Fuzzy TOPSIS and Fuzzy AHP-based MCDA for selecting the Optimal Location for a Solar PV-powered RO Desalination Unit in Visakhapatnam, India

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ABSTRACT

This feasibility study explores the viability of solar PV-powered Reverse Osmosis (RO) desalination in five locations in Visakhapatnam, India. The assessment integrates technical, economic, environmental, social, and political considerations using Multi-Criteria Decision Analysis (MCDA) with Fuzzy Technique for Order of Preference by Similarity to Ideal Solution (Fuzzy TOPSIS) and Fuzzy Analytic Hierarchy Process (Fuzzy AHP) methods to handle uncertainties in decision-making. The study evaluates the technical feasibility of the integration, conducts economic analysis, examines environmental impacts, investigates social benefits, and challenges, and analyzes the political landscape. The former emphasizes the significance of understanding challenges and potential solutions associated with RO desalination, aiming for sustainable development aligned with local and global goals. Yarada and Bheemili were the most suitable locations selected based on Fuzzy TOPSIS and Fuzzy AHP, respectively. The study also highlighted the need for public awareness and government support for desalination projects.

Keywords-solar PV-powered reverse osmosis desalination; MCDA; Fuzzy TOPSIS; Fuzzy AHP

I. INTRODUCTION

Visakhapatnam experiences water scarcity and pollution due to urbanization, industrial growth, and declining surface water supplies, leading to groundwater depletion and saline water intrusion [1]. Coastal waters face hygiene issues, such as pollution and eutrophication [2]. Seawater intrusion increases chloride ions and Total Dissolved Solids (TDS) above the acceptable levels [3]. Industrial wastewater discharges contaminate groundwater and increase the TDS in the northern part of the city [4]. Water issues threaten water supply, access, and quality whereas they impact public health and well-being [5]. Considering the water crisis, the existence of a desalination plant near Visakhapatnam is essential [6]. A feasibility study conducted at Chinni Rushikonda found acceptable salinity and TDS levels for a solar-powered Reverse Osmosis (RO) system [7]. Authors in [8] investigated the energy requirements and proposed a photovoltaic (PV) system for RO systems. Economic and environmental assessments evaluate the costs, benefits, and CO_2 emissions [9-10]. Authors in [10] focused on energy storage in desalination to ensure stable operations, especially when using renewable resources. Solar-powered desalination plants are of great importance in terms of sustainability and are a cost-effective alternative for freshwater production [11-16]. Solar-powered desalination has the potential to reduce water cost and alleviate Visakhapatnam's freshwater problems, thereby increasing the sustainability and resilience of the city's water supply [17-20].

Fuzzy Techniques for Prioritization by Similarity to Ideal Solutions (Fuzzy TOPSIS) and Fuzzy Analytical Hierarchy Process (Fuzzy AHP) excel at handling imprecise and ambiguous data and provide a framework robust and adaptable for evaluating complex systems with different and sometimes conflicting criteria [21–25].

The primary goal of this study is to determine the practicality of solar PV-powered RO desalination as a sustainable option across Visakhapatnam. This study attempts to identify the problems and potential solutions associated with RO desalination by analyzing its technical performance regarding water consumption, recovery rates, and compliance with water quality standards [26-27]. Economic efficiency is evaluated by calculating the total cost of the water produced, thereby evaluating the cost-effectiveness of the RO desalination process [11, 28-32]. This study considers the possibility of meeting Visakhapatnam's water needs while promoting local and global sustainability. Multi-Criteria Decision Analysis (MCDA) facilitates open and systematic decision-making, ultimately identifying the most favorable and sustainable solutions for desalination in the given area of Visakhapatnam.

II. METHODOLOGY

This feasibility study employs a comprehensive approach to assess the viability of solar PV-powered RO desalination in Visakhapatnam. The methodology integrates Technical, Economic, Environmental, Social, and Political (TEESP) considerations using a MCDA framework (Figure 1).

