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Do not put all your eggs in one basket: social perspectives on desalination and water recycling in Israel

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ABSTRACT

Israel has set ambitious goals in terms of the widespread adoption of desalination and water recycling technologies. Policy-makers in Israel consider these technologies as the key to improve urban water security but knowledge of stakeholder views on this policy approach is not well established. We deployed the Q-methodology, a qualitative–quantitative approach, to empirically determine social perspectives on desalination and water recycling across a wide range of stakeholders in the Israeli water sector. We identified the following four distinctive social perspectives: (1) desalination should be the option of last resort; (2) desalination is moving us to an infinite resource; (3) equating savings to resources is a dangerous illusion; and (4) desalination is (risky) electric water. A common characteristic of these perspectives is the belief that desalination is necessary for a water-secure country, but desalination should not be the only source of drinking water in Israel. Our findings indicate that Israeli stakeholders show complex and contingent understandings of the pros and cons of desalination and water recycling and the risks involved in too much reliance on a limited number of water sources. We discuss the potential implications of our findings for water management and security in Israel and other places with water scarcity concerns.

Key words: Desalination, Israel, Q-methodology, Social perspectives, Water policy, Water recycling

HIGHLIGHTS

- Using the Q-method, we identified four social perspectives on desalination and water recycling in Israel.
- Stakeholders believe that desalination provides water security, but it should not be the only water source.
- Stakeholders focus on the positive and negative aspects of water practices.
- The link between desalination and peace was a point of contention.
- Israeli stakeholders understand the pros and cons of desalination and water recycling.

INTRODUCTION

Awareness of water scarcity is very high in Israel (Feitelson, 2013; Katz, 2013; Siegel, 2015). Water was fundamental to the creation of the new state (Fischhendler & Heikkila, 2010); for example, David Ben-Gurion,

Israel's first prime minister, is often associated with the rallying cry to 'make the desert bloom' by carefully managing all the water that was allegedly 'wasted … without fully benefiting the thirsty soil' (Lipchin, 2003, p. 90). While Israel's water-conscious approach is certainly environmentally founded, religious, historical, social, and political causes have also contributed to Israel's contemporary culture of water conservation, with important roles often assigned to primary education, frequent media attention, and public water conservation campaigns (Lees, 1998; Siegel, 2015; Feitelson, 2018). Yet not all Israelis are equally concerned about water issues. The importance of 'the very different perspectives of the actors involved', particularly water managers and farmers, among other participants in the system, was recognized by Lees (1998, p. 2), who found that explanations on the reasons behind the successive water 'crises' and the solutions proposed to solve them vary greatly across sectors. Stakeholders' perception on water uses in general was also studied by Lipchin (2003), who explored how differences and commonalities in livelihood, culture, and socioeconomic capacities influence local water consumption patterns, attitudes, and perceptions toward water use and water scarcity in general.

In water-scarce countries like Israel, water recycling schemes and large-scale desalination facilities are increasingly used to address urban water insecurity. Water recycling is a complex process that resists a simple definition because it involves technical, social, environmental, economic, and institutional aspects that are better addressed using a 'water chain approach' (Huibers & van Lier, 2005). Even though water 'recycling' and water 'reuse' could be defined differently in specific cases, we will use these terms indistinctly in this paper to refer to all those processes in which treated, partially treated, or even raw (waste)water is directly or indirectly used again (reused) in agricultural or domestic settings, including direct potable reuse for drinking water (Gatto D'Andrea *et al.*, 2015). While Israel's water portfolio remains diversified to date, its dependence on seawater desalination as the main source of drinking water has dramatically increased. According to the Israeli Ministry of Finance (2020), 'seawater desalination is the most reliable of the [water] sources for enriching the water supply, since seawater is available in unlimited quantities and involves no dependency – neither on climate nor on political factors'. Israel's 'turn to the sea' as the primary source for desalination (Teff-Seker *et al.*, 2019) aligns with 'the continued perception among policy makers that desalination is the only option for bridging the country's water deficit' (Lipchin, 2003, p. 130), with assumed high support for desalination across stakeholder groups (Feitelson & Jones, 2014).

Studying perspectives or rationalities of key stakeholders who have direct bearing on water management is critically important to understand changes in water security and policy-making (Hassanzadeh *et al.*, 2019; Iribarnegaray *et al.*, 2021). This may be particularly sensitive regarding large-scale infrastructure projects where stakeholders are not always aligned with institutional narratives (Beckner *et al.*, 2019). Stakeholders' perspectives are also important because they may provide much needed legitimacy to water portfolios and water policies (Harris-Lovett *et al.*, 2015; Binz *et al.*, 2016). Either as part of society or as members of the water governance regime, stakeholders help produce framings of urban water security as it interacts with urbanization and urban-regional systems (Romero-Lankao & Gnatz, 2016). They also articulate urban water narratives to maintain, shift, or transform how urban water systems operate (Dobbie *et al.*, 2014).

