean thermocline energy. The simulation was conducted in FORTRAN using the international mathematical and statistical library (IMSL). They showed that the proposed cycle could achieve the highest level of universal performance ratio, UPR = 158, achieving about 18.8% of the ideal limit. Shahzad et al. [21] investigated the exergetic analysis for primary fuel percentage in the cycle according to the quality of working fluid utilized. They proposed the universal performance ratio (UPR) to evaluate desalination performance. They suggested that for future sustainability, desalination must achieve 25–30% of the thermodynamic limit. Shahzad et al. [22] presented the energy efficiency of the desalination processes. They proposed a standard universal performance ratio as a roadmap for achieving the 2030 sustainable development goals for seawater desalination. Shahzad et al. [23] presented a standard primary energy-based thermodynamic framework that showed all desalination processes performance vary some 10–14% from the thermodynamic limit. The current paper relates the technical and economic evaluation of a gas power plant in central Iran with regard to a combined electricity and freshwater generation system on Iran's southern shores. Two general conditions for power generation are considered: new turbines and major overhauled turbines. The combination of possible scenarios was performed using gas and steam turbines, heat recovery boilers, thermal and membrane desalination units (36 scenarios). Water desalination methods include multi-effect distillation (MED) and reverse osmosis (RO). Then, a discussion follows concerning the development of a technical-economic model of proposed schemes for the simultaneous generation of electricity and water using GE-F5 Hitachi turbines. A technical and economic evaluation of possible scenarios is presented in respect of two situations involving the use of new turbines and overhauled turbines.

2. Modeling

In this section, the technical and economic feasibility of the proposed schemes for the cogeneration of electricity and water using the GE-F5 Hitachi turbines is investigated. The climatic and geographical conditions of Bushehr and Chabahar are considered as the basis for calculations. The results of this study can be generalized due to the similarity of these two cities with cities in other regions of the Persian Gulf and Oman Sea. In the technical modeling, nine scenarios for combining gas turbines and water desalination units are discussed:

1. Gas turbine, reverse osmosis unit
2. Gas turbine, multi-effect distillation unit
3. Gas turbine, heat recovery boiler, multi-effect distillation, reverse osmosis
4. Gas turbine, heat recovery boiler, back-pressure steam turbine, multi-effect distillation unit
5. Two gas turbines, heat recovery boiler, back-pressure steam turbine, multi-effect distillation unit
6. Gas turbine, heat recovery boiler, back-pressure steam turbine, reverse osmosis, multi-effect distillation unit
7. Two gas turbines, heat recovery boilers, back-pressure steam turbine, reverse osmosis, multi-effect distillation unit
8. Gas turbine, heat recovery boiler, condensing steam turbine, reverse osmosis unit
9. Two gas turbines, heat recovery boilers, condensing steam turbine, reverse osmosis unit

Table 1: Technical Specifications of Gas Turbine GE-F5

Parameter	Value
ISO power, kW	24750
Efficiency, %	28.7
Heat rate, kJ/kWh	12555
Turbine inlet temperature, °C	993
Turbine outlet temperature, °C	479
Pressure ratio	10.2

Table 2: Site specifications

Parameter	Value	Value
	Bushehr	Chabahar
Temperature, °C	35	24
Relative Humidity, %	70	70
Seawater temperature, °C	35	25
Seawater TDS, ppm	42000	37000

A short A-B-C type code characterizes each scenario. Part A indicates the type of power cycle defined as 1GT, meaning one gas turbine and 2GT, two gas turbines. The second part indicates the type of steam turbine, BST denotes back-pressure steam turbine, and CST denotes condensing steam turbine. The third part of the code from the left indicates the type of water production unit, which can be MED, RO, MEDRO. So, for example, 2GT-BST-MEDRO means the use of two gas turbines, back-pressure steam turbine and a hybrid MEDRO desalination system.

2.1. Technical characteristics

24-megawatt GE-F5 Hitachi turbines are considered for the power generation cycle. The technical characteristics of the gas turbine are shown in Table 1.

