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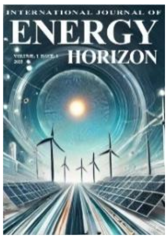

Research Article

Techno-Economic Performance Modeling of Integrated Nuclear-Reverse Osmosis Plants: A Case Study

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ABSTRACT

This study investigates the integration of nuclear energy into seawater desalination systems to achieve sustainable freshwater production. Nuclear reactors present significant potential as reliable, continuous, and low-carbon energy sources suitable for both thermal desalination processes, such as Multi-Effect Distillation (MED), Multi-Stage Flash (MSF), and membrane-based technologies like Reverse Osmosis (RO). The analysis employs the Desalination Economic Evaluation Program (DEEP), developed by the International Atomic Energy Agency (IAEA), as a techno-economic assessment tool to evaluate desalination systems powered by various energy sources. The comparative assessment between nuclear- and coal-based configurations highlights that the nuclear option offers lower production costs and higher energy efficiency under identical operating conditions. These findings demonstrate the potential of nuclear-powered desalination systems as a cost-effective and sustainable solution for future freshwater and energy generation. Nuclear desalination processes are found to be competitive with current fossil fuel-based desalination programs, with associated life cycle carbon emissions of nuclear-driven options being two to three orders of magnitude less than that of the fossil fuel-based route [1].

1. INTRODUCTION

1.1. The Energy Sector and Carbon Emissions

1.1.1. Hydrogen Evolution Reaction (HER) Mechanism

The combined impacts of global population growth, industrial expansion, and climate change have placed increasing pressure on freshwater resources, emerging as one of the most critical global challenges. According to the Worldwatch Institute, more than two-thirds of the world's population may experience water shortages by 2025 [2]. As traditional freshwater sources become insufficient to meet this rising demand, alternative solutions such as seawater desalination have gained importance as vital technologies for ensuring global water security. Among various desalination techniques, RO has become the most widely adopted owing to its modular scalability, high energy efficiency, and ability to produce high-quality freshwater from seawater or brackish sources. It is worth noting that previous studies estimate that the seawater pretreatment process accounts for approximately 25% of the total RO cost [3]. Nevertheless, desalination processes are inherently energy-intensive, and reliance on fossil fuels for energy input leads to significant greenhouse gas emissions, compromising their environmental sustainability [4]. Integrating nuclear energy with desalination processes—known as nuclear desalination—offers a sustainable and scalable alternative. Nuclear reactors can reliably provide the large-scale, continuous, and low-carbon energy required for both thermal desalination (MSF, MED) and membrane-based systems (RO)[5,6].This synergy not only reduces the environmental footprint of desalination but also enables cogeneration of electricity and potable water within the same facility, thereby enhancing overall energy utilization.[7] To systematically evaluate the techno-economic feasibility of such integrated systems, the International Atomic Energy Agency (IAEA) developed the Desalination Economic Evaluation Program (DEEP). This study aims to assess the technical and economic performance of nuclear-powered RO desalination systems using the DEEP model, providing a comprehensive analysis of their feasibility, sustainability, and contribution to long-term water and energy security.

2. BACKGROUND ON THE DEEP PROGRAM AND APPLICATIONS IN NUCLEAR DESALINATION

Nuclear-powered seawater desalination technologies are regarded as a promising and cost-competitive option for sustainable freshwater production. The Desalination Economic Evaluation Program (DEEP), developed by the International Atomic Energy Agency (IAEA), is a freely accessible analytical tool that enables the economic assessment of various desalination technologies

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integrated with different energy sources. Implemented as an Excel-based computational model, DEEP allows comparative analysis of multiple desalination configurations—such as MSF, MED, RO, and hybrid systems—driven by renewable, fossil, or nuclear energy. The program requires technical and economic input parameters, including the type of desalination technology, power source, feedwater salinity and temperature, plant capacity, discount rate, and fuel cost. It then calculates the Levelized Cost of Water (LCOW) and Levelized Cost of Electricity (LCOE) to identify the most feasible configuration under specific conditions [8,9]. Studies conducted in countries such as Japan, China, Pakistan, and India have demonstrated the feasibility of large-scale nuclear desalination [10]. Faibish and Konishi [11] reported that the cost of desalinated water could be as low as 0.040 USD/m³ under optimal conditions. Nisan and Dardour [12] analyzed several cogeneration systems utilizing waste heat from nuclear reactors through the DEEP program and found that all energy options resulted in lower power consumption and energy costs for the RO process compared to MED systems. Methnani [13] and Bouhelal et al. [14,15] used DEEP to show that nuclear-driven RO systems provide significant cost and energy advantages compared to fossil-fueled alternatives. Sun et al. [16] studied a 20,000 m³/d nuclear-powered desalination plant using the DEEP software package and found that RO exhibited stronger economic competitiveness than distillation-based processes (MED and MSF). The key cost factors identified were the interest rate, discount rate, and specific construction cost. Similarly, Al-Karaghouli and Kazmerski [17] analyzed a 2000 m³/d RO plant, concluding that it produced high-quality freshwater at a competitive cost of 0.986 USD/m³. In conclusion, the DEEP program serves as a robust tool for the techno-economic evaluation of desalination systems powered by various energy sources, highlighting the feasibility and cost-effectiveness of nuclear-powered freshwater production.

3. SYSTEM DESCRIPTION AND ANALYSIS

3.1. System Description

The proposed Nuclear-Driven Seawater Desalination System (Figure 1.) integrates a nuclear reactor as the primary heat and power source to operate a hybrid desalination facility combining Reverse Osmosis (RO) and Multi-Stage Flash (MSF) units. The system simultaneously supplies thermal and electrical energy, ensuring efficient and continuous desalination operation. High-temperature steam generated by the nuclear reactor is divided between the two processes: a portion is directed to the MSF unit for thermal distillation, while the remainder is converted to electricity through a steam turbine to power the RO unit and auxiliary systems (pumps, compressors, and control circuits). This dual-mode energy utilization enhances overall system efficiency and energy recovery. IAEA data indicate that countries such as India, Japan, Pakistan, and Kazakhstan have successfully operated nuclear desalination facilities for more than 250 reactor-years.

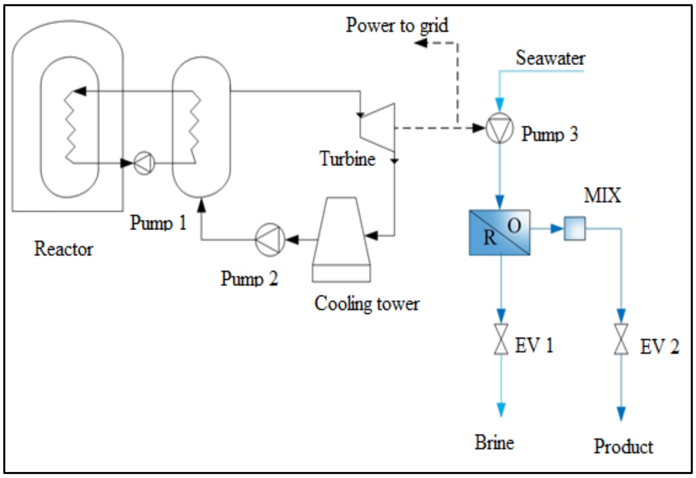

Figure 1. System schematics

For instance, India's hybrid MSF-RO nuclear desalination plant produces 4,500 m³/day of freshwater from the MSF unit and 1,800 m³/day from the RO unit. The proposed design follows a similar configuration, optimized for coastal regions with limited freshwater availability and proximity to nuclear infrastructure. The DEEP software is used to model and evaluate the performance, economic feasibility, and energy efficiency of the system.