Using the Q-methodology (or Q-method), it is possible to empirically identify social perspectives on an issue based on people's values and priorities rather than on institutional affiliation (Robbins, 2006). This can be useful to assess technologies and policy instruments by studying the characteristics and behaviors of specific actors and identifying some of the key ideas that influence decision-making and legitimacy within and outside water institutions (Gilg & Barr, 2006; Jones *et al.*, 2011). The Q-method has been extensively applied in environmental and sustainability research (Sneegas *et al.*, 2021). This method combines a qualitative approach with quantitative methods and allows for an empirical measure of people's subjectivity (McKeown & Thomas, 1988; Brown, 1996; Watts & Stenner, 2012). Using factor analysis, the Q-method seeks to reveal and describe

the opinions of knowledgeable stakeholders rather than a representative sample of a given population (Steelman & Maguire, 1999). Findings from a Q-study can also promote interaction and debate between researchers, respondents, and other local stakeholders in ways that may lead to new insights on the issues under study (Brannstrom *et al.*, 2011).

To better understand Israeli water stakeholder perspectives, we ask to what extent relevant stakeholders in the water sector share the official view that desalination is the best alternative to tackle Israel's long-term water problems, and what is the role they assign to water recycling schemes in the country. We hypothesize that even though desalination may be necessary to cover Israel's growing water needs, other sources of water with a longer history might still be perceived as necessary to ensure water security. Our specific goal is to provide a rigorous and explicit account of local stakeholders' perspectives on desalination and on other water recycling practices deeply embedded in the Israeli water management system. The paper is organized as follows: we first describe the Israeli desalination and water recycling sector and the use of the Q-method to elicit public perception. Then, we describe the study results, which produced four distinctive social perspectives on desalination and water recycling. We found commonalities among these perspectives, but also striking differences, leading us to conclude that the spectrum of positions was broader than initially expected, given the commonly assumed idea that desalination and water recycling enjoy widespread, and even uncritical, support in Israel. Our findings also show that even though desalination seems to enjoy more prominence as the main source of water in the perspectives identified, the role of water recycling and reuse is still considered relevant in local discourses, probably because this aligns well with long-term water management trajectories in the country. We discuss these findings in detail, drawing out some cross-cutting issues across the four social perspectives. Finally, we draw some conclusions and highlight the potential significance of our findings for water policy in Israel and other places facing water security challenges.

MATERIALS AND METHODS

Case study: Israel

Water governance in Israel is particularly complex. On the one hand, the Water Authority (WA), a government agency created in 2007 to replace the role of the former Water Commissioner (a position that was established in the 1959 Water Law), manages natural sources, pursues new water sources, sets prices and standards, and forecasts future potable water sources and supplies. On the other hand, Mekorot, Israel's only national water company, acts as a water wholesaler and is entirely self-funded through the water tariff mechanism. Mekorot and the WA are financially separated, with the water sector acting today as a 'closed market' with desalinated water as the only water source produced by private entities that is not owned by the state. Mekorot sources water from a combination of natural and 'unconventional' (e.g., desalinated and recycled) water sources, which it sells to municipal water corporations across Israel. These changes decoupled water infrastructure financing from government budgets. Desalination in Israel is now largely regulated through the tender process. Large-scale seawater reverse osmosis (SWRO) desalination plants are usually built and operated through Public–Private Partnerships, or PPPs (Greer *et al.*, 2021). The Water Desalination Administration (WDA) unit within the WA works directly with private companies to oversee PPP arrangements funding desalination facilities over the course of their lifetimes. The WDA does the site planning to decide where desalination facilities will be located, a process beginning ten to fifteen years before plants come online. The WDA head also sits on the marine desalination Interdepartmental Tender Committee (ITC), which manages the desalination tender process. ITC members also include representatives from the Ministry of Finance, the Ministry of Energy, and Inbal (Israel's state-owned insurance company).

Israel's 2004 National Outline Plan (NOP; 34/B/2) established that desalination should supply 775 million cubic meters (MCM) per year of drinking water by 2050 (Moatty, 2001, p. 102). Desalination has since become the core component of Israel's water management system and the primary policy option pursued by Israel in terms of water provision (Becker *et al.*, 2010; Teschner *et al.*, 2013; Gilmont, 2014; Tal, 2018). Since desalination plants need to operate year-round to reduce unit costs, desalinated water is fast becoming Israel's primary water source in 'a fundamental change in water management practice' (Feitelson & Rosenthal, 2012, p. 278). Israel is one of the world leaders in developing and exporting desalination technologies (Feitelson & Jones, 2014; Siegel, 2015; Tal, 2018). Marine desalination is also seen as a 'game-changer in transboundary hydro-politics' in the region, particularly in relation to Israel's geopolitical relations with Jordan and the Palestinian Authority (Aviram *et al.*, 2014, p. 609).