If the heat recovery boiler produces steam for the water cycle, the steam pressure and temperature will be 5.17 bar and 203°C, respectively. In the case of steam production by a heat recovery boiler used for the production of fresh water and power generation by a steam turbine, the pressure and temperature will be 40 bar and 470°C (high-pressure unit) and 9 bar and 175°C (low-pressure unit) [24].

Multi-effect distillation and reverse osmosis desalination and a combination of both for water desalting methods will be investigated. The temperature and relative humidity of the site (same for the power and water cycle), as well as the water salinity of the seawater, are shown in Table 2.

2.2. Economic evaluation factors of power generation and water desalination

The economic analysis was done in Camfar software and the product prices calculated in Excel. The economic evaluation methods used to examine the economic feasibility of a project and prioritize various economic plans are: net present value method (NPV), internal rate of return (IRR), payback period and price. In the NPV method, the funds (income or cost) are referenced to the start of the timeframe through discount rates. The NPV of a project is obtained from the sum of the two vectors (income and cost). The NPV [25] can be calculated using the equation 1:

$$NPV = \Sigma \frac{B_t - C_t}{(1+i)^t} \tag{1}$$

It should be noted that when comparing two or more projects, it is preferable to choose a project with a larger NPV (and, of course, a positive one). If the initial investment and life of the investigated projects differ, it is best to use a comparison of the NPV ratio schemes, according to equation 2 which derives from the division of the NPV into the initial investment amount of the plan and plans for economic priority, which can be sorted in descending order.

$$NPV\ Ratio = \frac{NPV}{Investment} \tag{2}$$

The IRR that represents an acceptable profitability indicator is the rate at which the current value of all revenues is equal to the current value of all costs. In other words, the IRR is the rate at which the NPV equals zero. After calculating the IRR, it is compared with the minimum returnable rate (or expected rate) and, if the IRR is higher than the minimum rate, it is either accepted or otherwise rejected. The IRR can be calculated by using the equation 3.

$$\sum \frac{B_t - C_t}{(1+IRR)^t} = 0 \tag{3}$$

In the payback period, the goal is to determine the period in which the initial investment will return, irrespective of the interest rate. The payback period is calculated as follows [25]:

$$\sum R_t \geq G \tag{4}$$

The basis of the price approach is to calculate all cumulative costs of the construction and operation of the power plant. Consequently, for each cubic meter of fresh water produced, the levelized cost of water is calculated based on the currency used. One dollar today is more valuable than a dollar a year later because it can be invested. To calculate the time value of money, the cost recovery factor (CRF) has been used:

$$CRF = \frac{i\,(1+1)^n}{(1+i)^n - 1} \tag{5}$$

To prioritize the plans, the schemes are arranged in ascending order, based on this index, and a more economic plan has a lower cost. To calculate the final product price, all parameters affecting prices such as investment, fuel costs, repairs, and maintenance are considered. In this paper, all four methods are evaluated.