3.2. System Analysis

The governing equations used for the reverse osmosis (RO) system model in the DEEP program are defined as specified in reference [7]. The total power in the system, expressed in MW, is calculated as follos:

$$Q_{ms} = Q_{sp} + Q_{bp} + Q_{hp} + Q_{er} + Q_{om} \tag{1}$$

Where Seawater Q_sp is the seawater pumping power MW, which can be calculated from the following equation [7]:

$$Q_{sp} = \frac{F_{sms}\, DP_{sm}}{E_{sm}\, 9866} \tag{2}$$

Q_{bp} represents the power of the booster pump (in MW) and is calculated using the equation given below:

$$Q_{bp} = \frac{F_{sms}\, DP_{bm}}{E_{bm}\, 9866} \tag{3}$$

Q_{er} represents the energy recovery (in MW) and is calculated using the formula given below:

$$Q_{er} = \{-F_{sms}\,(1 - R_r)\, E_{er}\left(DP_{hm} - DP_{spd} - DP_{cd}\right) \tfrac{KmSGC}{10000} - (1 - R_r)\, E_{er}\, Q_{hp} \tag{4}$$

Q_{om} represents the other power component (in MW) and is calculated using the following equation:

$$Q_{om} = \frac{W_{ac}\, Q_{som}}{24\ \times 1000} \tag{5}$$

Q_{hp} represents the power of the high-pressure pump (in MW) and is calculated using the equation given below:

$$Q_{hp} = \frac{F_{sms}\, DP_{hm}}{E_{hm}\, E_{hhm}\, 9866} \tag{6}$$

Here, DP_{hm} represents the pressure increase (in bar) provided by the high-pressure pump and is calculated using the equation given below:

$$DP_{hm} = P_{avg} + NDP + \frac{DP_{spd}}{2} + DP_{pp} + DP_{ps} \tag{7}$$

The design net driven pressure (NDP) is obtained using the following method:

$$NDP = \frac{D_{flux}}{N_{flux} kmSCF}\, NDP_n\, \frac{kmTCF}{kmFF} \tag{8}$$

Where $kmSCF$ is the salinity correction factor.

$$kmSCF = 1.5 - 0.000015\ \times 0.5\left(1 + \frac{1}{1 - Rr}\right) TDS \tag{9}$$

Rr is the Optimal Recovery Ratio

$$Rr = 1 - \frac{0.00115}{P_{max}}\, TDS \tag{10}$$

And $kmTCF$is the temperature correction factor

$$km_{TCF} = EXP\left(A\left(\frac{1}{Tim - 273} - \frac{1}{25 + 273}\right)\right) \tag{11}$$

DP_{hm} represents the pressure rise (in bar) of the pump at high temperature.

$$DP_{hm} = P_{avg} + DNP + \frac{DP_{spd}}{2} + DP_{pp} + DP_{ps} \tag{12}$$

P_{avg} represents the mean osmotic pressure (in bar):

$$P_{avg} = \frac{\pi(TDS, Tim) + \pi(dso.Tim)}{2}\, kmAiiCF \tag{13}$$

The osmotic pressure function $\pi(C,T)$π(C,T) (in bar) is defined as follows:

$$\pi(C,T) = 0.0000348\,(Tim + 273)\,\frac{C}{14.7} \tag{14}$$

dso expresses the salinity level of salt water (in ppm).

$$dso = \frac{TDS}{1 - Rr} \qquad (15$$

Table 1. Symbols used in the DEEP RO gpverning equation

Model Parameter Symbols			
Membrane Specifications	The highest pressure the membrane is designed to withstand.	P_{max}	bar
	Average permeate flow rate anticipated in the design.	D_{flux}	l/m^3h
	Rated or specified permeate flux under nominal conditions.	N_{flux}	l/m^3h
	Water permeability constant for the polyamide membrane.	A	-
	The standard net pressure differential for operation.	NDP_n	bar
	A correction factor for the collective effect of individual ions.	$kmAiiCF$	-
	A factor to account for performance decline due to membrane fouling.	$kmFF$	-
Pump Data	The overall pressure loss throughout the entire system.	DP_{spd}	bar
	Pressure losses that occur in the permeate stream after the membrane.	DP_{pp}	bar
	The pressure measured at the pump's intake point.	DP_{ps}	bar
	The outlet pressure of the reject or concentrate stream.	DP_{cd}	bar
	Pressure head generated by the primary seawater pump.	DP_{sm}	bar
	Additional pressure head supplied by the booster pump.	DP_{bm}	bar
	An adjustment factor for the specific gravity of the concentrate.	$kmSGC$	-

DEEP program considers the cost analysis to estimate the levelized power and water cost as well as the cost of the components of the power plant and the desalination unit.

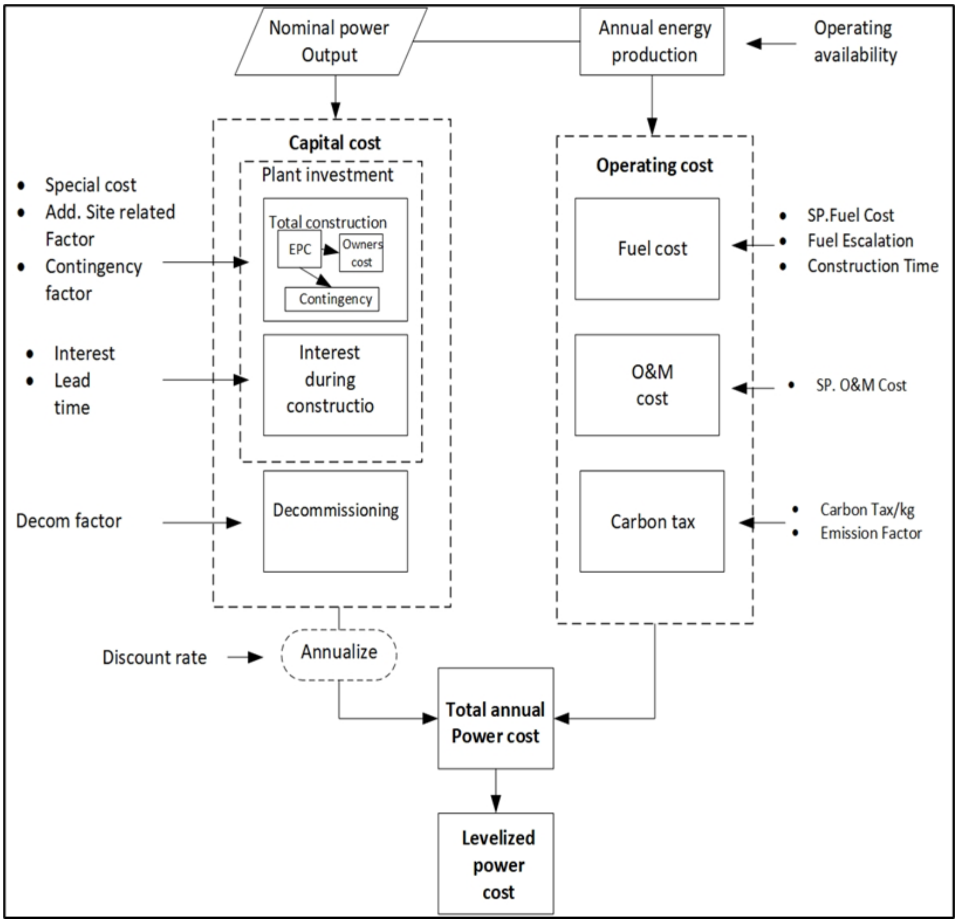

Figure 2. Cost breakdown of power plant economic model [7]