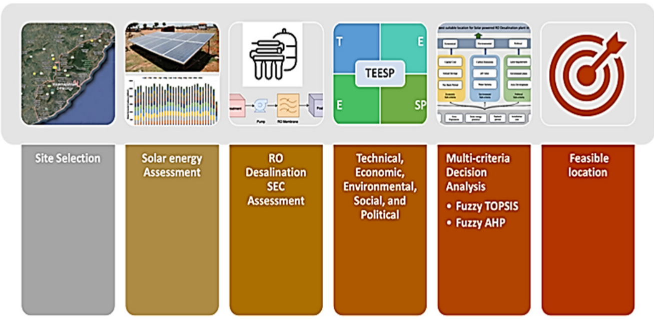

Fig. 1. The followed methodology.

A. *Selection of Sites and Data Collection*

Five potential locations in Visakhapatnam were considered, based on factors, such as their proximity to the coast, land availability, and solar irradiance. Data were collected taking into account all TEESP aspects, including water quality, cost, environmental impact, population demographics, and government policies. The locations were examined using technical data from sources like GVMC, NSRDB, expert consultations, and on-site evaluations, considering factors like topography, water salinity, population, density, coast, sun irradiation, and infrastructure, as detailed in Table I.

TABLE I. VISAKHAPATNAM LOCALITIES: KEY CHARACTERISTICS

Locality	Bheemili	Rushikonda	Peda Waltair	Yarada	Pudimadakha
Distance from the city (km)	29	16	4	26	52
Coordinates	17.884°N, 83.439°E	17.8025°N, 83.3853°E	17.7329°N, 83.3322°E	17.63°N, 83.24°E	17.6860°N, 83.0087°E
Population	64239	17682	35283	3500	10804
Water consumption (m³/day)	5137.5	1100	2200	1000	850
Coastal proximity (m)	423.7	105.57	133.91	243	135.44

B. *Multi-Criteria Decision Analysis (MCDA)*

The current feasibility study examines the TEESP aspects of RO desalination in five locations employing MCDA for informed decision-making, comparing incommensurable factors and prioritizing relevant aspects over one over another.

1) *Technical Feasibility*

The study evaluates the technical feasibility of integrating an RO desalination system with a solar PV power source. Factors like energy generation, storage requirements, and compatibility between the systems are considered. The Specific Energy Consumption (*SEC*) of a RO desalination plant can be determined by local water demand, water quality, first year of operation, and energy source. A mathematical model can be created to optimize SEC, bearing in mind retentate pressure drop and membrane capacity demand ratio [21-34]. The choice of the energy source, e.g. thermal or solar, can influence the water footprint of an RO desalination system.

The net pressure difference across the membrane is:

$$\Delta P = \left(\frac{M_p}{3600*TCF*FF*A_e*N_e*N_v*k_w}\right) + \Delta\pi \quad (1)$$

The permeate flow rate (M_p) is a function of the element area (A_e), the number of membrane elements (N_e), the number of pressure vessels (N_v), the Temperature Correction Factor (TCF), the membrane Fouling Factor (FF), water permeability (k_w), and net osmotic pressure across the membrane ($\Delta\pi$).

The necessary power input in kilowatts to operate the RO driving pump is given by:

$$P_{hpp} = \left(\frac{1000*M_f*\Delta P}{3600*\rho_f*\eta_{hpp}}\right) \quad (2)$$

The expression represents the feed flow rate (M_f) in kilograms per second, the density of the feed flow rate (ρ_f), and the efficiency of the driving pump (η_{hpp}). *SEC* [kWh/m^3] is given by:

$$SEC = \frac{P_{hpp}}{M_p} \quad (3)$$

A thorough analysis of solar energy resources is crucial for the construction of a solar-powered RO desalination plant. This stage reveals crucial data influencing the system's efficiency, cost-effectiveness, and long-term sustainability. Evaluating solar resources helps determine the optimal position for solar PV panels, considering factors like shade, orientation, and tilt angle. Sun irradiance statistics from the NSRDB show strong potential for solar-powered RO desalination in all five considered locations near Visakhapatnam. Table II provides data on solar power generation and infrastructure needs in these locations. It calculates daily RO unit consumption and assumes 540 Wp solar panels for total area and panel count. Inverter and battery ratings are 100 kW and 600 Ah, respectively.