Water recycling and reuse were among the first policy options pursued by the state of Israel to combat water scarcity, after early efforts to adopt seawater desalination proved too costly. Water recycling, together with drip irrigation and the increasing reliance on imported staple foods managed to decouple, to a great extent, agricultural produce from water used in irrigation and irrigated area as early as the 1980s (Shelef, 1991; Feitelson, 2013). Approximately 85–90% of sewage is treated and reused for agricultural purposes or aquifer replenishment making Israel the country with the highest rate of water reclamation in the world (Siegel, 2015; Tal, 2018). Water recycling sometimes raises public concern, and the social acceptance of this practice has been studied for several decades in many parts of the world, including Israel and other Middle Eastern countries (Sims & Baumann, 1974; Alhumoud & Madzikanda, 2010; Carr *et al.*, 2011; Fielding *et al.*, 2019). Willingness to use (treated) wastewater in agriculture and willingness to pay for crops grown with recycled water depend on several issues such as water scarcity, education, costs and benefits, health risks, and even religious concerns (Gatto D'Andrea *et al.*, 2015). Direct or indirect potable reuse usually face the strongest opposition due to the likelihood of human contact with wastewater (the 'yuck factor') (Ormerod & Scott, 2012). Public opinion, however, can be influenced by advertising campaigns and it has been shown in Israel and elsewhere that open participation is important for water reuse schemes to succeed (Lipchin, 2003; Marks, 2006).

Together with wastewater recycling, seawater desalination heralded a new 'era' in Israel's water management (Feitelson & Rosenthal, 2012, p. 273). In fact, Israel has aggressively deployed marine desalination over the past two decades, expanding beyond brackish and small- to mid-scale plants (Spiritos & Lipchin, 2013; Teff-Seker *et al.*, 2019). A severe drought in 1998–2001 prompted the Israeli government to conduct a nation wide conservation campaign and consider large-scale SWRO desalination in the Mediterranean Sea, with the first plant coming online in 2005. The five largest desalination facilities currently operating in Israel provide 585 MCM/year. Concession agreements for two more plants were signed in 2019 and 2020 (Ministry of Finance, 2020). Upon completion of these plants, overall production will increase to 885 MCM/year, which would represent roughly 90% of the annual municipal and industrial water consumption. Today, the combined water production of the 50 large-, medium-, and small-scale desalination facilities providing drinking water to different Israeli municipalities amounts to more than 2.8 MCM/day[1]. Theoretically, this volume is more than enough to supply the entire population of Israel (more than 9 million people), assuming a *per capita* water consumption of 83 m^3/year (227 L/day) as estimated by Portnov & Meir (2008). This water availability exceeds projections made a decade ago by almost 40% (see Spiritos & Lipchin, 2013, p. 103).

[1] According to DesalData, there are 95 desalination plants in Israel, but the majority are small brackish water plants. From: https://www.desaldata.com/. Last accessed 8 February 2022.

Research design

Our analytical approach relies upon the Q-method, a quantitative–qualitative procedure that identifies social perspectives or subjective viewpoints in a thematic area or domain (Sneegas *et al.*, 2021). The Q-method does not generalize to a population, but the social perspectives are assumed to exist outside the study group and may inform large *n* surveys. We followed a standard methodological protocol (McKeown & Thomas, 1988; Watts & Stenner, 2012) consisting of the following steps: (1) purposively identifying participants, (the *P-set*); (2) developing the body of subjective statements that represent the broader discursive domain being studied (the *concourse*) and selecting relevant statements (the Q-*set*); (3) interviewing participants and asking them to rank-order the statements according to their level of (dis)agreement in a quasi-normal distribution (Q-*sorts*); and (4) by-person factor analysis of the Q-sorts and subsequent interpretation (Figure 1).

We selected participants likely to have well informed and clearly articulated opinions on the research topic, focusing on six stakeholder categories across civil (universities/research centers, non-profit organizations), public (water companies, state sector), and private water sectors (market sector services, desalination facilities) (see Supplemental Material, Table S1). Participants were selected using a snowball approach from an initial set of local contacts obtained by members of the research team. A team member conducted 33 in-person interviews in January–February 2020 with 37 key stakeholders in Israel using a semi-structured interview framework. Interviews were recorded and later transcribed by a third party, then coded according to eight *a priori* pertinent themes and an additional emergent code (Israeli–Palestinian relations) that was identified through iterative coding passes (description of the themes is provided in Supplemental Material, Table S2).