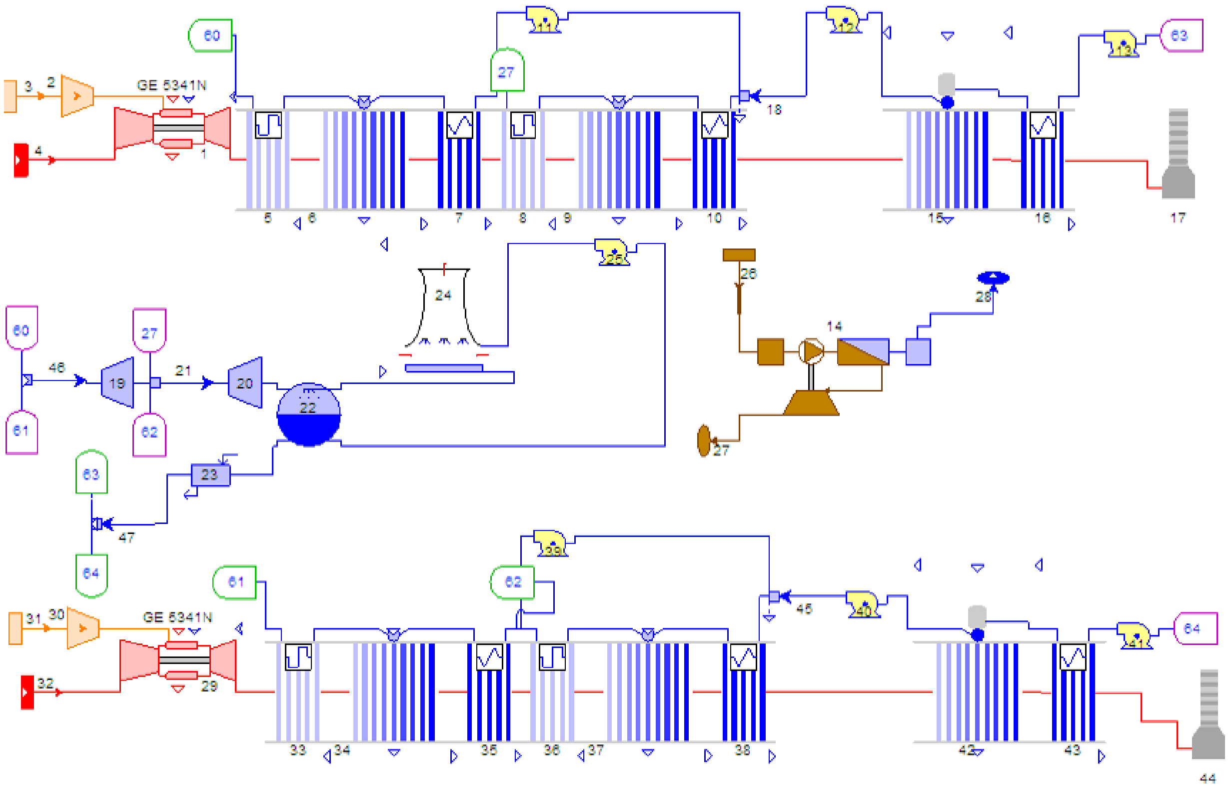

Figure 1: Schematic diagram of two gas turbines, a heat recovery boiler, a condensing steam turbine and a reverse osmosis unit modeling in Thermoflow software

Table 3: Produced fresh water production in all scenarios at two sites (Bushehr and Chabahar)

Scenarios	Bushehr	Chabahar
	Value, m^3/day	Value, m^3/day
GT-RO	84103	100014
GT-MED	9092	9092
GT-MED/RO	72737	31380
GT-BST-MED	7274	7501
2GT-BST-MED	14548	14564
GT-BST-MED/RO	100649	20912
2GT-BST-MED/RO	200938	41482
GT-CST-RO	129564	154567
2GT-CST-RO	259127	309134

Table 4: Technical characteristics of the cogeneration system for the scenario of two gas turbines, heat recovery boiler, distillation steam turbine and reverse osmosis unit

Parameter		Value
Electrical Power, kWe	Gas unit	44707.6
	Steam unit	25124.3
	Gross power	69832
	Net power	780.4
Auxiliary device(s)	Power unit	99
	Water unit	67849.3
	Fuel compressor	33
	Pump	371.9
	Miscellaneous	698.3
	Total plant auxiliary	69052
	Fuel consumption, kg/s	3.518
	Water production, m^3/day	309134 (68MIGD)

3. Result and discussion

In this section, the results are calculated for different scenarios of water desalination and power generation, with the aim being maximum production of fresh water in Bushehr and Chabahar. In each scenario, electric power production, internal power consumption, fuel consumption, and gross freshwater production are computed. A schematic diagram of modeling in Thermoflow software is shown for one of the scenarios in Fig. 1.

The climatic and geographical conditions of Bushehr and Chabahar are considered as the basis for calculations; the amount of water produced in all scenarios is summarized in Table 3.

The highest amount of water produced is obtained by the two gas turbines, a heat recovery boiler, condensing steam turbine and reverse osmosis unit at the Chabahar site. The technical results of this scenario are summarized in Table 4. The total net power generated by this system is calculated as 780.4 kilowatts and the amount of gross water production as 309.134 cubic meters per day.

The results of the economic modeling of all scenarios (NPV ratio) at the Bushehr and Chabahar sites for overhauled and new turbines are summarized in Table 5. The results show that the last scenario (2GT-CST-RO) has the highest NPV ratio among all the scenarios in all four states.