TABLE II. AVERAGE DAILY SUM OF GLOBAL HORIZONTAL IRRADIANCE

Locality	Average daily sum of global horizontal irradiance [kWh/m^2/day]
Bheemilipatnam	4.63
Rushikonda	4.6725
Peda Waltair	4.6025
Yarada	4.61166
Pudimadakha	4.665

2) Economic Feasibility

The economic evaluation of the PV-RO desalination unit involves thorough market research, cost analysis, and consultations with industry experts to consider all financial aspects, including installation costs, procurement, maintenance, and potential impacts. The evaluation compares the system's financial aspects to alternatives, considering both capital and operational costs. Benefits include water value and environmental gains. Table III shows the estimated values of the parameters relevant to the energy needs of the RO unit.

TABLE III. PARAMETER ESTIMATION FOR THE DESIGN OF A SOLAR POWER PLANT THAT MEETS THE ENERGY NEEDS OF THE RO UNIT

Parameters	Bheemili	Rushikonda	Peda Waltair	Yarada	Pudimadakha
Estimated energy consumed by the RO unit (MWh/day)	20.36	4.46	8.83	0.859	3.41
PV panels required	7542	1656	3272	319	1267
PV power (MW/day)	4.07	0.89	1.76	0.17	0.68
Required area for solar panels (Acres)	6.03	1.32	2.61	0.25	1.01
Required inverter rating (MW)	3.39	0.74	1.47	0.14	0.56
Total inverters required	34	8	15	2	6
Storage battery size (MWh)	56.56	12.41	24.53	23.86	94.98
Total batteries required	1964	431	852	83	330
Annual energy generated (MWh/Yea)	7432	1631	3223	3135	1248

Cost-benefit analysis weighs total costs (capital +and operational) against benefits. Notably, capital cost heavily influences feasibility, especially for location-specific RO plants. Table IV displays the solar power plant's capital cost based on panel needs and market prices. Equipment and site costs comprise the direct capital cost, which estimates total investment. Table V estimates annual savings by assuming the monthly municipal water bill as the desalination savings.

3) Environmental Feasibility

To comprehensively understand the environmental implications, the study utilizes life cycle assessment, environmental impact analysis, and leverages the existing literature. This multifaceted approach assesses carbon footprint, water usage, and other potential environmental impacts associated with the solar PV-powered desalination process. Water quality adheres to RO plant standards (pH and TDS monitored, Yarada having the highest pH). PV-RO environmental impact was evaluated using LCA/EIA tools. Analysis identifies potential impacts and guides design/operation for minimal footprint. Key inputs: feed TDS 42816 mg/L, product TDS 500 mg/L, module cost $800/m², land cost $100/m², discount rate 8%, lifespan 25 years, PV degradation 0.8, CO_2 emissions: PV panels 50 g/kWh, grid 500 g/kWh, life cycle emissions: panels 2500 gCO_2/Wp, grid 750 gCO_2/kWh.