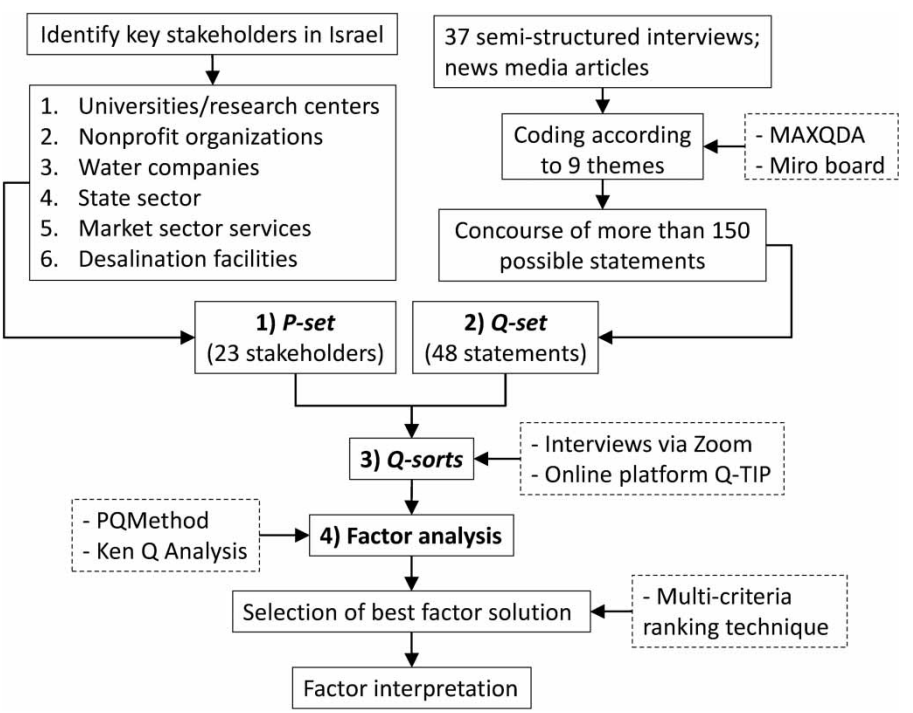

Fig. 1 | Scheme of our methodological approach showing the main steps followed during the research process. Dashed lines indicate auxiliary methods used in some stages.

Between September 2021 and January 2022, we invited a total of 55 participants, including the 37 earlier participants, to complete Q-sorts. Our final *P*-set included 23 stakeholders, reflecting a response rate of 41.8%. Of the 37 original interviewees, 18 (48.6%) also completed Q-sorts. We developed the concourse by identifying relevant statements in coded segments from semi-structured interviews and a document review of news media articles published between January 2000 and May 2020. We coded segments using MAXQDA Analytics Pro 2020 software (Release 20.4.2) and built the final Q-set using Miro, an online collaborative whiteboard platform. Out of an initial number of more than 150 possible statements, we selected a final set of 48 statements after three passes of edits and comments. As shown in Table 1, we selected a similar number of statements across the nine themes identified. We piloted the final Q-set among the research team, making final adjustments to improve clarity and statement length. Owing to COVID-19 social distancing and travel restrictions, we conducted Q-sorts via Zoom using the free online Q-method platform Q-TIP (Nost *et al.*, 2019)[2]. According to Meehan *et al.* (2022), online data collection in Q studies offers several strategic and practical advantages and could capture greater diversity in social perspectives and geographies while holding true to the theoretical principles of the Q-method. We asked participants to complete the Q-sort exercise by sorting the statements in a forced-choice structure (Supplemental Material, Table S3). We asked participants about the reasons behind their choices, particularly for statements placed at both ends of the distribution or on the neutral zone, to better understand their sorting rationale. We also prompted participants, as part of the interview protocol, to give their opinion on the potential usefulness of understanding public perception for policy-making. Virtual Q-sorts and interviews lasted between 30 and 60 min. Research team members recorded the online Q-sorts and post-sort interviews, which were also transcribed and then coded in MAXQDA to provide additional qualitative data to inform the interpretation.

