ELSEVIER

Desalination 114 (1997) 1–12

DESALINATION

Multi-criteria analysis of non-conventional energy technologies for water desalination in Jordan

Bilal A. Akash[a*], Odeh R. Al-Jayyousi[b], Mousa S. Mohsen[a]

[a]*Department of Mechanical and Industrial Engineering,* [b]*Department of Civil Engineering, Applied Science University, Amman 11931, Jordan*
Tel. +962 (6) 837181; Fax +962 (6) 832899

Received 27 May 1996; accepted 30 July 1997

Abstract

The gap between water supply and demand is widening in Jordan. Sound measures to overcome this gap are essential for sustainable water development. In this paper non-conventional energy technologies for water desalination are discussed. These include hydropower, solar, wind, and nuclear technologies. Using multi-criteria analysis, options were evaluated for best water uses considering water productivity and environmental sustainability criteria. It was concluded that hydropower and solar technologies are most effective for water desalination in Jordan. On the other hand, wind and nuclear technologies have low likelihood to be viable in the short term.

Keywords: Multi-criteria analysis; Non-conventional energy; Desalination; Jordan

1. Introduction

Jordan is characterized by an arid to semi-arid climate. Rainy seasons are short and annual rainfall intensities range from 600 mm in the northwest to less than 50 mm in the eastern and southern deserts, which form about 91% of the country's surface area [1]. Jordan's 1995 population was approximately 4 million, and increasing at a yearly rate of 3.6% [2]. Accordingly, the population of Jordan is estimated to reach 4.9 and 6.6 million in the years 2000 and 2010, respectively. The yearly per capita usage of fresh water is 200 m^3 compared with 7500 m^3 as the world's yearly average [3]. In 1993, Jordan consumed 983 million m^3 [4]. The contribution of surface water, ground water, and treated-waste water amounted to 400, 533, and 50 million m^3, respectively. Water consumption from all resources was 738, 214, and 33 million m^3 for agricultural, industrial, and municipal use, respectively.

*Corresponding author.

PII S0011-9164(97)00148-3

Water demand is rapidly increasing due to increased development and the high rate of population increase. At the same time, water resource development constraints are increasing due to high investment cost and quality degradation. According to Murakami [5], by the beginning of the 21st century, Jordan will have depleted virtually all of its renewable sources of fresh water, if current patterns of consumption are not radically altered as quickly as possible. Generally, to reduce the gap between supply and demand, there are two basic solutions: increasing the supply and decreasing the demand. There are few options to increase the non-conventional water resources which are looked at as supplements to—but not substitutes for—conventional water supply. These options include irrigation with saline water, desalination of brackish or seawater, reuse of treated municipal waste water, rain-water harvesting, cloud seeding, and importing water across boundaries.

Desalination has been widely used in oil-producing countries. However, desalination of sea or brackish water could prove economically to be feasible in some areas in Jordan. The unit cost of water production by desalination in different countries varies considerably. In Jordan, although water and energy resources are scarce, the cost of water production can be minimized by efficient utilization of the sources available and by using non-conventional energy resources. In this work, the application of non-conventional desalination technologies in Jordan is evaluated. These technologies include hydropower, solar, wind-power, and nuclear desalination.

Using a decision-support system through a multi-criteria analysis, the analytic hierarchy process (AHP), an attempt is made to assist decision-makers to evaluate the use of the above non-conventional energy technologies by matching the best technology with the most suitable user. Table 1 shows a synthesis of literature comparing various technologies which include technology type, capacity, unit cost, and location.

The following is a description of various potential non-conventional technologies to be used for water desalination in Jordan. It intends to address options, constraints, and feasibility.

2. Hydropower reverse osmosis desalination in Jordan

2.1. Disi-Aqaba groundwater hydro-scheme

Qa Disi wellfield (see Fig. 1) is located at an elevation of 840 m above sea level and at a distance of about 80 km from the port of Aqaba. By assuming a flow discharge of 0.663 m^3/s with 800 m effective differential head of water, it is estimated that 5.2 MW of hydro-potential energy can be used. The utilization of such energy can be accomplished by installing a series of mini-hydro stations situated at different locations, along the flow of water, with a differential head of 200 m of water. The proposed scheme is shown in Fig. 1 and given in more details elsewhere [6]. The unit water cost for 14.6 million m^3 is estimated to be US $0.41/$m^3$.

2.2. Aqaba hybrid pumped-storage scheme

The theoretical study for producing an annual amount of 100 million m^3 of fresh water using hydropowered seawater desalination was described [7,8]. About 17.5 million m^3 of fossil groundwater currently being pumped from Disi sandstone aquifer to Aqaba will be saved, with the rest being pumped to Amman.