TABLE IV. ESTIMATED CAPITAL COST OF THE DESALINATION PLANT

Parameters	Bheemili	Rushikonda	Peda Waltair	Yarada	Pudimadakha
Capital cost of the high pressure pump	587400	587400	587400	587400	587400
Capital cost of RO equipment	1001550	849806	896060	804181	838175
RO site capital cost	100155	84980.6	89606	80418.1	83817.5
Direct capital cost of RO	1101705	934786	985666	884599	921992.5
Indirect capital cost of RO	297460.35	252392	266129	238841	248937
Total capital cost of RO	1399165.35	1187178	1251795	1123440	1170930
Total solar panels cost	3737475.056	820638	1621455	158082	627868.05
Solar inverter cost	3365.64	3365.64	3365.64	3365.64	3365.64
Total solar inverter cost	114431.76	26925	50484	6731.28	20193.84
Battery cost	300	300	300	300	300
Total battery cost	589200	129300	255600	24900	99000

TABLE V. ANNUAL SAVINGS AND PAYBACK PERIOD

Parameters	Bheemili	Rushikonda	Peda Waltair	Yarada	Pudimadakha
No. of houses	20550	4400	8800	852	3400
Monthly water cost based on municipal water bills ($/month)	1.47	1.47	1.47	1.47	1.47
Annual savings ($/year)	362502	77616	155232	15029.28	59976
Pay back period, (years)	17	28	21	88	32

4) Social and Political Feasibility

To evaluate the social and political feasibility of implementing solar PV-powered RO desalination in Visakhapatnam, a survey was conducted. This survey aimed to capture public perceptions, concerns, and expectations regarding the project in the five potential locations considered in the feasibility study. The survey targeted residents, community leaders, local businesses, and government officials in each location using a mixed-method approach. Structured questionnaires were administered to gather demographics, awareness of water challenges, project acceptance, perceived benefits, concerns, and preferred water pricing models. The survey questions were:

1. How familiar are you with desalination technology?
2. Do you believe that desalination could be a viable solution to water scarcity in Visakhapatnam?
3. How important do you consider the use of renewable energy sources, such as solar PV, to power desalination plants?
4. Are you concerned about the potential environmental impacts of desalination, such as brine discharge?
5. Do you believe that the benefits of desalination outweigh the potential risks and challenges?
6. How confident are you that the government would support the development of desalination projects in Visakhapatnam?
7. Do you think that desalination projects would be affordable for the local community?
8. Are you willing to pay more for your water if it came from a desalination plant?
9. Do you feel that the local community should have a say in the decision-making process for desalination projects?
10. What are your biggest concerns about desalination projects in Visakhapatnam?
11. What factors do you think influence political decisions regarding desalination projects?

Figures 2-5 show the survey results for the first four questions across all considered areas.

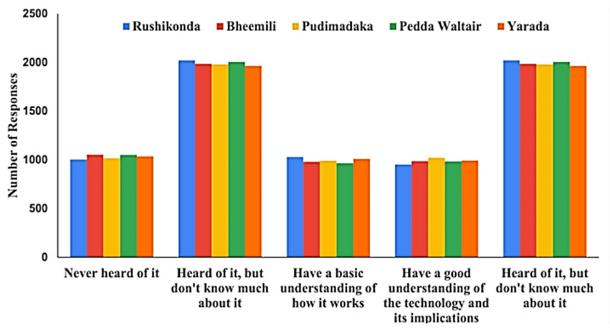

Fig. 2. Responses for Question 1.

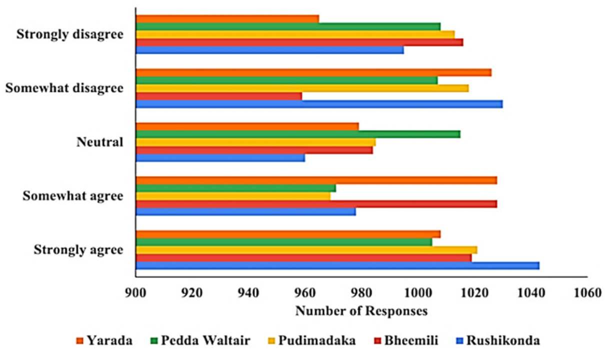

Fig. 3. Responses for Question 2.