Q-sorts were processed with PQMethod 2.35, free software[3]. Digital versions of all individual Q-sorts and factor exemplars were generated using Ken Q Analysis version 0.11.1 web application. Factor exemplars are the average, hypothetical Q-sorts that summarize the opinions of the respondents who align with a given factor. In Q-method, a 'factor' is synonymous with 'social perspective'. Input files for PQMethod were generated with Ken Q Data version 1.0.3 from Excel files containing the participants' responses. All available Q software packages perform at least the following three basic statistical processes: (1) calculation of the correlation matrix; (2) extraction and rotation of significant factors by Principal Components Analysis (PCA); and (3) definition of a set of values for each model factor or factor exemplar. Factor rotation was done using Varimax orthogonal rotation. The correlation or similarity between a respondent's Q-sort and a given factor, is defined by the factor 'loading'. Respondents with high loadings on a given perspective are the ones who define that perspective, since their Q-sorts were closer to the factor exemplar than other people's (Webler *et al.*, 2009). Three members of the research team conducted the analysis separately and compared the results of two to five-factor solutions using the simple multiple attribute ranking technique (SMART) to select the number of factors that represented the most robust empirical solution (Saaty, 2008). We interpreted the selected factors as social perspectives by relying mostly on statistically significant ($p < 0.05$) and highly significant ($p < 0.01$) 'distinguishing' statements. These statements are crucial to describe social perspectives because they are significantly different among the factors, especially if they show up in only one factor. References to non-significant statements were included only if they reinforced the description of the factors. We also relied on semi-structured interviews and Q-sort interviews to better interpret individual responses and social perspectives as a whole.

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[2] Q-TIP is now open to all researchers at: https://qtip.geography.wisc.edu/. Last accessed 17 February 2022.

[3] Available at: http://schmolck.org/qmethod/. Last accessed 17 February 2022.

Table 1 | Factor scores (*Z*) and values (V) for statement grouped by theme, with numbers referring to the random order used during Q interviews.

Statements		*Z* (V)			
No.	**Full statement**	**Factor 1**	**Factor 2**	**Factor 3**	**Factor 4**
Theme (a) Water Security					
2	In Israel, water security is also political security. If a rocket hits a desal plant, that's a problem. Protecting those infrastructures is a national security priority (CS).	1.75 (4)	1.47 (3)	1.60 (3)	1.79 (4)
3	A stable system of good quality water supply is crucial for economic development, and desalination is the X factor to make sure we have nonstop quality water.	0.82 (2)	1.26 (3)	1.75 (4)	0.25 (0)
12	Direct potable reuse is a big risk for a very small country like Israel. Even if it's competitive price wise, it's safer to desalinate.	−1.29 (− 3)	−0.7 (− 1)*	−1.48 (− 4)	0.58 (1)**
46	With water reuse, the main risk is to public health because it's impossible to monitor and control decentralized wastewater treatment systems (CS).	−1.03 (− 2)	−1.12 (− 3)	−1.62 (− 4)	−0.70 (− 1)
48	Thanks to desalination and water reuse technologies, Israel is a water-secure country where our citizens don't have to worry about water.	−0.19 (− 1)	0.13 (0)	−1.32 (− 3) **	−0.05 (0)
Theme (b) Water Systems					
5	Grey water is still an untapped resource in Israel. Government should create more flexibility for households to reuse treated grey water.	0.29 (0)	0.03 (0)	0.05 (1)	−0.72 (− 1)*
16	A centralized water system that controls all water – fresh water, ground water, surface water, rain water, reclaimed wastewater, desalinated water – that's the only way we can manage water correctly.	0.59 (1)	1.00 (2)	−0.36 (− 1)*	−1.15 (− 2)*
31	Desalination should be the option of last resort. Conservation and sustainable use must be the priority.	1.67 (4)**	−0.98 (− 2)	−0.88 (− 2)	−0.43 (− 1)
33	A comprehensive approach to manage a variety of water sources is very important. There is no silver bullet, whether that's desalination or reused water or fixing leaks in the pipes.	0.60 (1)	0.42 (1)	1.38 (3)	1.13 (3)
37	Desalination is an infrastructure project of the highest national importance for Israel in the 21st century.	−0.14 (0)	1.20 (3)	−0.35 (− 1)	0.99 (2)
41	We need more storage capacity for recycled water. Farmers mostly use water in the summer, and there is not enough storage for recycled water in the winter, so a lot of recycled water goes to the sea.	0.76 (2)	−0.73 (− 2)	−0.53 (− 1)	0.29 (0)
45	Saying we will save water in the urban sector is an insufficient reason for postponing the establishment of desalination plants. Equating savings to resources is a dangerous illusion.	−1.73 (− 4)**	−0.23 (0)	0.72 (2)**	−0.57