During off-peak hours, as shown in Fig. 2, seawater can be pumped to an 8.2 million m^3 reservoir. This reservoir will be located at 600–650 m above sea level, in the Aqaba mountain range. Water will be flown back to the sea through a penstock yielding an effective water pressure of 60 kg/cm^2 at the end of the pipe. In addition to 100 million m^3 of fresh water, 600 MW of peak electric power can be produced annually. The unit water cost is estimated to be about US $0.69/$m^3$.

Table 1
Summary of different non-conventional energy-powered desalination technologies

Technology	Capacity	Cost, US$/$m^3$	Location	Ref.	Notes
Hydropower (Disi-Aqaba)	14.6×10^6 m^3y	0.41	Aqaba, Jordan	[6]	Proposed scheme
Hydropower (Aqaba hybrid pumped-storage)	100×10^6 m^3/y	0.69	Aqaba, Jordan	[7]	Proposed scheme to be working in conjunction with nuclear or thermal plant
Hydropower (Red-Dead Seas canal)	630×10^o m^3/y		Near Dear Sea, Jordan	This work	Project is being investigated
Concrete solar still	0.39 m^3/m^2.y	72	Papua, New Guinea	[11]	Distilled water is produced
GI sheet solar still	0.33 m^3/m^2.y	—	Papua, New Guinea	[11]	Distilled water is produced
FRP solar still	0.37 m^3/m^2.y	144	Papua, New Guinea	[11]	Distilled water is produced
Atlantis solar pond	1000–10,000 m^3/d	2.85–1.84	Proposed	[16]	80,000 m^2 for 1000 m^3/d; 800,000 m^2 for 10,000 m^3/d
Solar-assisted single-stage RO	100–1000 m^3/d	3.5 –2.0	Ranking, TX, US	[10]	Collect. area 20.4 m^2
Solar-assisted single-stage SPRO	1.5 m^3/d	5.5	Concepcion, Mexico	[10]	Photovoltaic 2.5 kW (peak)
Solar-assisted MSF-RO	20–25 m^3/d	10	Sulaibiya, Kuwait	[10]	Collect. area 1000 m^2
Stand-alone wind energy conversion RO system	—	5.5 –3.5 @6–8 m/s	US	[18]	
Autonomous wind-driven RO	—	3–5 @ 6–8 m/s	US	[18]	
Nuclear dual-purpose LMFBR and RO	300,000 m^3/d	4.1 kW/m^3	Japan	[21]	
Nuclear dual-purpose LTMTMED	400,000 m^3/d	0.44–0.49/m^3	US	[21]	
Nuclear dual-purpose MFTGR and RO	100,000 m^3/d	2.5/m^3 [a]	Arabian Gulf	[21]	
Nuclear dual-purpose MSF and HTME	250,000–286,000 m^3/d	9.98–7.19/m^3	Saudi Arabia	[22]	

[a] Currency is in DM.