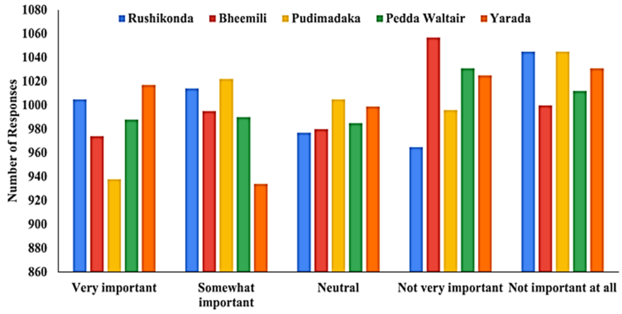

Fig. 4. Responses for Question 3.

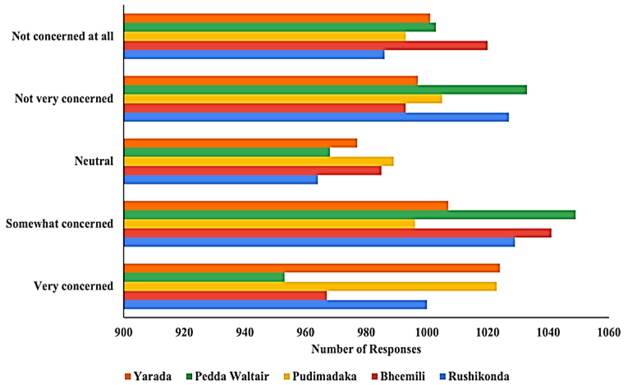

Fig. 5. Responses for Question 4.

III. FUZZY TOPSIS AND FUZZY AHP

Fuzzy TOPSIS and fuzzy AHP methods are deployed to solve MCDM problems. Fuzzy TOPSIS combines fuzzy information and Quality Function Deployment (QFD) to rank and evaluate alternatives based on their closeness coefficient values. It allows for the integration of subjective and ambiguous data expressed as fuzzy-defined integers or linguistic variables [21]. On the other hand, fuzzy AHP is a widely utilized approach that employs pairwise comparisons to determine the relative importance of criteria and alternatives. It provides a way to obtain weights for decision-making [22]. By combining these two methods, decision makers can effectively assess and prioritize alternatives based on multiple criteria, considering both qualitative and quantitative factors. This approach has been applied in various domains, such as solid waste management [23] and supplier evaluation and selection [24].

A. Criteria Identification in Fuzzy TOPSIS

MCDA is conducted based on the decision matrix or pairwise matrix. The decision matrix is generated based on a survey from the water supply experts. Table VI portrays the pair-wise comparison matrix, which is suggested by the three distinct decision-makers positioned. Table VII depicts the combined decision matrix, which is used to aggregate and combine the information related to each criterion and their respective weights. The Weighted Normalized Fuzzy Decision Matrix is implemented to incorporate weighted criteria, handling fuzzy information, ensuring fair and unbiased comparison among criteria, and enhancing the interpretability of the decision model, as observed in Table VIII. After taking the results into account, the Yarada area is deemed as the most excellent location for a solar-powered RO desalination plant, followed by Bheemili.

TABLE VI. PAIRWISE COMPARISON MATRIX

	Attribute	Bheemili	Rushikonda	Peda Waltair	Yarada	Pudimadakha
Decision Maker 1	Technical	MG	G	A	E	VG
	Economical	E	A	MG	P	MP
	Environmental	A	MG	G	E	VG
	Social	E	A	VG	VP	MP
	Political	VP	MG	MP	E	G
Decision Maker 2	Technical	E	A	VG	MG	G
	Economical	P	MG	A	E	G
	Environmental	A	VG	MG	E	G
	Social	E	A	VG	VP	MP
	Political	VG	G	E	P	MP
Decision Maker 3	Technical	MP	G	A	E	VG
	Economical	E	MG	VG	MP	A
	Environmental	A	E	MG	VP	E
	Social	MP	VP	VP	G	E
	Political	VP	G	P	MP	A

E: Excellent, VG: Very good, MG: Medium good, G: Good, A: Average, MP: Medium Poor, P: Poor