The economic analysis of reverse osmosis (RO) plants is primarily related to electrical energy consumption, as they do not require any heat input or auxiliary heat source. This simplifies the economic evaluation process compared to distillation-based desalination systems. However, because RO systems rely largely on electricity for energy consumption, their total energy requirements are significantly higher than those of distillation plants. The economic analysis of the costs of energy resources used in desalination plants encompasses energy consumption components, along with capital and operating expenses. In this context, the contribution and distribution of energy costs to the system's economics are summarized in the cost breakdown model presented in Figure 3.

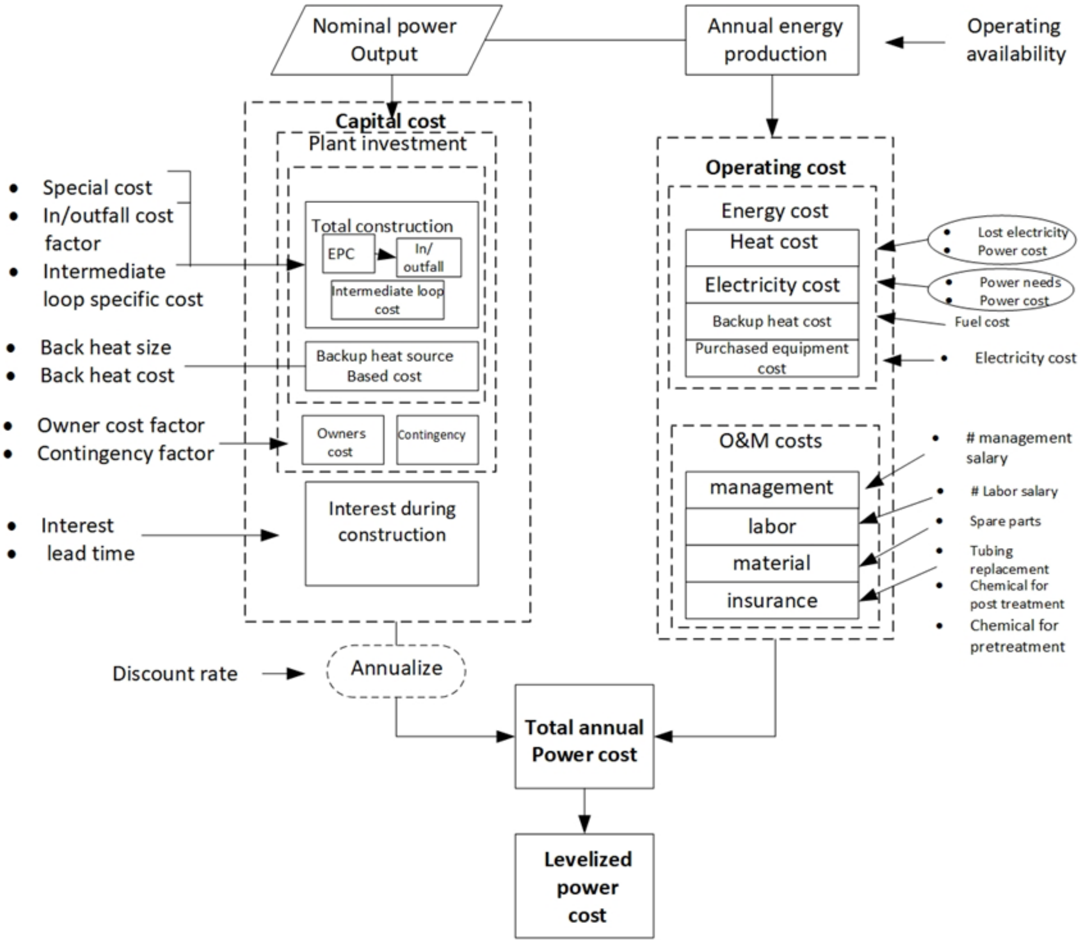

Figure 3. Cost breakdown of desalination plant economic model (Adopted from [7])

The energy cost of a water power plant is calculated by multiplying the total electrical energy used and lost by the unit cost of electricity generated by the plant. The water production cost is calculated based on the ratio between the annual total revenue and the annual water production. For reverse osmosis (RO) plants, the annual required revenue is defined as the sum of operating and maintenance expenses, annualized cost, and electricity consumption costs. Conversely, the water production cost is expressed as the ratio of this annual revenue to the annual amount of water produced. The cost of water production in reverse osmosis systems includes all economic components arising during the production process, excluding costs related to water storage, distribution, and transportation. The default values and specific parameters used in the economic modeling of water power plants in the DEEP (Desalination Economic Evaluation Program) software are presented in detail in the relevant source [7].

3.3. Sustainability and Safety Considerations

Nuclear-powered desalination systems offer the potential for a low-carbon, sustainable solution for regions with insufficient water resources, provided they comply with strict safety protocols and environmental regulations. Compliance with safety standards established by the International Atomic Energy Agency (IAEA) ensures the operational integrity of the reactor and the safe management of radioactive waste. Furthermore, the integration of Small Modular Reactors (SMRs) into desalination plants increases plant safety and significantly reduces potential operational risks through passive cooling systems and self-activating safety shutdown mechanisms.

3.4. The uncertainty and sensitivity range for DEEP model parameters

The estimated Levelized Cost of Water (LCOW) is highly affected by any variations of the cite-specific input data. Therefore, the uncertainty and sensitivity analyses crucial and critical for gaining the validated results [18]. The trend of the outputs such as water cost and energy consumption gained in the DEEP are non-linear function of input parameters such as pressure, salinity and temperature [19]. The typical sensitivity of DEEP model outputs to its primary economic and physical inputs can be summarized as follow: The typical range of salinity (35000 ppm to 45000 ppm) [20], an increase of the salinity increases the osmotic pressure as a result the more energy required and more membrane stages needed to meet water quality standers. The uncertainty in salinity occurs from poor water intake and seasonal variation which is have enormous effects on the osmosis pressure, the high-pressure pump of RO might have to operate higher outside of their efficient range. Furthermore; feed temperature range is estimated between (15 °C to 35 °C) the viscosity benefit from increasing temperature as it lowers which is good for the flux [21]. Nevertheless; the risk of membrane fouling and scaling rises. The increase of the operating pressure above 75 bar in RO leads to an increase of the Specific Energy Consumption [22].