Theme (c) Governance-Regulatory Environment					
10	Civil society's main focus should be on government to demand stricter regulation, inspections, and deterrents for the desalination industry.	0.33 (0)	−0.73 (− 2)	−0.08 (0)	−1.56 (− 4)*
19	The private desal companies basically manage the government in Israel. We have a very weak government and these big money moguls are managing the decision-making in Israel.	−1.01 (− 2)**	−2.26 (− 4)	0.25 (1)**	−1.99
20	Desalination and water reuse pose great risks if strong regulations and adequate enforcement are not in place.	0.55 (1)	−0.45 (− 1)	0.04 (0)	0.52 (1)
26	There are downsides to relying solely on Mekorot to provide water. Municipalities should preserve the ability to produce water by themselves in case something happens.	−1.01 (− 2)	−1.09 (− 3)	1.70 (4)**	−1.05 (− 2)
34	Government should give the right incentives, fair and transparent competition, and know when not to interfere with the private desalination sector.	−0.27 (− 1)	0.45 (1)	0.05 (0)	−1.46 (− 4)**
Theme (d) Barriers and Risks					
6	Desalination gives people a false sense of water security and abundance, and Israel has put conservation on the backburner as a result.	0.61 (1)	−1.07 (− 3)**	1.06 (2)	−0.14 (0)*
17	Desalination has much lower job creation potential than demand side approaches (CS).	−0.15 (0)	−0.53 (− 1)	−0.26 (− 1)	−0.38 (− 1)
27	Since less people are learning water and sewage engineering and public sector salaries are low, knowledge ends up in the private desalination sector, creating an undesirable imbalance.	−0.52 (− 1)	−0.58 (− 1)	1.09 (2)**	−0.2 (0)
32	We can identify pollutants in very low concentrations. We need regulations to remove these compounds from the water reuse system so that produce irrigated with reclaimed wastewater is safe to eat.	0.93 (2)	0.18 (1)	0.66 (1)	0.84 (2)
42	Desalination is electric water. Every time you open the faucet you're actually also using more electricity, so we need to educate people to save water even though we have desalination.	0.34 (1)	−0.27 (− 1)	−0.21 (0)	1.10 (3)*
43	Desalination allows the private sector to have its hand on our faucet. The more dependent we are on desalination for drinking water, the more we're giving a lot of power to very, very few people.	−0.63 (− 1)	−1.59 (− 4)	0.14 (1)*	−0.94 (− 2)
Theme (e) Promoters and Facilitators					
4	Thanks to desalination and water reuse developments, Israel can be the Silicon Valley of water and become a technology-driven export power.	0.74 (1)	1.05 (2)	0.98 (2)	0.15 (0)
8	Climate change and population growth leave us with no alternative. There is no more water available, so we require desalination and reuse.	0.98 (3)*	1.83 (4)	−0.64 (− 1)**	1.70 (4)
15	Israel has access to the Mediterranean Sea, so we have unlimited water, meaning we're never going to be out of water for desalination.	−1.18 (− 3)	1.68 (3)**	−0.90 (− 2)	0.62 (1)**

(*Continued.*)

Table 1 | Continued

Statements		*Z* (V)			
No.	**Full statement**	**Factor 1**	**Factor 2**	**Factor 3**	**Factor 4**
23	Desalination requires a stable energy supply, so the natural gas offshore in Israel is a game-changer to improve energy security and lower the prices of desalinated water.	−0.93 (− 2)**	1.00 (2)	0.41 (1)	0.52 (1)
Theme (f) Technological Transitions and Pathways					
22	Desalination is a big financial commitment that comes at the expense of something else. You're committing the money for 25 years ahead, so you close some opportunities.	−1.26 (− 3)	−0.79 (− 2)	−1.88 (− 4)	0.70 (2)**
28	Desal is moving us to an infinite resource. Sure, you pay money, you invested in infrastructure, but once it's in place, it's not an issue anymore.	−1.40 (− 3)	1.07 (2)**	−0.92 (− 2)	−0.99 (− 2)
29	Demand for R&D is different for water reuse and desalination. In desal, you get one main technology, reverse osmosis. But for water reuse, there is more demand to develop new technologies.	−0.36 (− 1)	−0.11 (0)	−0.70 (− 2)	−1.20 (− 3)
30	I think we will see 100% desalinated drinking water and almost 100% reuse of wastewater in the future in Israel.	0.18 (0)	0.52 (2)	−1.01 (− 2)	−0.29 (0)
35	Our old water reuse infrastructure can't support the growing population. We need smart technology to manage the system, and this is a transition the whole water sector will have to go through (CS).	0.50 (1)	0.31 (1)	0.05 (0)	0.24 (0)
Theme (g) Cost–Value–Nexus					
1	Giving water away for free is not an option. You can't decide on water supply technologies like desalination and water reuse without looking at who's going to pay and if it's affordable (CS).	1.21 (3)	1.72 (4)	1.85 (4)	0.97 (2)
11	Water reuse is much more economical than seawater desalination, so it makes more sense to pursue water reuse first.	1.38 (3)*	0.03 (0)	−0.14 (0)	0.70 (2)*
24	Desalination should remain funded from water prices and disconnected from government budgets.	−0.06 (0)**	0.69 (2)**	−1.37 (− 3)	−1.18 (− 3)
38	Rising water prices because of large water infrastructure projects are a big issue because farmers can't afford the price of water that we're going to see in the future owing to desalination (CS).	−1.10 (− 2)	−0.54 (− 1)	−0.47 (− 1)	−0.38 (− 1)
40	Once you build a desalination plant, you want people to use as much water as they can. You don't want them to save because then the Build-Operate-Transfer partnership can't hold.	−1.83 (− 4)	−0.86 (− 2)	−0.17 (0)*	−1.31 (− 3)