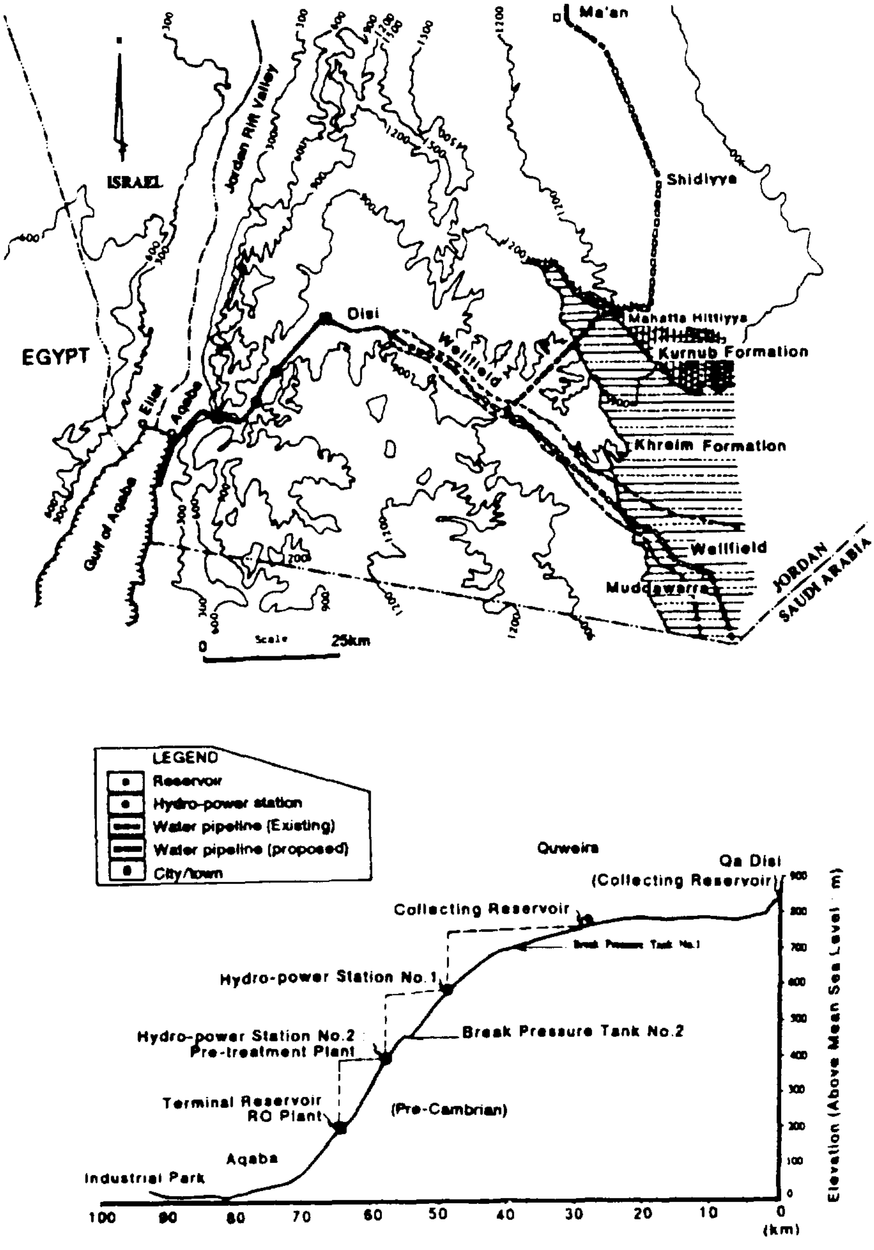

Fig. 1. Disi-Aqaba hydropowered RO desalination scheme. Source: Murakami [6].

2.3. *Red Sea–Dead Sea canal hydro-power scheme*

A potential hydropower development used for desalination of seawater by linking the Red and Dead Seas together is considered in our analysis. The Dead Sea, which is located at an elevation of more than 400 m below sea level (BSL) is roughly 200 km to the north of the Gulf of Aqaba. It is an extension of the Red Sea. The Dead Sea has no outlet; its level is a function of inflow and