4. RESULTS FOR NUCLEAR DRIVEN DESALINATION SYSTEM

4.1. Nuclear Driven Desalination System Using DEEP Sustainability and Safety Considerations

In this study, a nuclear energy-based cogeneration system that provides fresh water production and electricity generation together is proposed. The system in question carries out the processes of seawater desalination and electricity generation through a single energy source, nuclear energy. Electricity production is provided through the steam cycle, a portion of the electrical energy obtained is used for the reverse osmosis (RO) system, and excess energy is transferred to the electricity grid. Within the scope of design parameters, the system capacity is assumed to be 100,000 m³/day fresh water production capacity, taking into account the annual interest rate of 5%, where seawater with a salinity of 35,000 ppm is processed at a feed temperature of 25 °C. The water production amount, salinity level and cost performance of the proposed cogeneration system were analyzed using DEEP (Desalination Economic Evaluation Program) software version 5.1. Table 2 shows the basic parameters and default values entered into the DEEP program during the modeling process.

Table 2. The input values required in DEEP program [23]

Selected Desalination Method	Reverse osmosis
Energy Source	Nuclear and steam cycle
Daily Production Capacity (m^3/d)	100000
Seawater Salinity Level (ppm)	35000
Feed Water Temperature (℃)	25
Assumed Interest Rate (%)	5
Economic Discount Rate (%)	5
Annual Fuel Cost Increase (%)	3
Operational Pressure Limit (bar)	69

The performance of the proposed nuclear-powered reverse osmosis (RO) desalination system was analyzed using the Desalination Economic Evaluation Program (DEEP). In the analyses, the feed seawater salinity was determined to be 35,000 ppm and the recovery rate 42%. The simulation results are presented in Table 3. According to these results, the salinity level of the produced freshwater was found to be compliant with drinking water standards, while a significant increase occurred in the salinity of the concentrate stream (brine). Economic evaluations regarding freshwater production were carried out considering the technical assumptions and operating conditions of the system.

Table 3. Output results from DEEP program

seawater salinity (ppm)	Recovery ratio (%)	Fresh water salinity (ppm)	Brine salinity (ppm)	Feed flow rate (m^3/d)	Brine flow rate (m^3/d)	Product flow rate (m^3/d)	Fresh water cost ($\$/m^3$)	Power cost (\$/kWh)	Feed pressure (bar)	Specific power use (kWh/m^3)
35000	42	243	60000	240000	140000	100000	0.773	0.067	54.3	2.93

The findings show that the nuclear-powered RO system exhibits an economically viable performance. The feed seawater mass flow rate was calculated as the ratio of the product water mass flow rate to the feed water mass flow rate, based on the definition of the recovery rate. In addition, the effects of key parameters such as feed seawater temperature and salinity on both freshwater and electricity production costs were examined. The analysis results revealed that an increase in feed water temperature has a significant impact on the cost of freshwater production. In particular, a significant reduction in the total freshwater production cost was observed when the feedwater temperature was increased from 20 °C to 35 °C. This indicates that feedwater temperature is a critical parameter affecting the economic performance of nuclear energy-assisted RO desalination systems.The total cost components of the power plant are presented in Figure 4. As a result of the economic analysis, it was determined that approximately 69% of the total annual cost consists of capital expenses, 18% of fuel costs, and 13% of operation and maintenance (O&M) expenses.

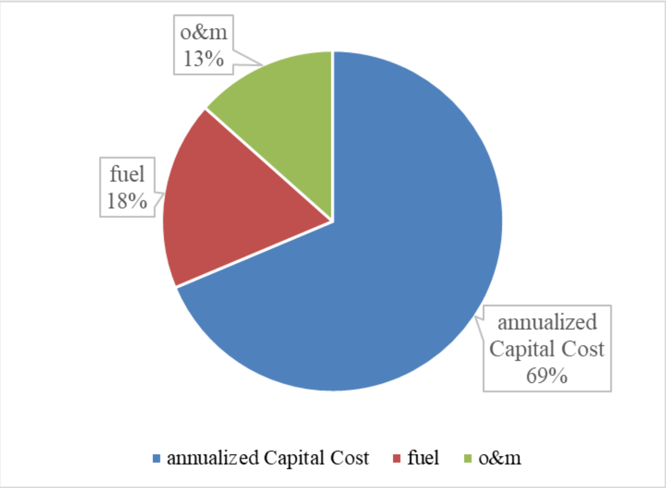

Figure 4. The breakdown of capital, operating, and maintenance costs of a nuclear power plant

The distribution of cost components for a desalination plant is presented in Figure.5. According to the analysis results, annual capital costs have the highest share, accounting for 45% of the total plant cost. This is followed by electricity costs at 29%. Material, electricity supply, and labor costs account for 18%, 4%, and 3% of the total cost, respectively.

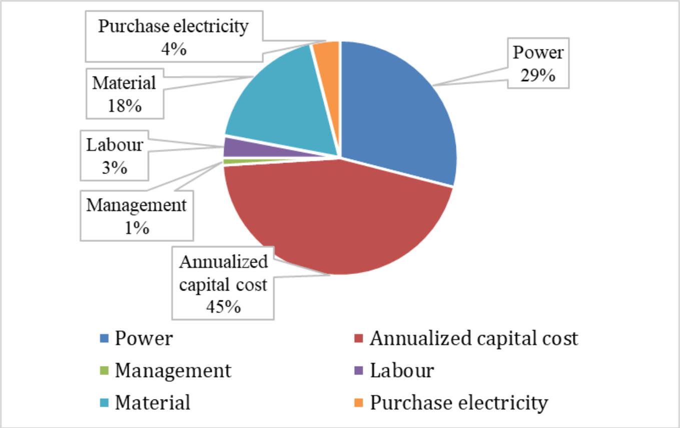

Figure 5. Cost breakdown of the desalination system

As mentioned before, one of the most important advantages of using DEEP software is that it provides the opportunity to evaluate the performance of the proposed system by analyzing the effects of various critical parameters on water production and fuel costs. In this context, a parametric study was carried out to investigate the effects of seawater feeding temperature, salinity rate and interest rate on water and electricity costs. Analysis results show that the increase in seawater feed temperature has a significant impact on product water cost. It was determined that when the feed temperature was increased from 20 °C to 35 °C, a decrease of approximately 3% in fresh water production costs was observed, while the electricity cost was not significantly affected by this change. The data presented in Table C.4 reveals that increasing the feed water temperature also increases the salinity of the product water. This is due to the increase in the amount of salt passing through the membrane and the permeate flow rate at higher temperatures. As a result, the required operating pressure decreases at higher feed temperatures, whereas higher pressures are required at lower temperatures, resulting in lower total dissolved salt content.