TABLE VII. COMBINED DECISION MATRIX

		Bheemili	Rushikonda	Peda Waltair	Yarada	Pudimadakha
Benefit Criteria	Technical	2	3	3	4	5
		5.333	5.3333	5	7	6.66666
		9	7	8	9	8
Cost-Criteria	Economical	1	3	3	1	2
		6	4.6666	5.3333	4.3333	4.333333
		9	6	8	9	7
	Environmental	3	4	4	1	5
		4	6.6666	5.3333	5.6666	7
		5	9	7	9	9
Benefit Criteria	Social	2	1	1	1	2
		6.333	3	5	2.6666	4.66666
		9	5	8	7	9
	Political	1	4	1	1	2
		3	5.66666	4.3333	4.3333	4.33333
		8	7	9	9	7

TABLE VIII. WEIGHTED NORMALIZED FUZZY DECISION MATRIX

	Bheemili	Rushikonda	Peda Waltair	Yarada	Pudimadakha
Technical	1.3333	2	2	2.666	3.33
	4.14814	4.14814	3.8888	5.444	5.185
	8	6.22	7.1111	8	7.111
Economical	0.7777	1.166	0.875	0.77777	1
	1.333	1.714	1.5	1.8461	1.8461
	9	3	3	9	4.5
Environmental	1	0.5555	0.7142	0.555	0.5555
	1.5	0.9	1.125	1.0582	0.8571
	2.3333	1.75	1.75	7	1.4
Social	0.888	0.44444	0.444444	0.444	0.8888
	3.5185	1.6666	2.7777	1.48148	2.5925
	6	3.3333	5.3333	4.6666	6
Political	0.33333	1.3333	0.3333	0.33333	0.6666
	1.3333	2.51851	1.92592	1.9259	1.92592
	4.4444	3.8888	5	5	3.8888

1) *Closeness Coefficient and Ranking*

Distance from fuzzy Positive ideal solution($di*$) and fuzzy negative solution($di-$) are calculated from Tables VI-VIII. The closeness coefficient (CCi) is found by:

$$CCi = \frac{di-}{di*+di-} \quad (4)$$

The final ranks along with their respective CCi values are provided in Table IX.

TABLE IX. CLOSENESS COEFFICIENT AND RANKING

	*di**	*di-*	*di*+di-*	*CCi*	Rank
Bheemili	5.392932262	7.479264	12.8722	0.58104	2
Rushikonda	10.545277	1.933078	12.47836	0.154915	5
Pedda Waltair	9.10773317	3.126423	12.23416	0.255549	4
Yarada	3.070940007	9.774925	12.84586	0.760939	1
Pudimadaka	7.756154035	4.472874	12.22903	0.365759	3

B. *Criteria Identification in Fuzzy AHP*

The use of Fuzzy AHP involves several steps to systematically assess the relative importance of criteria and sub-criteria in a decision-making context. The main steps in using Fuzzy AHP are:

- Define the decision hierarchy
- Assign fuzzy linguistic variables
- Expert input and pairwise comparisons
- Build fuzzy pairwise comparison matrices
- Aggregation of judgments
- Fuzzy weight calculation
- Consistency check
- Fuzzy Consistency Ratio (FCR)
- Finalize fuzzy weights
- Sensitivity analysis
- Integration with the decision-making process

This study begins with constructing a decision hierarchy that breaks down the problem into a hierarchical structure of criteria and sub-criteria.