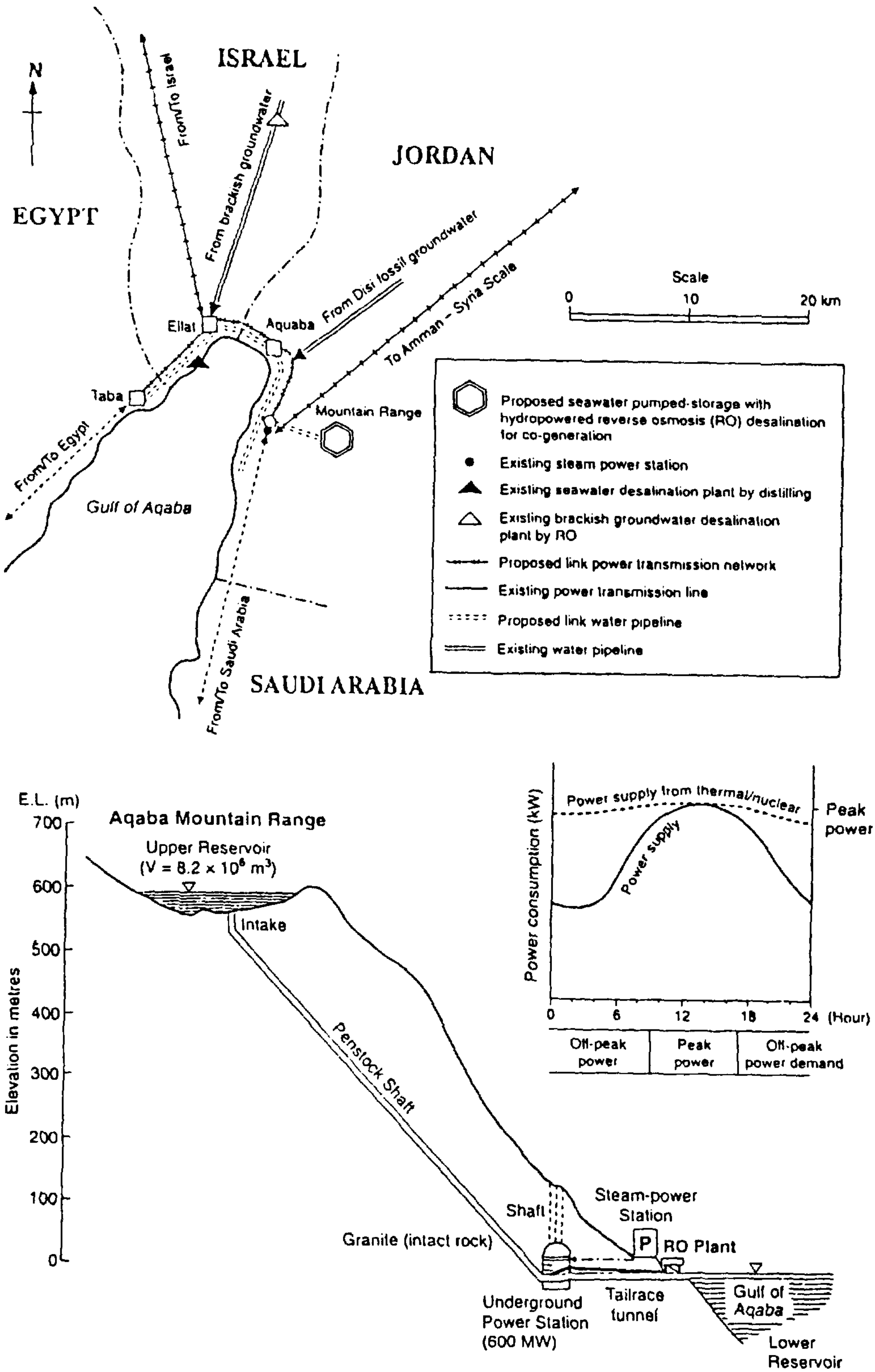

Fig. 2. Aqaba hybrid pumped-storage scheme. Source: Middle East Water Commission [8].

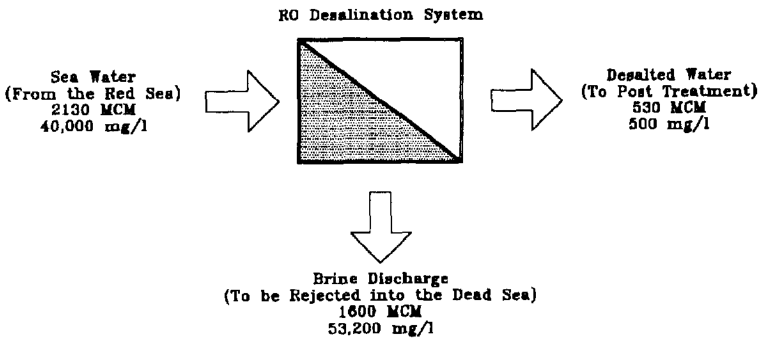

Fig. 3. Schematic and flow diagram of RO desalination system.

evaporation of water. For thousands of years the Sea maintained an equilibrium with the annual inflow and evaporation of water. This resulted in a constant sea level. For example, in 1930 the surface of the Dead Sea was measured at its historical elevation of about 390 m BSL. The Jordan River is considered the main tributary of the Dead Sea. Over the years, due to the increase in population and agricultural development, water was diverted for irrigation in the Jordan Valley and neighboring countries. Therefore, its elevation was forced to drop drastically. In 1993 it was 408 m BSL. To halt this trend, it will be necessary to introduce a substantial amount of new water to the sea. Seawater from the Red Sea can be used as a source of water needed for diversion into the Dead Sea. This diversion can be used to either maintain the sea at its current level and thus stop its dropping, or even to bring it back to its historical level. The power obtained from such a process may be used to desalinate water and allow even more water to be diverted from the Jordan River. The brine of the RO desalination units would be the source of water into the Dead Sea. The salinity of the Dead Sea is extremely high — roughly, 300,000 mg/l [5] — and the discharge of brine into the sea will not effect its salinity by any substantial margin.

The annual amount of water that is evaporated from the surface of the Dead Sea is about 1600 million m^3 [7]. In Fig. 3 it can be seen that roughly 2130 million m^3 of seawater can be drawn annually from the Red Sea (with a TDS concentration of 40,000 mg/l). Assuming 25% conversion in RO desalination plants near the Dead Sea, then 530 million m^3 of fresh drinking desalted water can be produced annually at 500 mg/l. By performing a mass balance, it can be found that the amount of water (with a concentrated salinity of 53,200 mg/l) that is discharged into the Dead Sea would be 1600 million m^3, i.e., equal to the amount of water evaporated.