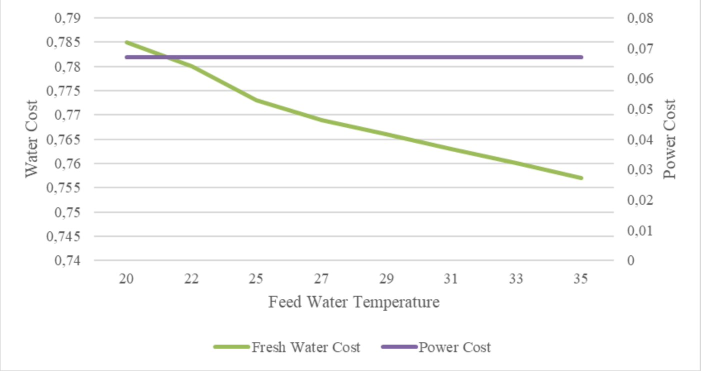

Figure 6. Effects of feed water temperature on water and power cost

The effects of interest rates on water production and electricity costs were analyzed and evaluated in detail. As seen in Figure 7, increasing the interest rate from 4% to 7% resulted in an increase in the freshwater production cost of approximately \$0.018/m³. Similarly, it has been observed that the increase in interest rates slightly increases the cost of electricity, creating a cost increase of 0.4 cents per kWh. When Table C.2 and Figure 7 are examined together, it is clear that changes in interest rates have a direct and measurable impact on both freshwater and electricity production costs.

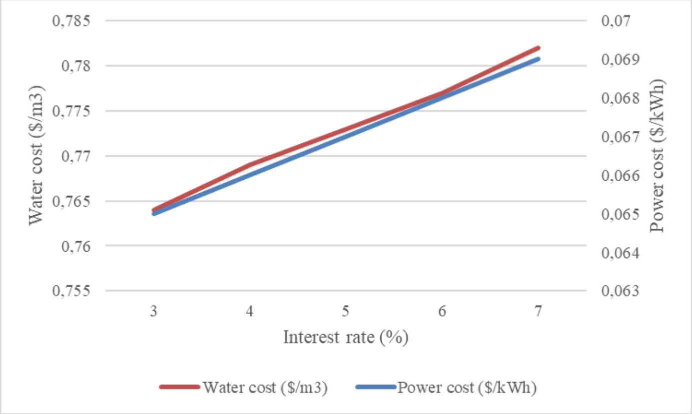

Figure 7. Effect of interest rate on water and power cost

The effects of seawater salinity were analyzed in order to evaluate the applicability of different parts of the designed cogeneration system. This approach is based on the fact that the salinity of seawater varies significantly on a regional scale. Whether the effects of salinity decrease on system performance have been examined or not, the findings are presented in Table C.3.

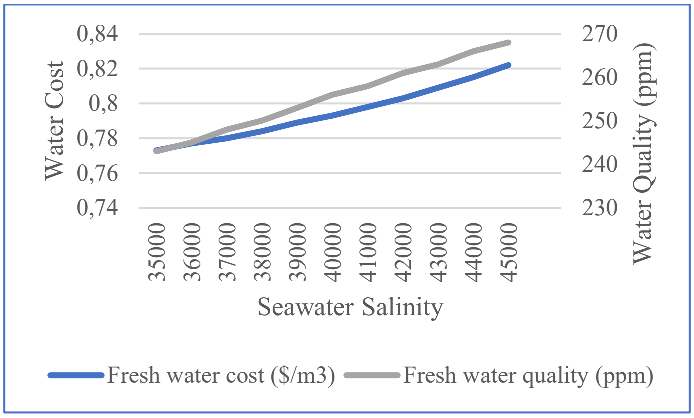

Figure 8. Effects of seawater salinity on fresh water cost and quality

The study results indicate that increasing seawater feed salinity from 35,000 ppm to 45,000 ppm results in increased freshwater costs, energy consumption, and feed pressure. Higher salinity levels necessitate the use of high-pressure feed pumps, resulting in increased energy consumption and decreased freshwater quality. The effects of seawater salinity on freshwater costs, freshwater quality, energy consumption, recovery rate, feed flow rate, and brine flow rate are summarized in Fig. 8.–11. and Table C.3, respectively. These findings clearly demonstrate the direct impact of changes in salinity on reverse osmosis system performance.

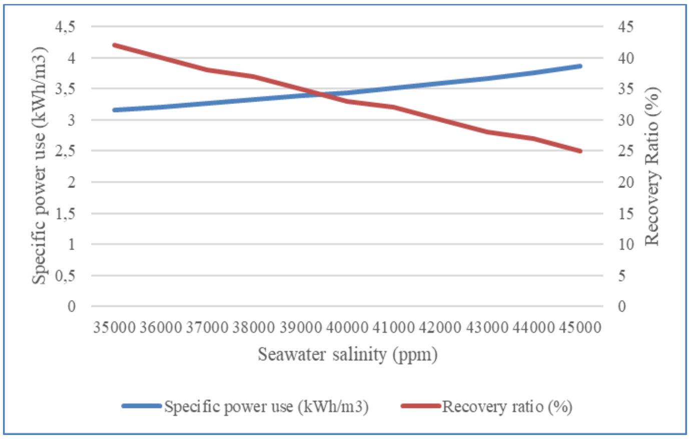

Figure 9. Effects of seawater salinity on specific power use and recovery ratio

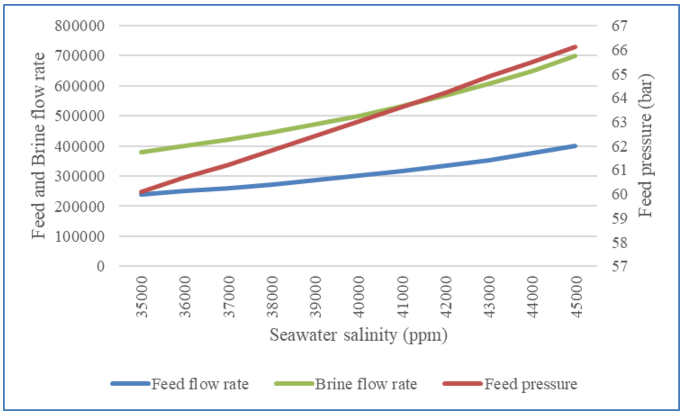

Figure 10. Effects of seawater salinity on feed flow rate, brine flow rate and feed pressure

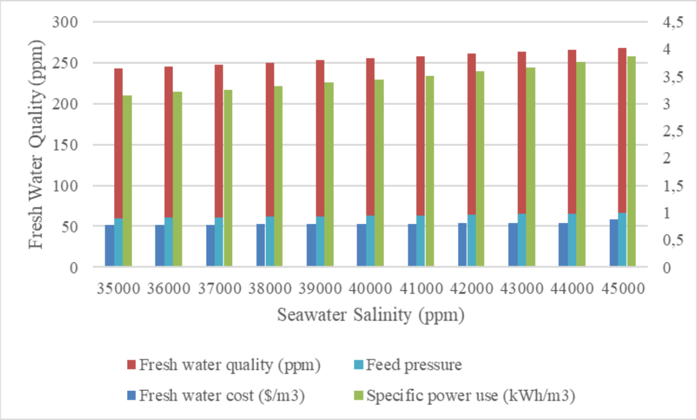

Figure 11. Effects of seawater salinity

The effects of different feed pressures in the reverse osmosis (RO) system on water and energy costs under feed water temperatures were analyzed. The analysis results show that pressure consumption does not significantly impact energy costs. In contrast, water costs decrease until the optimum RO feed pressure, determined as the membrane design pressure, is reached; after this point, they increase. Figure 12. provides a detailed diagram showing the effects of changes in reverse osmosis pressure on both water costs and energy costs.