The technical results of the scenarios for Bushehr and

Table 5: Economic characteristics of NPV ratio for water and electricity generation scenarios

	Bushehr (overhauled units)	Bushehr (new units)	Chabahar (overhauled units)	Chabahar (new units)
Scenarios	NPV ratio			
GT-RO	1.61	1.45	1.73	1.57
GT-MED	0.68	0.35	1.01	0.58
GT-MED/RO	1.19	1.06	0.95	0.74
GT-BST-MED	1.12	0.51	1.41	0.69
2GT-BST-MED	1.38	0.60	1.72	0.79
GT-BST-MED/RO	1.47	1.29	1.12	0.73
2GT-BST-MED/RO	1.81	1.57	1.40	0.88
GT-CST-RO	1.88	1.62	2.01	1.76
2GT-CST-RO	2.28	1.94	2.42	2.09

Table 6: Technical results of the scenarios for Bushehr

	Gross power, kWe	Net power, kWe	Power consumption, kWe	Water production, m^3/day MED	RO
Bushehr					
GT-RO	20812	57.7	20754	84103	-
GT-MED	20619	16451	4147.9	-	9092
GT+HRSG+MEDRO	20619	709.4	19910	63645	9092
1GT+HRSG+BST+ MED	26636	22982	3655	-	7274
2GT+HRSG+BST +MED	53333	46023	7310	-	14584
1GT+HRSG +BST +MEDRO	26636	242.7	26394	93195	7274
2GT+HRSG+ BST+ MEDRO	53333	552.4	52780	186390	14584
1GT+HRSG+ CST+RO	32730	206.6	32523	129564	-
2GT+HRSG+ CST+RO	65578	542.8	65035	259127	-
Chabahar					
GT-RO	22676	432.5	22243	100014	-
GT-MED	22492	21692	799.9	-	9092
GT+HRSG+MEDRO	22492	16974	5518	20457	10923
1GT+HRSG+BST+ MED	28632	27783	849.3	-	7501
2GT+HRSG+BST +MED	57221	55549	1672.7	-	14564
1GT+HRSG +BST +MEDRO	28579	24674	3905	13638	7274
2GT+HRSG+ BST+ MEDRO	57221	49417	7804	27277	14565
1GT+HRSG+ CST+RO	34856	329.5	34526	154567	-
2GT+HRSG+ CST+RO	69832	780.4	69052	309134	-

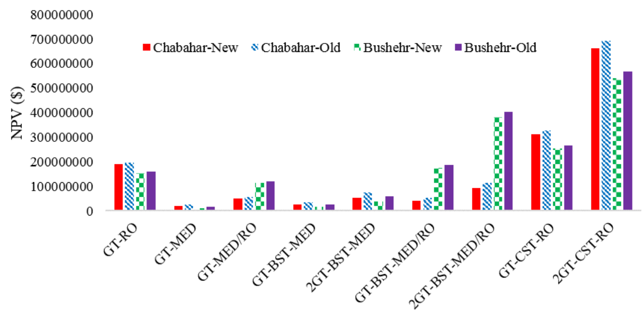

Figure 2: Economic result-NPV values for all scenarios

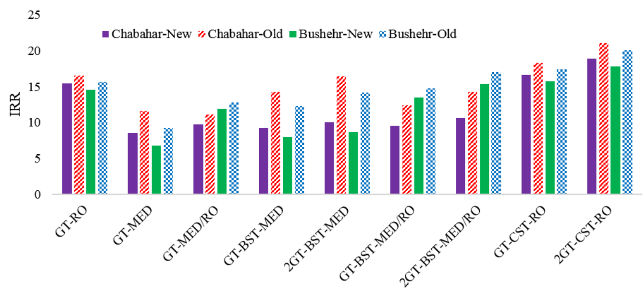

Figure 3: Economic result-IRR values for all scenarios

Chabahar are presented in Table 6. Gross power, Net power, Power consumption and Water production are the parameters whose values are calculated.

Economic analysis of the scenarios for two sites (Bushehr and Chabahar) is presented in Figures 2–5). NPV values for different scenarios at the Bushehr and Chabahar sites are compared with the use of new and overhauled turbines in Fig. 2. The results show that the final scenario, namely two gas turbines, heat recovery boiler, condensing steam turbine and reverse osmosis unit, has the highest NPV of all the scenarios. This value of the Chabahar site with the overhauled turbines is the highest.