Theme (h) Climate Change and Sustainability Dimensions					
7	It's important to protect the environment, but if environmental protections kill the desalination project, you won't have people to enjoy the environment.	−1.87 (− 4)*	−0.44 (− 1)	−0.37 (− 1)	−1.03 (− 2)
13	Desalination is a major risk to marine biodiversity, because the accumulated impact of so much brine on the marine environment is a great unknown.	0.19 (0)**	−2.22 (− 4)**	−0.76 (− 2)	−0.94 (− 2)
14	Desalination plants that run on fossil fuels produce a lot of emissions. We need to promote desalination plants that run on renewable energy.	1.65 (3)	0.45 (1)**	1.39 (3)	−1.37 (− 3)**
21	Instead of building another desalination plant and eventually releasing more CO2 and using more energy, we need to educate people how to use water in a smart way.	0.77 (2)	−1.07 (− 3)**	0.09 (1)	0.62 (2)
36	Water reuse is an environmental improvement for stream rehabilitation. It doesn't return the same quality, but you'll have water in the stream which is better than not having it (CS).	−0.25 (− 1)	0.35 (1)	0.20 (1)	0.48 (1)
47	With desalination, Israel is entering an era of sustainable use of water resources, and that will eventually lead to the reviving of the streams and the natural water ecosystems.	−0.69 (− 1)	0.10 (0)	−1.47 (− 3)*	−0.38 (− 1)
Theme (i) Israeli–Palestinian Relations					
9	The Mediterranean is a small bathtub, so pollution eventually reaches someone else. We have to work with our neighbors as if there are no political borders to protect the water for desalination.	1.78 (4)	0.15 (1)**	1.27 (2)	1.65 (3)
18	The political situation with the Palestinian Authority has to be fixed because we get their sewage in our seawater, surface water, and aquifers which affects our desalination.	0.76 (2)	0.09 (0)*	0.87 (2)	1.65 (3)*
25	In the past, the water shortage has been a pretext for war. Today, in our region the subject of developing new water sources like desalination can serve as a bridge for peace.	0.80 (2)	1.88 (4)**	−1.31 (− 3)**	0.60 (1)
39	The idea that desalination will lead to peace in the Middle East is not true. Additional water supply will not solve who controls the Temple Mount or where the Palestinian capital will be.	−1.15 (− 2)	−0.78 (− 2)	1.58 (3)	1.85 (4)
44	Israel should use its desal knowledge as a public diplomacy tool, helping countries around us build and establish desalination and water reuse (CS).	−0.16 (0)	0.10 (0)	0.03 (0)	0.46 (1)

Note: Significant ('distinguishing') statements for each factor indicated for $p < 0.05$ (*) and $p < 0.01$ (**). *Z*-scores in standard deviations.
CS, consensus statement.

The overall salience ascribed to the nine themes by the different social perspectives identified was calculated by adding the *Z*-scores of the statements in each theme (as absolute values) and normalizing the sum to the number of statements per theme (Webler *et al.*, 2009). Salience estimates the agreement or disagreement of a factor with entire themes, not just single statements, and can therefore help better understand the underlying rationale of social perspectives. Since salience reflects the importance assigned to themes by participants, it can also help validate the inclusion of such themes in the study.

RESULTS AND DISCUSSION

Social perspectives

A four-factor solution was considered the most robust empirical solution for our study (see Supplemental Material, Table S4). This solution explained 58% of the variance and all factors contained more than two defining sorts (see Table 2 with different factor characteristics). Factors were clearly different since correlations between them were relatively low (less than 0.5) (Table 3). Respondent affiliations and correlations with extracted factors are shown in Table 4. Table 1 also presents factor scores and values for each statement in the Q-set, organized by theme. Reference to statements used to describe factors include the statement number (e.g., #15), the rank value assigned to this statement in the factor (e.g., 0, + 4, −2), and the level of significance, if applicable (* for significant statements at $p < 0.05$, and ** for highly significant statements at $p < 0.01$). Respondents are identified with their IDs and we indicate their factor number and loading (e.g., NON01; F1 = 0.8393).