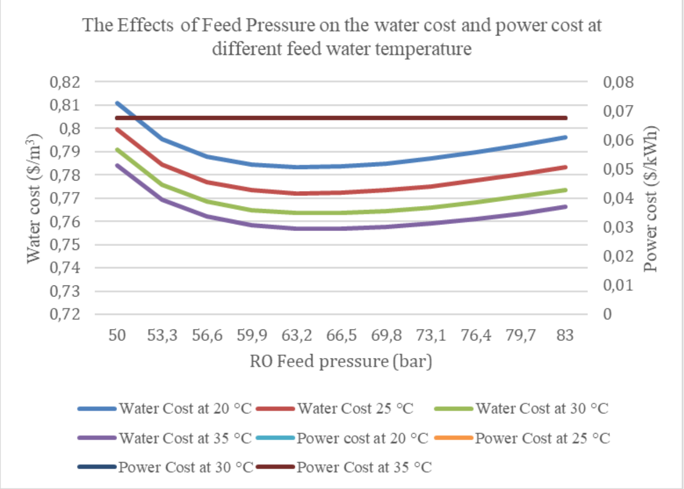

Figure 12. The effect of reverse osmois (RO) feed pressure on water and energy costs in a nuclear-powered cogeneration system

The effects of discount rates , interest rates and specific fuel costs on system performance are studied and examined in detail. The analysis results, shown in Figure 13., reveal that interest calculations increase both freshwater and electricity costs. However, the thermal utilization percentage was unaffected by this change.

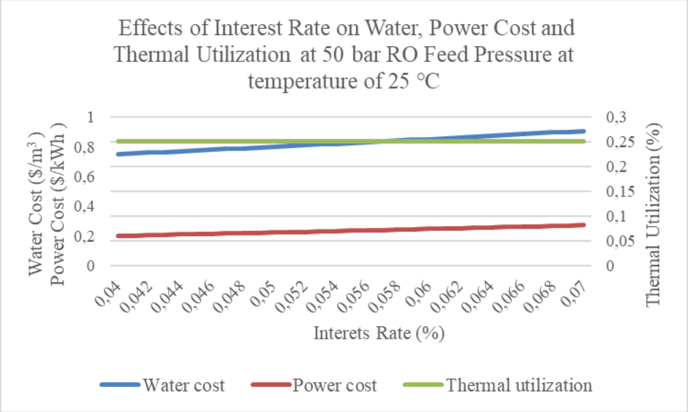

Figure 13. Effects of Interest Rate on Water, Power Cost and Thermal Utilization at 50 bar RO Feed Pressure at a temperature of 25°C

The impact of changes in the discount rate on water and electricity costs was examined (Figure 14). The analysis results show that increasing the discount rate from 4% to 7% results in a significant increase in both fresh water costs and electricity costs.

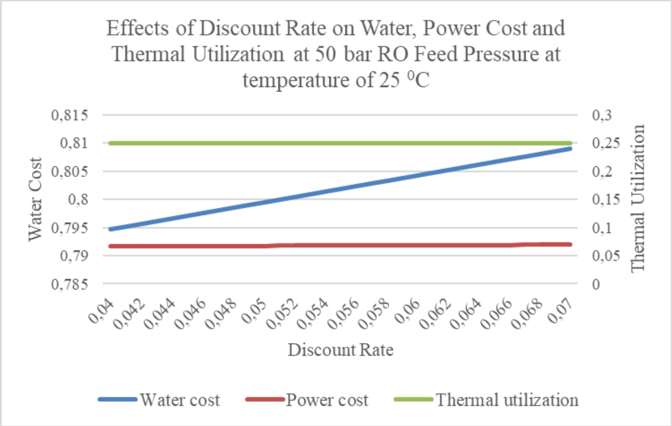

Figure 14. Effects of Discount Rate on Water, Power Cost and Thermal Utilization at 50 bar RO Feed Pressure at a temperature of 25°C

The analysis results show that changes in specific fuel cost have no significant impact on electricity costs and thermal usage. However, an increase in specific fuel cost directly leads to an increase in freshwater production costs.

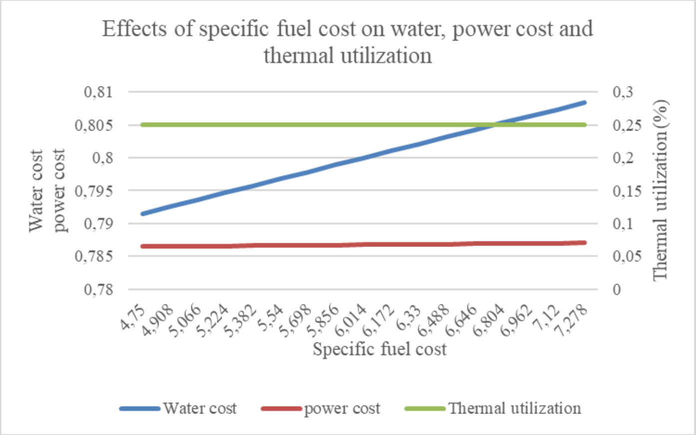

Figure 15. Effects of specific fuel cost on water, power cost and thermal utilization

5. CONCLUSION

A techno-economic assessment conducted using the DEEP software demonstrates that a nuclear-powered desalination system represents a competitive and sustainable alternative for large-scale freshwater production. Despite the limited thermal output data available in the software, the economic analysis shows that integrating nuclear energy with the reverse osmosis (RO) process results in significantly lower production costs compared to fossil fuel–based configurations, particularly coal-fired systems. Under the analyzed conditions, the nuclear-powered system achieves a freshwater production cost of US\$ 0.773/m³ and an electricity generation cost of US\$ 0.067/kWh, consistent with the findings reported by Gnaifaid [24]. These results confirm that nuclear energy can effectively meet both water and power demands with improved cost-effectiveness and reduced environmental impact. Owing to its reliability, scalability, and independence from regional resource constraints, nuclear energy offers a promising long-term solution for sustainable desalination, especially in regions facing increasing freshwater scarcity.

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APPENDIX A

Table C. 1. Effects of feed water temperature

Feed water temperature (℃)	Specific Power use for desalination (kWh/m^3)	Fresh water cost ($/m^3)	Power cost ($/kWh)	Fresh water salinity (ppm)	Brine salinity (ppm)	Feed water pressure (bar)
20	3.32	0.785	0.067	206	60000	64.4
22	3.25	0.780	0.067	221	60000	62.5
25	3.15	0.773	0.067	243	60000	60.1
27	3.10	0.769	0.067	257	60000	58.7
29	3.05	0.766	0.067	272	60000	57.4
31	3.01	0.763	0.067	286	60000	56.3
33	2.97	0.760	0.067	301	60000	55.2
35	2.93	0.757	0.067	316	60000	54.3

Table C. 2. Effects of interest rate on the fresh water and power cost.