3. Solar desalination

Solar desalination can be used in the production of fresh potable water. Its application is not restricted to remote and arid regions, but also may be used for small communities. According to Howe [9], at an average water consumption of 0.40 m^3/person-per-day, a small community with a total population of 200 can benefit more from solar desalination than transporting water at distances of 16 km or longer with lower costs. During hot season, solar insolation is high, and water is at its peak rate of consumption. There are two methods used to produce fresh water from brackish or seawater by the utilization of solar energy [10]; one is the direct application of solar energy using solar stills, or conversion to thermal power or to mechanical power through a heat cycle. The other is the indirect application of the sun's heat for the conversion to electrical power using collectors, mirrors, or solar cells.

There are various designs of solar stills

[11–13]. Usually they have a single- or double-slope solar collectors. In either case, they operate on absorbing solar radiation through transparent cover, usually made of glass, which is then transmitted to water. The production rate of water can vary with design of solar stills and location. Usually they have an annual production rate per collector surface area of 800–1000 L/m^2.

Solar desalination plants are considered small-size desalination units when compared with fuel-operated units. There are number of solar desalination plants currently in use throughout the world. A solar plant in Greece was designed to produce a maximum of 27 m^3/d of fresh water [9]. Another was designed in Abu-Dhabi, capable of producing 80 m^3/d. A five-year operational performance and reliability of the unit was published [14]. Another was also designed by a joint Spanish and German research team to produce 72 m^3/d [15]. All three plants use seawater to be desalinated into fresh water by using solar energy.

Like most Middle Eastern countries, Jordan enjoys long periods of sunshine. The weather has over 300 cloudless days per year. Future technology suggests that the Dead Sea itself can be used as a 450 km^2 solar lake, operating a 2500 MW power plant [7]. In part, some of the electric energy can be used for desalination using RO technology.

4. Wind energy desalination

Wind energy can be combined with RO desalination techniques for the production of fresh drinking water. Initial studies have shown that wind energy can be an appropriate method for RO desalination [17,18]. There are number of sites in Jordan with potentially high wind speeds to be utilized for this purpose. Habali et al. [19] have presented the three most potential sites in Jordan: Ras Munif, Mafraq and Aqaba. Wind speeds range from 4 to 23 m/s throughout 80% of the whole year.

Wind-powered RO desalination could become more economic in the future because, firstly, current developments indicate fuel costs are steady or increasing. Secondly, wind turbine costs are becoming less expensive. Thirdly, RO desalination costs are decreasing due to the continuing development in membrane technology. At a cost of US$ 3–6/m^3 of water (see Table 1), wind desalination might not be appropriate for most applications. But for some remote villages in Jordan's Badia, wind energy could be utilized for sustaining human settlements and the habitat.

5. Nuclear desalination

Nuclear energy offers an advantage to fossil energy from an environmental point of view. Ragheb et al. [20] reported the production of 1 million m^3 of fresh water from nuclear energy would avoid the emission of 2 million tons of CO_2, 20,000 tons of SO_2, and 6000 tons of NO_x, as compared to desalination by energy from fossil fuel. The technical feasibility of using nuclear power in desalination was reported by a number of researchers [21–23]. In all different studies there are clear indications that nuclear energy has the potential to reduce water cost. In Jordan, where no fossil energy resources are available, nuclear energy may present a positive impact on water cost, as it has had on electricity in many countries.

Recent studies [21] have shown that there are only two types of desalination processes, namely the RO and MED. They are varying in reliability, simplicity and adaptability. The modular high-temperature gas cooled reactor (MHTGR), and the liquid metal fast breeder reactor (LMFBR) can be employed in the new design of dual-purpose plants. That is due to their small size and compatibility with desalination applications.

A number of studies in the U.S., Germany, and Japan on nuclear desalination has been conducted [21]. The MHTGR was used in both the U.S. and Germany. While the LMFBR was used in Japan and the LTHMED process was used in the U.S. The cost of producing water was reported to be DM 2.5/m^3 and US$0.44 to 0.49/$m^3$ for both German and American studies, respectively.

Nuclear energy was used for desalination purpose in the city of Skeichenko in Russia. The complex is a large multi-purpose plant, and it has been supplying the city with fresh water, electricity, and thermal energy [20]. It provides 0.14 million m^3 of fresh water per day, and generates 150 MW of electric power. The actual cost of water was reported to be 0.48 ruble/m^3.

The average annual cost of water production consists of annual production charges, operation and maintenance cost, and cost of fuel. Nuclear power plants are highly capital intensiv; it was reported that the annual capital charges represent more than 70% of the total average annual production cost.

Having described the above options for non-conventional energy technologies, the following is a framework for evaluating and devising best uses for each technology.