IRR values are shown in Fig. 3. The results for the final scenario at Chabahar with the overhauled turbines has the highest IRR of all the scenarios.

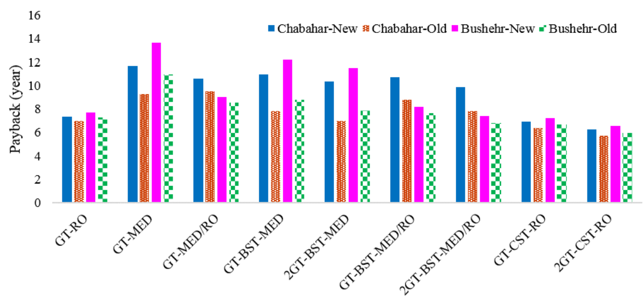

Figure 4: Economic result-payback values for all scenarios

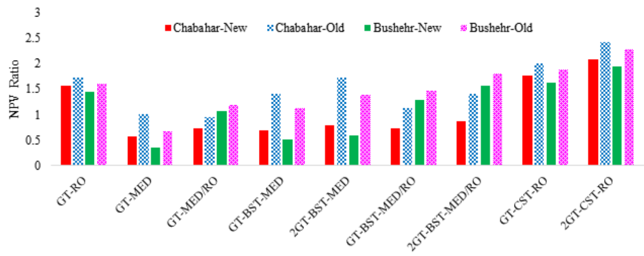

Figure 5: Economic result - NPV ratio values for all scenarios

Table 7: Economic parameters of superior scenarios

Economic parameters	NPV, $	IRR, %	Payback period, year	NPV ratio
Bushehr- overhauled turbine	567364300	20.1	5.94	2.28
Chabahar-overhauled turbine	692844931	21.06	5.72	2.42
Bushehr- new turbine	539268482	17.9	6.53	1.94
Chabahar-new turbine	662841366	18.9	6.25	2.09

The criteria for the payback period for the various scenarios in Bushehr and Chabahar are compared using new and overhauled turbines in Fig. 4. The lowest payback period is seen in the final scenario. The scenario of two gas turbines, heat recovery boiler, condensing steam turbine and reverse osmosis unit at Chabahar require the least time to return capital of all the scenarios with the overhauled turbines.

The NPV ratio for all scenarios in Bushehr and Chabahar are presented using new and overhauled turbines in Fig. 5. The final scenario has the highest NPV ratio of all the scenarios. The use of overhauled turbines at the Chabahar site enjoys the best economic justification for implementation.

Therefore, the selected scenario information on all four final models, including scenarios for the use of new and overhauled turbines at both Bushehr and Chabahar sites, is compiled from the 36 scenarios in Table 7. Regarding the results, it can be concluded that the scenario of two gas turbines, heat recovery boiler, condensing steam turbine and reverse osmosis unit in all four modes using new or overhauled turbines at the Chabahar and Bushehr sites enjoy the best economic characteristics. High NPV values, shorter payback period, high NPV ratios and larger IRRs all fit in this scenario. Therefore, it was the most profitable and economic justification for this plan.

The economic criteria presented in the table above are more attractive to the private sector, because they examine the profitability of the plans and the return on investment and deal with revenue and expenditure in the calculations. An economic criterion that only covers costs is the product price, which represents the cost of generating a unit of product (water) over its lifetime. The final price of water production is calculated in various scenarios at the Bushehr and Chabahar

Table 8: Price of water production in all scenarios

Scenario	Parameter	Bushehr	Chabahar
GT-RO	Water price, \$/m^3	0.56	0.55
GT-MED	Water price, \$/m^3	1.06	1.06
GT-MED/RO	Water price, \$/m^3	0.63	0.77
GT-BST-MED	Water price, \$/m^3	1.08	1.07
2GT-BST-MED	Water price, \$/m^3	1.02	1.02
GT-BST-MED/RO	Water price, \$/m^3	0.59	0.8
2GT-BST-MED/RO	Water price, \$/m^3	0.56	0.76
GT-CST-RO	Water price, \$/m^3	0.54	0.54
2GT-CST-RO	Water price, \$/m^3	0.52	0.51