1. Technical (Total energy consumed by the RO, Specific energy consumption by RO, Solar irradiance, Number of solar panels)
2. Economical (Capital cost, O & M cost, Payback period)
3. Environmental (Water TDS, Water salinity, Water requirement, Carbon emissions)
4. Social (Population, Job creation)
5. Political (Land need, Development)

Table X exhibits the pair-wise comparison matrix, often used in AHPs or decision-making scenarios. Each cell in the matrix represents a comparison between two locations

(Bheemili, Rushikonda, Pedda Waltair, Yarada, Pudimadka) based on a certain technical criterion. The values in the cells denote the strength of preference or dominance of one location over the other in terms of the specified criterion. The diagonal elements (from the top left to the bottom right) represent self-comparisons. For the off-diagonal elements, each cell contains a numerical value that represents the preference or strength of one location over the other. Higher values typically indicate a stronger preference or dominance. The upper triangle and lower triangle of the matrix are mirror images of each other, as the comparison between Location A and Location B is the same as the comparison between Location B and Location A. The values in the matrix seem to be normalized, possibly indicating relative preferences or weights. Tables XI and XII belong to the AHP and provide the Fuzzy Geometric Mean Values for the technical criteria associated with different locations (Bheemili, Rushikonda, Pedda Waltair, Yarada, Pudimadaka) and their de-fuzzified values.

TABLE X. PAIR-WISE COMPARISON MATRIX (TECHINICAL)

	Bheemili	Rushikonda	Pedda Waltair	Yarada	Pudimadka
Bheemili	1	3	1	7	5
	1	4	2	8	6
	1	5	3	9	7
Rushikonda	0.2	1	0.2	3	1
	0.25	1	0.25	4	2
	0.333	1	0.333	5	3
Pedda Waltair	0.333	3	1	1	2
	0.5	4	1	2	3
	1	5	1	3	4
Yarada	0.111	0.2	0.333	1	0.25
	0.125	0.25	0.5	1	0.333
	0.1423	0.33	1	1	0.5
Pudimadkha	0.1423	0.33	0.25	2	1
	0.1667	0.5	0.333	3	1
	0.2	1	0.5	4	1

TABLE XI. FUZZY GEOMETRIC MEAN VALUE (TECHINICAL)

Bheemili	**0.254046747**	**0.304182171**	**0.39424132**
Rushikonda	0.902880451	1.148698355	1.528142136
Pedda Waltair	0.440930103	0.608364342	0.870550563
Yarada	2.111785765	2.861938162	3.519482029
Pudimadaka	1.201124434	1.64375183	2.111785765
Total	**4.910767501**	**6.56693486**	**8.424201813**
Inverse Weights	**0.203634157**	**0.152278045**	**0.118705608**

TABLE XII. DE-FUZZIFIED VALUES (TECHINICAL)

	Fuzzy weight			COA	Normalized weight
Bheemili	0.03015	0.04632	0.0802	0.05225	0.04752561
Rushikonda	0.107176	0.17492	0.31118	0.19776	0.179869661
Pedda Waltair	0.052340	0.09264	0.17727	0.10741	0.097700743
Yarada	0.250680	0.4358	0.7166	0.4677	0.425412866
Pudimadka	0.142580	0.25030	0.43003	0.2743	0.24949112
	Total			1.0994	1

In Table XIII, the pair-wise comparison matrix of thee five aspects can be seen. The values in Table XIV and Table XV represent the calculated fuzzy geometric mean values for each location across the specified criteria and their de-fuzzified values. Table XVI demonstrates the Fuzzy AHP rankings for the locations on the basis of the specified criteria. For example, Bheemili has the highest overall score and is ranked 1st, indicating it is the most preferable location considering the Technical, Economical, Environmental, Social, and Political criteria. The rankings provide a comprehensive evaluation of the locations with respect to the weighted criteria.