6. Methodology of the hierarchical analysis

In order to model multi-objective water desalination technologies in Jordan, Saaty's AHP was adopted [24]. A detailed procedure along with a numerical example can be found in Appendix A [4,25]. Briefly, relative weights were determined through pairwise comparison. The model can be applied by breaking down the complex unstructured scorecard problems into component parts. Value tree structures are formed in order to arrange these attributes into hierarchical orders. Numerical values are assigned to represent subjective judgments on the relative importance of each part. These judgments are then

Table 2
Ranking system of the analytic hierarchy process as adopted by Saaty [24]

Intensity of importance	Definition	Explanation
1	Of equal importance	Two activities contributing equally to an objective
3	Weak importance of one activity over another	Experience and judgment that slightly favors one item over another
5	Essential or strong importance	Experience and judgment that strongly favors one item over another
7	Very strong or demonstrated importance	Activity is favored very strongly over another
9	Absolute importance	Evidence favors one item over all
2,4,6,8	Intermediate values between adjacent scale values of importance	Compromise is needed
Reciprocals of the above, non-zero	If activity *i* has one of the above non-zero numbers assigned to it when compared with activity *j*, then *j* has the reciprocal value when compared with *i*	Assumption is reasonable
Rationales	Ratios arising from scale	If consistency is to be obtained using such values

synthesized via the use of eigenvectors to determine which variables have the highest priority.

A finite number of values to rank (scale) the importance is assigned. AHP scale ranges from 1 (to denote equal importance of two attributes) to 9 (to represent an absolute importance of one attribute over another). The ranking system used by AHP is presented in Table 2. After the problem is decomposed to a tree or "hierarchy" of components of various levels, a pairwise comparison is carried out from the top level to lower levels. Then after each comparison, a "consistency" check is made to enable the analyst to revise his/her weights so as to obtain a consistency value below 0.1.

For this study, various desalination technologies in Jordan are being studied for evaluation and to define criteria and appropriate uses. The problem was broken into different levels to construct a hierarchy tree. The hierarchy tree shown in Fig. 4 is composed of four levels. The first level defines the "goal" to be achieved which is to select the best energy system producing desalinated water. The second level outlines the main "technologies" to produce energy. These include hydropower, solar, wind, and nuclear. The third level list criteria. The fourth level defines water uses, i.e., domestic, industrial, and agriculture.

7. Results and discussion

In light of hierarchical analysis, relative global weights were generated. They are shown in Figs. 5 and 6. Fig. 5 shows relative weight comparison of type of technology vs. water use with respect to water productivity criteria, i.e., return of 1 m^3 in each water sector. The relative weight comparison of type of technology vs. use with respect to environmental sustainability criteria, as defined in [4], is shown in Fig. 6. Results show that under water productivity criteria the highest weights were obtained for hydropower to be used in domestic and industrial sectors (with relative weights of 0.181 and 0.162, respectively). However, solar technology can very well be used in industrial sector (with relative weight of 0.188). Wind technology may be used in domestic. On the other hand, under environmental sustainability criteria (see Fig. 6), hydropower and solar technologies can be used in domestic and industrial sectors (with relative weights of 0.084 and 0.086, respectively). Moreover, based on environmental sustainability criteria, solar and nuclear energy may be used in agricultural and domestic uses (with relative weights of 0.039 and 0.030, respectively). Overall, nuclear and wind energy seems not be the most appropriate technologies to be used in water desalination in the short term in Jordan.

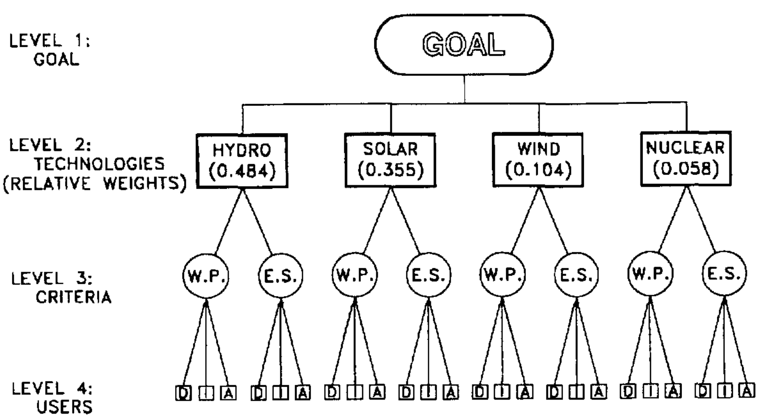

Fig. 4. Structure of the hierarchy.