Interest rate (%)	Power cost ($/kWh)	Water cost ($/m^3)
3	0.065	0.764
4	0.066	0.769
5	0.067	0.773
6	0.068	0.777
7	0.069	0.782

Table C. 3. Effects of seawater salinity

Seawater salinity (ppm)	Fresh water cost ($/m$^{3)}$	Fresh water quality (ppm)	Specific power use (kWh/m$^{3)}$	Feed flow rate	Feed pressure	Brine flow rate	Brine salinity (ppm)	Recovery ratio (%)
35000	0.773	243	3.15	240000	60.1	140000	60000	42
36000	0.777	245	3.21	250000	60.7	150000	60000	40
37000	0.780	248	3.26	260870	61.2	160870	60000	38
38000	0.784	250	3.32	272727	61.8	172727	60000	37

39000	0.789	253	3.38	285714	62.4	185714	60000	35
40000	0.793	256	3.44	300000	63.0	200000	60000	33
41000	0.798	258	3.51	315789	63.6	215789	60000	32
42000	0.803	261	3.59	333333	64.2	233333	60000	30
43000	0.809	263	3.67	352942	64.9	252941	60000	28
44000	0.815	266	3.76	375000	65.5	275000	60000	27
45000	0.822	268	3.86	400000	66.1	300000	60000	25

Table C. 4. Effects of Interest Rate on Water, Power cost and Thermal Utilization (Coal Case)

Interest Rate (%)	Water Cost ($/m3)			Power Cost ($/kWh			Thermal Utilization (%)		
	RO Feed Pressure (50 bar)	RO Feed Pressure (60 bar)	RO Feed Pressure (70 bar)	RO Feed Pressure (50 bar)	RO Feed Pressure (60 bar)	RO Feed Pressure (70 bar0	RO Feed Pressure (50 bar)	RO Feed Pressure (60 bar)	RO Feed Pressure (70 bar)
0.04	0.8126586	0.782203	0.7822808	0.0798957	0.0798957	0.0798957	0.2545715	0.2554375	0.2554353
0.041	0.8163855	0.7858285	0.7859066	0.0802145	0.0802145	0.0802145	0.2545715	0.2554375	0.2554353
0.042	0.8201355	0.789476	0.7895544	0.0805369	0.0805369	0.0805369	0.2545715	0.2554375	0.2554353
0.043	0.8239085	0.7931454	0.793224	0.0808627	0.0808627	0.0808627	0.2545715	0.2554375	0.2554353
0.044	0.8277043	0.7968364	0.7969153	0.0811921	0.0811921	0.0811921	0.2545715	0.2554375	0.2554353
0.045	0.8315227	0.800549	0.8006282	0.0815249	0.0815249	0.0815249	0.2545715	0.2554375	0.2554353
0.046	0.8353637	0.8042831	0.8043625	0.0818612	0.0818612	0.0818612	0.2545715	0.2554375	0.2554353
0.047	0.8392272	0.8080386	0.8081182	0.0822008	0.0822008	0.0822008	0.2545715	0.2554375	0.2554353
0.048	0.8431129	0.8118152	0.8118952	0.0825439	0.0825439	0.0825439	0.2545715	0.2554375	0.2554353
0.049	0.8470207	0.8156129	0.8156931	0.0828903	0.0828903	0.0828903	0.2545715	0.2554375	0.2554353
0.05	0.8509506	0.8194315	0.8195121	0.0832401	0.0832401	0.0832401	0.2545715	0.2554375	0.2554353
0.051	0.8549023	0.823271	0.8233518	0.0835931	0.0835931	0.0835931	0.2545715	0.2554375	0.2554353
0.052	0.8588758	0.8271311	0.8272123	0.0839495	0.0839495	0.0839495	0.2545715	0.2554375	0.2554353
0.053	0.8628708	0.8310118	0.8310932	0.0843091	0.0843091	0.0843091	0.2545715	0.2554375	0.2554353
0.054	0.8668873	0.8349129	0.8349946	0.0846719	0.0846719	0.0846719	0.2545715	0.2554375	0.2554353
0.055	0.870925	0.8388343	0.8389163	0.0850379	0.0850379	0.0850379	0.2545715	0.2554375	0.2554353
0.056	0.8749839	0.8427757	0.842858	0.0854071	0.0854071	0.0854071	0.2545715	0.2554375	0.2554353
0.057	0.8790638	0.8467372	0.8468198	0.0857795	0.0857795	0.0857795	0.2545715	0.2554375	0.2554353
0.058	0.8831645	0.8507185	0.8508014	0.0861549	0.0861549	0.0861549	0.2545715	0.2554375	0.2554353
0.059	0.8872858	0.8547195	0.8548028	0.0865334	0.0865334	0.0865334	0.2545715	0.2554375	0.2554353
0.06	0.8914278	0.8587401	0.8588236	0.086915	0.086915	0.086915	0.2545715	0.2554375	0.2554353
0.061	0.89559	0.8627801	0.862864	0.0872996	0.0872996	0.0872996	0.2545715	0.2554375	0.2554353
0.062	0.8997726	0.8668394	0.8669235	0.0876872	0.0876872	0.0876872	0.2545715	0.2554375	0.2554353
0.063	0.9039751	0.8709178	0.8710022	0.0880778	0.0880778	0.0880778	0.2545715	0.2554375	0.2554353
0.064	0.9081976	0.8750151	0.8750999	0.0884712	0.0884712	0.0884712	0.2545715	0.2554375	0.2554353
0.065	0.9124399	0.8791314	0.8792165	0.0888676	0.0888676	0.0888676	0.2545715	0.2554375	0.2554353
0.066	0.9167017	0.8832662	0.8833517	0.0892669	0.0892669	0.0892669	0.2545715	0.2554375	0.2554353
0.067	0.920983	0.8874197	0.8875054	0.089669	0.089669	0.089669	0.2545715	0.2554375	0.2554353
0.068	0.9252836	0.8915915	0.8916776	0.0900739	0.0900739	0.0900739	0.2545715	0.2554375	0.2554353
0.069	0.9296033	0.8957815	0.895868	0.0904816	0.0904816	0.0904816	0.2545715	0.2554375	0.2554353
0.07	0.9339419	0.8999897	0.9000764	0.090892	0.090892	0.090892	0.2545715	0.2554375	0.2554353

Table C. 5. Effects of Discount Rate on Water, Power cost and Thermal Utilization