Table 9: Specifications of the superior scenario

Combined Cycle Block (2Gas Turbine +1Condensing steam Turbine) + RO (309134 m^3/day)	
RO Desalination capacity, m^3/day	309134
Cogeneration efficiency, %	47.92
Availability, %	90
Construction period, years	1
Operation period, years	25
Net power, kWh	6152673.6

sites, as described in Table 8. By examining the results, the lowest water production price relates to the final scenario, namely two gas turbines, heat recovery boiler, condensing steam turbine and reverse osmosis unit at both Bushehr and Chabahar sites.

As a result, with a private and public approach, the final scenario is selected as the best scheme. The specifications of the proposed scheme will be described in Table 9. The cogeneration efficiency of the system with a production of 309134 m^3/day will be 47.92%.

The sensitivity analysis of the important economic parameters of this scenario is presented using the overhauled turbines in the following diagrams. Scenarios with positive NPV are economically justified and, as shown in Fig. 6, in this scenario, up to a discount rate of 20%, the net present value is positive, and therefore the project in this area is economical. Where the discount rate is more than 20%, the NPV is negative and becomes non-economic. If the discount rate is more than 20%, the net present value will be negative and the scenario will be a non-economic plan.

Fig. 7 shows the sensitivity analysis of the IRR index of the project in terms of sales revenue, fixed costs and operating costs. As revenue increases, the IRR will increase, whereas with decreasing fixed and operating costs, the IRR will decrease.

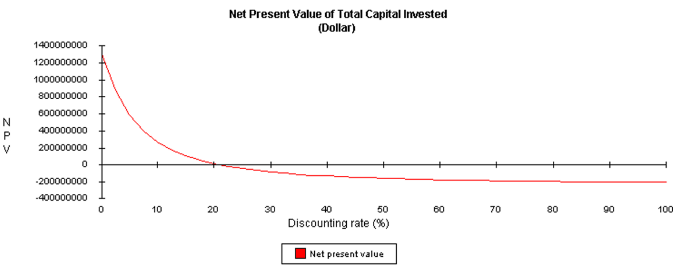

Figure 6: NPV of 2GT-CST-RO scenario

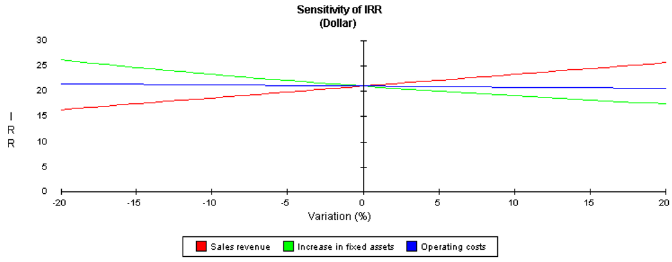

Figure 7: IRR of 2GT-CST-RO scenario

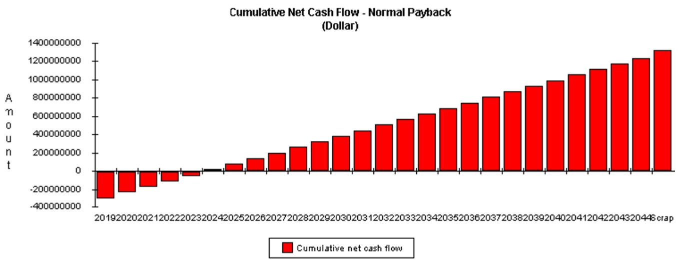

Figure 8: Payback period of 2GT-CST-RO scenario

According to Fig. 8, it takes approximately about six years to return the initial investment.

With electricity price increments, in nine scenarios at Chabahar, the price of water changes according to Table 10.

According to the table, the lowest growth of price is attributable to the RO method, due to the high volume of water production. This table is summarized in the diagram (Fig. 9).

By assuming at least electric power production (less than 100 kilowatts), the ambient temperature is selected based on the average monthly temperature, and the technical modeling for maximum freshwater production is repeated. The variation of water production in the best scenario with regard to temperature changes during the months of the year is shown in Fig. 10. In some months of the year, when freshwater production outstrips demand, water storage systems can be used to cope with predicted peaks in water demand.