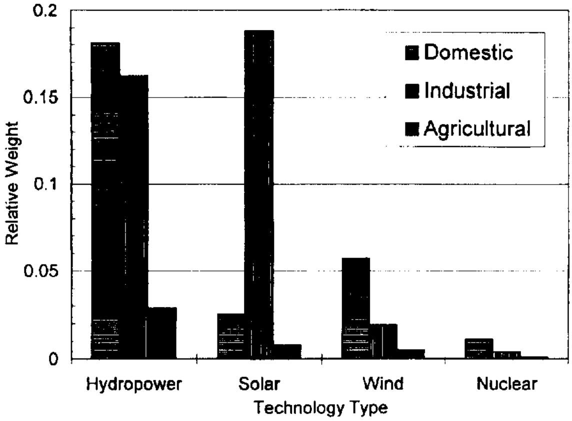

Fig. 5. Technology type vs. use based on water productivity criteria.

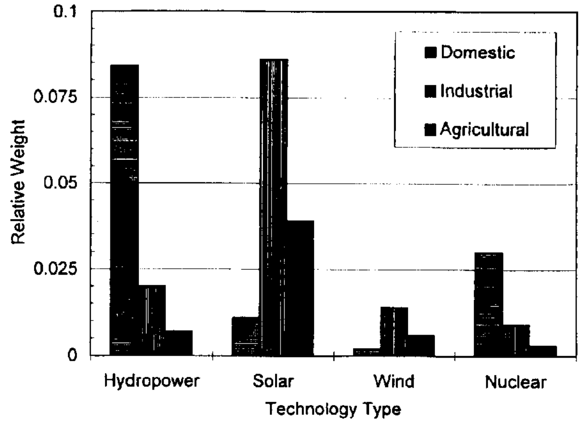

Fig. 6. Technology type vs. use based on environmental sustainability criteria.

The relative weights were mostly high for domestic and industrial under water productivity criteria. This may be justified on the basis of high return per cubic meter and contribution of water to the Gross National Product (GNP) in case of industrial uses, and the priority allocation policy for domestic uses. It should be noted that wind energy may be feasible and appropriate only for specific locations; i.e., the Badia areas in Jordan. On the other hand, nuclear energy is viewed as an option for the long term due to the constraints with respect to technology transfer, human resources development, and high cost.

8. Conclusions

Due to Jordan's severe water scarcity, it must rely on other non-conventional energy powered desalination technologies. The use of hydropower in desalination is technically feasible. This energy can be utilized to provide water for domestic and industrial sectors. The use of solar energy with 21st century technology can be utilized in desalting brackish water in many parts of the country. Wind energy can be utilized in areas where wind has a high average speed. Nuclear energy is to be considered for the long term in Jordan. Further research and studies in this area are needed to ensure technical and economic feasibility of each technology.

References

[1] E. Salameh, Proc., Symposium on Jordan's Water Resources and Their Future Potential, Amman, Jordan, 1992, pp. 113–120.
[2] Department of Statistics, Amman, Jordan, 1995.
[3] M. Bilbeisi, Proc. Symposium on Jordan's Water Resources and Their Future Potential, Amman, Jordan, (1992), pp. 7–29.
[4] O.R. Al-Jayyousi and M.R. Shatanawi, Int. J. Water Resources Development, 11 (1995), 315.
[5] M. Murakami, Int. J. Water Resources Development, 11 (1995) 391.
[6] M. Murakami, Managing Water for Peace in the Middle East, United Nations University Press, Tokyo, Japan, 1995, pp. 167–201.
[7] M. Murakami, and A.T. Wolf, Int. J. Water Resources Development, 11 (1995) 163.
[8] Middle East Water Commission, Int. J. Water Resources Development, 11 (1995) 351.
[9] E.D. Howe, Desalination, 60 (1986) 307.
[10] E.E Delyannis, Desalination, 67 (1987) 3.
[11] G.N. Tiwari, Desalination, 82 (1991) 233.
[12] A.Y. Maalej, Desalination, 82 (1991) 207.
[13] G.N. Tiwari, K. Mukherjee, K.R. Ashok and Y.P. Yadav, Desalination, 60 (1986) 191.
[14] A. El-Nashar and A. Qamhiyeh, Desalination, 82 (1991) 165.