Discount Rate (%)	Water Cost ($/m3)			Power Cost ($/kWh)			Thermal Utilization (%)		
	RO Feed Pressure (50 bar)	RO Feed Pressure (60 bar)	RO Feed Pressure (70 bar)	RO Feed Pressure (50 bar)	RO Feed Pressure (60 bar)	RO Feed Pressure (70 bar)	RO Feed Pressure (50 bar)	RO Feed Pressure (60 bar)	RO Feed Pressure (70 bar)
0.04	0.8472245	0.8159279	0.8160079	0.0825404	0.0825404	0.0825404	0.2545715	0.2554375	0.2554353
0.041	0.8475965	0.8162778	0.8163578	0.08261	0.08261	0.08261	0.2545715	0.2554375	0.2554353
0.042	0.8479687	0.8166278	0.8167079	0.0826798	0.0826798	0.0826798	0.2545715	0.2554375	0.2554353
0.043	0.848341	0.8169779	0.8170581	0.0827496	0.0827496	0.0827496	0.2545715	0.2554375	0.2554353
0.044	0.8487134	0.8173281	0.8174083	0.0828194	0.0828194	0.0828194	0.2545715	0.2554375	0.2554353
0.045	0.849086	0.8176784	0.8177587	0.0828894	0.0828894	0.0828894	0.2545715	0.2554375	0.2554353
0.046	0.8494587	0.8180289	0.8181092	0.0829594	0.0829594	0.0829594	0.2545715	0.2554375	0.2554353
0.047	0.8498315	0.8183794	0.8184597	0.0830295	0.0830295	0.0830295	0.2545715	0.2554375	0.2554353
0.048	0.8502044	0.81873	0.8188104	0.0830996	0.0830996	0.0830996	0.2545715	0.2554375	0.2554353
0.049	0.8505774	0.8190807	0.8191612	0.0831698	0.0831698	0.0831698	0.2545715	0.2554375	0.2554353
0.05	0.8509506	0.8194315	0.8195121	0.0832401	0.0832401	0.0832401	0.2545715	0.2554375	0.2554353
0.051	0.8513239	0.8197825	0.8198631	0.0833104	0.0833104	0.0833104	0.2545715	0.2554375	0.2554353
0.052	0.8516973	0.8201335	0.8202141	0.0833808	0.0833808	0.0833808	0.2545715	0.2554375	0.2554353
0.053	0.8520709	0.8204846	0.8205653	0.0834513	0.0834513	0.0834513	0.2545715	0.2554375	0.2554353
0.054	0.8524445	0.8208359	0.8209166	0.0835218	0.0835218	0.0835218	0.2545715	0.2554375	0.2554353
0.055	0.8528183	0.8211872	0.821268	0.0835924	0.0835924	0.0835924	0.2545715	0.2554375	0.2554353
0.056	0.8531922	0.8215387	0.8216195	0.0836631	0.0836631	0.0836631	0.2545715	0.2554375	0.2554353
0.057	0.8535663	0.8218902	0.8219711	0.0837338	0.0837338	0.0837338	0.2545715	0.2554375	0.2554353
0.058	0.8539404	0.8222418	0.8223228	0.0838047	0.0838047	0.0838047	0.2545715	0.2554375	0.2554353
0.059	0.8543147	0.8225936	0.8226747	0.0838755	0.0838755	0.0838755	0.2545715	0.2554375	0.2554353
0.06	0.8546891	0.8229455	0.8230266	0.0839465	0.0839465	0.0839465	0.2545715	0.2554375	0.2554353
0.061	0.8550637	0.8232974	0.8233786	0.0840175	0.0840175	0.0840175	0.2545715	0.2554375	0.2554353
0.062	0.8554384	0.8236495	0.8237307	0.0840886	0.0840886	0.0840886	0.2545715	0.2554375	0.2554353
0.063	0.8558131	0.8240017	0.8240829	0.0841597	0.0841597	0.0841597	0.2545715	0.2554375	0.2554353
0.064	0.8561881	0.8243539	0.8244353	0.0842309	0.0842309	0.0842309	0.2545715	0.2554375	0.2554353
0.065	0.8565631	0.8247063	0.8247877	0.0843022	0.0843022	0.0843022	0.2545715	0.2554375	0.2554353
0.066	0.8569383	0.8250588	0.8251402	0.0843735	0.0843735	0.0843735	0.2545715	0.2554375	0.2554353
0.067	0.8573136	0.8254114	0.8254929	0.0844449	0.0844449	0.0844449	0.2545715	0.2554375	0.2554353
0.068	0.857689	0.8257641	0.8258456	0.0845164	0.0845164	0.0845164	0.2545715	0.2554375	0.2554353
0.069	0.8580645	0.8261169	0.8261985	0.084588	0.084588	0.084588	0.2545715	0.2554375	0.2554353
0.07	0.8584402	0.8264698	0.8265514	0.0846596	0.0846596	0.0846596	0.2545715	0.2554375	0.2554353

Table C. 6. Effects of Specific Fuel Cost on Water, Power cost and Thermal Utilization (Coal Case)

Specific Fuel Cost ($/MWh)	Water Cost ($/m3)			Power Cost ($/kWh)			Thermal Utilization (%)		
	RO Feed Pressure (50 bar)	RO Feed Pressure (60 bar)	RO Feed Pressure (70 bar)	RO Feed Pressure (50 bar)	RO Feed Pressure (60 bar)	RO Feed Pressure (70 bar)	RO Feed Pressure (50 bar)	RO Feed Pressure (60 bar)	RO Feed Pressure (70 bar)
16.535485	0.8059186	0.7791662	0.7792346	0.0896402	0.0682496	0.0682496	0.2504978	0.2554375	0.2554353
17.735485	0.8119878	0.784593	0.784663	0.0921558	0.0702699	0.0702699	0.2504978	0.2554375	0.2554353
18.935485	0.818057	0.7900198	0.7900914	0.0946713	0.0722903	0.0722903	0.2504978	0.2554375	0.2554353
20.135485	0.8241262	0.7954465	0.7955198	0.0971869	0.0743106	0.0743106	0.2504978	0.2554375	0.2554353
21.335485	0.8301954	0.8008733	0.8009482	0.0997024	0.076331	0.076331	0.2504978	0.2554375	0.2554353
22.535485	0.8362646	0.8063	0.8063766	0.102218	0.0783513	0.0783513	0.2504978	0.2554375	0.2554353
23.735485	0.8423338	0.8117268	0.811805	0.1047335	0.0803717	0.0803717	0.2504978	0.2554375	0.2554353
24.935485	0.8484029	0.8171536	0.8172334	0.1072491	0.082392	0.082392	0.2504978	0.2554375	0.2554353
26.135485	0.8544721	0.8225803	0.8226618	0.1097647	0.0844123	0.0844123	0.2504978	0.2554375	0.2554353
27.335485	0.8605413	0.8280071	0.8280902	0.1122802	0.0864327	0.0864327	0.2504978	0.2554375	0.2554353
28.535485	0.8666105	0.8334338	0.8335186	0.1147958	0.088453	0.088453	0.2504978	0.2554375	0.2554353
29.735485	0.8726797	0.8388606	0.838947	0.1173113	0.0904734	0.0904734	0.2504978	0.2554375	0.2554353
30.935485	0.8787489	0.8442873	0.8443754	0.1198269	0.0924937	0.0924937	0.2504978	0.2554375	0.2554353
32.135485	0.8848181	0.8497141	0.8498038	0.1223424	0.094514	0.094514	0.2504978	0.2554375	0.2554353
33.335485	0.8908873	0.8551409	0.8552322	0.124858	0.0965344	0.0965344	0.2504978	0.2554375	0.2554353
34.535485	0.8969565	0.8605676	0.8606606	0.1273735	0.0985547	0.0985547	0.2504978	0.2554375	0.2554353

Table C. 7. Effects of RO feed Pressure on Power and Water Cost and Thermal Utilization at 25 °C

RO Feed Pressure (bar)	Water Cost ($/m3)	Power Cost ($/kWh)	Thermal Utilization (%)
45	0.9393896	0.0832401	0.2521417
47.3	0.8818857	0.0832401	0.2537216
49.6	0.8542662	0.0832401	0.2544804
51.9	0.8388504	0.0832401	0.254904
54.2	0.8296193	0.0832401	0.2551576
56.5	0.8239626	0.0832401	0.255313
58.8	0.8205655	0.0832401	0.2554063
61.1	0.8186942	0.0832401	0.2554577
63.4	0.8179077	0.0832401	0.2554794
65.7	0.8179251	0.0832401	0.2554789
68	0.8185597	0.0832401	0.2554614
70.3	0.8196828	0.0832401	0.2554306