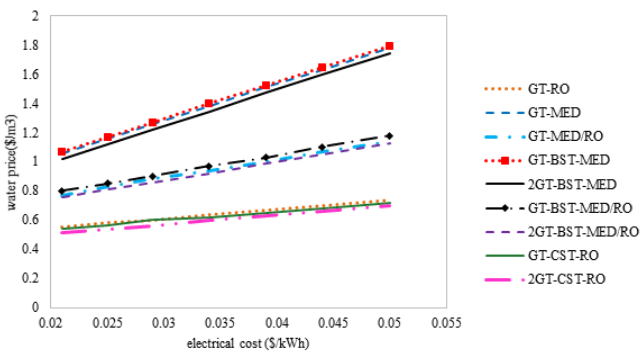

Figure 9: Water price variation by increasing the price of electricity

Table 10: Water price variation by increasing the price of electricity at the selected site for all scenarios

Scenario	GT-RO	GT-MED	GT-MED/RO	GT-BST-MED	2GT-BST-MED	GT-BST-MED/RO	2GT-BST-MED/RO	GT-CST-RO	2GT-CST-RO
Water production, m^3/day	100014	9092	31380	7501	14564	20912	41482	154567	309134
Electrical cost, $/kWh	Water price, $/m^3	Water price, $/m^3	Water price, $/m^3	Water price, $/m^3	Water price, $/m^3	Water price, $/m^3	Water price, $/m^3	Water price, $/m^3	Water price, $/m^3
0.021	0.55	1.06	0.77	1.07	1.02	0.8	0.76	0.54	0.51
0.025	0.58	1.16	0.83	1.17	1.12	0.85	0.81	0.56	0.54
0.029	0.6	1.26	0.88	1.27	1.22	0.9	0.86	0.6	0.56
0.034	0.64	1.38	0.94	1.4	1.34	0.97	0.92	0.62	0.6
0.039	0.67	1.51	1	1.52	1.47	1.03	0.99	0.65	0.63
0.044	0.7	1.63	1.07	1.65	1.6	1.1	1.05	0.68	0.66
0.05	0.74	1.78	1.14	1.79	1.74	1.18	1.13	0.72	0.7

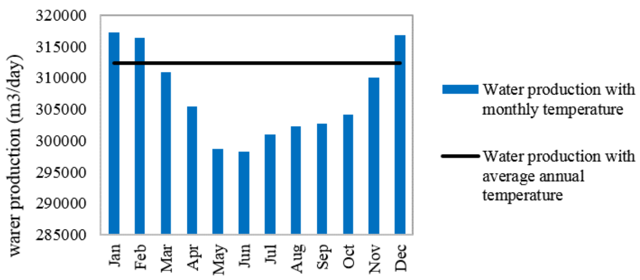

Figure 10: Water production variation based on the monthly average temperature at Chabahar site for superior scenario

4. Conclusion

A broad range of scenarios of power and fresh water production were analyzed. The best scenario was chosen after performing a review of the results of the technical-economic analysis of different scenarios of power and water cogeneration system for maximum water production. From the viewpoint of the private sector and profitability, the 2GT-CST-RO project (two gas turbines, a heat recovery boiler, condensing steam turbine and reverse osmosis unit at the Chabahar site) is the most attractive scenario, because of all the studied scenarios it has the highest NPV ratio (2.42), IRR (21.06%), and the shortest payback period – taking approximately 6 years to return the initial investment of the plan. Also, in terms of the price of water produced by different scenarios, the 2GT-CST-RO scenario has the lowest price (0.51 $/m^3). So, this scenario is deemed the best method for cogeneration.

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Nomenclature

BST Back-pressure steam turbine

Bt Benefits

CHP Combined heat and power

CRF Cost recovery factor

CST Condensing steam turbine

Ct Costs

G Investment

GT Gas turbine

i Discount rate

IRR Internal rate of return

MED Multi-effect distillation

MIGD Million imperial gallons per day

n Number of years

NPV Net present value

R Revenue

r Payback period

RO Reverse Osmosis

t Time