TABLE XIII. PAIR-WISE COMPARISON MATRIX

	Technical	Economical	Environmental	Social	Political
Technical	1	0.125	0.143	0.111	7
	1	0.143	0.1667	0.125	8
	1	0.1667	0.2	0.143	9
Economical	6	1	2	0.333	2
	7	1	3	0.5	3
	8	1	4	1	4
Environmental	5	0.25	1	0.2	5
	6	0.333	1	0.25	6
	7	0.5	1	0.333	7
Social	7	1	3	1	1
	8	2	4	1	2
	9	3	5	1	3
Political	0.111	0.25	0.143	0.333	1
	0.125	0.333	0.1667	0.5	1
	0.143	0.5	0.2	1	1

TABLE XIV. FUZZY GEOMETRIC MEAN VALUE

Technical	**1.877566626**	**2.111785765**	**2.352158045**
Economical	0.378929142	0.501577318	0.659753955
Environmental	0.657038826	0.802741562	0.9563525
Social	0.30096015	0.378929142	0.543946443
Political	2.338942837	3.103691148	3.764474495
Total	**5.553437582**	**6.898724935**	**8.276685438**
Inverse weights	**0.180068649**	**0.144954323**	**0.120821313**

TABLE XV. DE-FUZZIFIED VALUES

	Fuzzy weight			COA	Normalized weight
Technical	0.2268	0.30611	0.42354992	0.31883	0.30256
Economical	0.0457	0.0727	0.118801003	0.07909	0.075059
Environmental	0.0793	0.1163	0.172209102	0.12265	0.11639
Social	0.0363	0.0549	0.097947701	0.06307	0.05985
Political	0.2825	0.4498	0.677863835	0.47011	0.44612
	Total			1.053	1

TABLE XVI. FUZZY AHP RANKING

	Bheemili	Rushikonda	Pedda Waltair	Yarada	Pudimadkha
Technical	0.014379	0.0544222	0.0295608	0.1287150	0.07548
Economical	0.003567	0.0135009	0.0073333	0.0319313	0.01872
Environmental	0.056848	0.0338910	0.0159810	0.0038914	0.00577
Social	0.002844	0.0107669	0.0058483	0.0254651	0.01493
Political	0.249406	0.0536708	0.1130517	0.0161469	0.01384
SUM	0.32704	0.1662521	0.1717753	0.2061499	0.1287
Rank	1	4	3	2	5

IV. CONCLUSIONS

Visakhapatnam, India has a growing need for desalination plants as the city is facing water challenges and a high demand for water due to population growth, industrialization, and urbanization. Solar PV powered RO desalination could be a possible sustainable solution for the growing water needs of the city. This paper explores the feasibility of solar - powered RO desalination in Visakhapatnam. Initially, data regarding water salinity, population, coastal proximity, and localized water consumption from different locations in the city were collected. The data were analyzed and five possible locations, which were considered as feasible, were identified. These locations are Bheemili, Rushikonda, Pedda Waltair, Yarada, and Pudimadka. The technical feasibility of an RO desalination plant was assessed for every location. The specific energy consumption of each plant varied from 3.96 kWh/m^3 to 4.02 kWh/m^3. Because of the minor water salinity in Yarada, the specific energy consumption is minimum at that location. Economic analysis was also conducted to assess the overall cost of the system. Due to its population, the maximum returns were found in Bheemili, which reflects in lesser payback period (17 years). Environmental impact was assessed by calculating the carbon emissions, which can be minimized by using the solar PV system. A survey was conducted in all locations. The survey reveals that 20% of people need to be made aware of desalination technology, 40% are familiar with it but not a lot, 20% have a basic understanding, and 20% have a good understanding of desalination.

Multi-criteria decision analysis was utilized to find the best feasible location. Fuzzy TOPSIS and Fuzzy AHP methods were selected in this paper. The result identified three locations: Bheemili, Rushikonda, and Yarada. Bheemili has the highest total weighted score, making it the most preferable location overall. Rushikonda has the second-highest weighted score in TOPSIS but ranks 4th in AHP due to its lower scores in some criteria. Yarada consistently performs well in both methods, ranking 1st in Fuzzy TOPSIS and 2nd in Fuzzy AHP. The choice between Yarada and Bheemili as the ideal location is determined by the precise decision factors and their respective relevance. The research offers a comprehensive knowledge of technical, economic, environmental, social, and political issues, enabling a holistic decision-making process that aligns with sustainable development goals while meeting Visakhapatnam's water demands.

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