[15] A. Gregorzewski, K. Genthner, E. Zarza, J. Leon, J. de Gunzboourg, G. Alefeld and J. Scharfe, Desalination, 82 (1991) 145.
[16] M. Posnansky, Desalination, 67 (1987) 81.
[17] P. Feron, Wind Engineering, 9 (1985) 180.
[18] C.G. Warfel, J.F. Manwell and J.G. McGowan, Solar & Wind Technology, 5 (1988) 549.
[19] S.M. Habali, M.A.S. Hamdan, B.A. Jubran and A.I. Zaid, Solar Energy, 38 (1987) 59.
[20] M. Ragheb, K. Toukan and R. Al-Weshah, Proc. Int. Symp. on Water Resources in The Middle East: Policy and Institutional Aspects, Urbana, IL, USA, 1993, pp. 173–180.
[21] A. Ez-Dean, M.J. Crijns, J. Kupitz, G.F. Tusel and K. Wangnick, Desalination, 81 (1991) 505.
[22] I.I. Kutbi and A.M.A. Ahmed, Desalination, 58 (1986) 43.
[23] I.I. Kutbi, Z.A. Sabri and A.A. Hussein, Desalination, 58 (1986) 113.
[24] T.L. Saaty, The Analytic Hierarchy Process, McGraw-Hill, New York, 1980.
[25] T.L. Saaty, Decision Making for Leaders: The Analytic Hierarchy Process for Decision Making, RWS, Pittsburgh, PA, 1988.

Appendix A
Explaining AHP as a methodology for evaluating alternatives

A brief description of AHP as a methodology for evaluating alternatives is outlined below, based on Saaty [25].

1. The first step involves the composition or structuring of a hierarchy of the components of the problem or issue to be analyzed. This phase may involve a group decision making to explore the various perspectives of the problem. In this paper, the hierarchy was composed of the following levels (from top to bottom): goal, technologies, criteria and users. However, these components are by no means exhaustive; other levels may be incorporated into the hierarchy such as strategies, scenarios, and/or actors.

2. The second step is to make pairwise comparisons, i.e., to compare the elements of a hierarchy in pairs (as will be shown in the numerical example below) against a given goal or criterion. To perform pairwise comparisons, a matrix is used to compare different variables; this is done as follows:

- Start at the top of the hierarchy to select the criterion (C), or property, that will be used for making the first comparison. Then, from the level immediately below, take the elements to be compared for example, A_1, A_2, A_3, ..., A_N, considering that we have N elements;
- Arrange these elements in a matrix as shown in Table A1;
- In this matrix compare element A_1 in the column on the left with A_1, A_2, A_3, and so on in the row on the top with respect to property C in the upper left-hand corner. To compare elements, one should ask, "How much more strongly does this element possess or contribute to influence, satisfy, or benefit the property than does the element with which it is being compared?"
- To fill the matrix of pairwise comparisons, we may use the numerical values 1 through 9 presented in Table 2 (see text). When comparing one element in a matrix with itself, the comparison must give unity (1) which represents the values in the diagonal of the matrix.
- To illustrate how to form a normalized matrix and to come up with relative weights in a generalized form, the following numerical example is presented: Suppose that the outcome of pairwise comparison was made for three elements A_1, A_2, and A_3 with respect to criterion C as shown in Table A2.

Table A1
Simple matrix for pairwise comparison

C	A_1	A_2	...	A_N
A_1	1			
A_1		1		
·			1	
A_N				1

Table A2
Simple matrix comparing three elements for criterion C

C	A_1	A_2	A_3
A_1	1	.5	.25
A_2	2	1	.5
A_3	4	2	1
Column total	7	3.5	1.75

Table A3
Normalized matrix

C	A_1	A_2	A_3	Average of rows
A_1	1/7	1/7	1/7	0.14
A_2	2/7	2/7	2/7	0.29
A_3	4/7	4/7	4/7	0.57

Table A4
Technology type vs. use based on water productivity criteria

Use	Type of technology			
	Hydro-power (0.484)	Solar (0.355)	Wind (0.104)	Nuclear (0.058)
Domestic	0.181	0.025	0.057	0.011
Industrial	0.162	0.188	0.019	0.004
Agricultural	0.029	0.008	0.005	0.001

Table A5
Technology type vs. use based on environmental sustainability criteria

Use	Type of technology			
	Hydro-power (0.484)	Solar (0.355)	Wind (0.104)	Nuclear (0.058)
Domestic	0.084	0.011	0.002	0.030
Industrial	0.020	0.086	0.014	0.009
Agricultural	0.007	0.039	0.006	0.003

To synthesize our judgments so as to get relative weights, the following steps are to be taken: (a) Add values in each column; then divide each entry in each column by the total of that column to obtain the normalized matrix as shown in Table A3. (b) Average the rows in each row of the normalized matrix; this yields the percentages of overall relative priorities of the elements A_1, A_2, and A_3; hence, we can make deductions with reference to relative weights as calculated above. The relative weights which were presented earlier (i.e., in Figs. 5 and 6) have the following numerical values which are presented in Tables A4 and A5, respectively.