Factor 1: desalination should be the option of last resort

Factor 1, which explained 21% of the variance and was defined by the sorts of eight participants representing diverse groups, except representatives of desalination facilities (Table 4), strongly supports the idea that

Table 2 | Factor characteristics.

Variable	Factors Factor 1	Factor 2	Factor 3	Factor 4
Eigenvalues	7.227	3.149	1.709	1.422
Percentage of variance explained	21	19	10	8
Number of defining sorts	8	8	3	3
Average relative coefficient	0.80	0.80	0.80	0.80
Composite reliability	0.970	0.970	0.923	0.923
Standard error of Factor *Z*-scores	0.174	0.174	0.277	0.277

Note: Eigenvalues from unrotated matrix for eight factors. Other variables from the four-factor solution.

Table 3 | Correlations between factor scores.

Factors	Factor 1	Factor 2	Factor 3	Factor 4
Factor 1	1	0.3125	0.3326	0.3756
Factor 2	0.3125	1	0.095	0.4015
Factor 3	0.3326	0.095	1	0.2455
Factor 4	0.3756	0.4015	0.2455	1

Table 4 | Respondent affiliations listed alphabetically and correlations with extracted factors.

Participants		Factor loadings with 'X' indicating defining sorts							
Sort ID	Sectoral affiliation	Factor 1		Factor 2		Factor 3		Factor 4	
DES01	Desalination facilities	−0.0872		0.7311	X	−0.1065		0.1337	
DES02	Desalination facilities	−0.2104		0.6661	X	−0.2794		0.1740	
DES03	Desalination facilities	0.2950		0.6659	X	0.0314		0.1392	
PRI01	Market sector services	0.5147		0.6750	X	0.1492		0.0997	
PRI02	Market sector services	0.3999		0.0540		−0.1237		0.5658	X
PRI03	Market sector services	0.4749	X	0.2767		0.1194		0.3076	
PRI04	Market sector services	0.2477		0.7259	X	0.3372		−0.0916	
NON01	Non-profit organizations	0.8393	X	−0.0939		0.1041		−0.0485	
NON02	Non-profit organizations	0.7928	X	−0.0314		0.3844		−0.0316	
PUB01	State sector	0.0924		0.4089		0.1967		0.6527	X
PUB02	State sector	0.4900	X	0.1989		0.0013		0.2004	
PUB03	State sector	0.6236	X	−0.2519		0.0838		0.4742	
PUB04	State sector	0.1168		0.6784	X	−0.0026		0.0862	
UNI01	Universities or research centers	0.1299		0.1842		0.2854		0.7122	X
UNI02	Universities or research centers	0.6806	X	0.1383		−0.1004		0.2993	
UNI03	Universities or research centers	0.5575		0.2924		0.5505		0.0930	
UNI04	Universities or research centers	0.4213		0.2082		0.6187	X	−0.1452	
UNI05	Universities or research centers	0.0330		0.5924	X	0.2033		0.1362	
UNI06	Universities or research centers	0.6284	X	0.3916		0.0232		0.1114	
WAT01	Water companies	0.3528		0.6283	X	−0.1597		−0.0093	
WAT02	Water companies	0.7235	X	0.2280		0.1187		0.1416	
WAT03	Water companies	0.1174		0.0398		0.7177	X	0.2248	
WAT04	Water companies	−0.1207		−0.2196		0.6660	X	0.1283	

Note: Significant factors were extracted and rotated by PCA (Varimax function).

desalination should be the option of last resort and advocates for water conservation and sustainable water use (see, for instance, statement #31: + 4**). Notably, the factor's two highest scores belong to the only two participants affiliated with non-profit organizations. The participant with the highest score (NON01; F1 = 0.8393) indicated that 'conservation and sustainable use must be the priority … the first focus', particularly in a context of water scarcity and political conflict over land.

This perspective assigns the utmost importance to environmental protection even if this may affect or delay the establishment of new desalination facilities, as indicated by the negative value ascribed to statement #7 (−4*). In line with this environmental approach, Factor 1 views saving water in the urban sector as a powerful tool that may reduce the immediate need for desalination plants since water savings can be safely considered additional water resources (#45: − 4**). Water recycling thus makes more economic sense for this perspective than embarking on allegedly more costly seawater desalination (#11: + 3*). This perspective is not, however, against desalination technology. In fact, respondents believe that, in the long term, desalination is probably the only way to counteract the effects of climate change, population growth, and water scarcity in the region (#8: + 3*).

Claims made by some respondents who aligned with Factor 1 help understand its supporting ideas. For example, respondent PUB03 (F1 = 0.6236) was 'not against desalination, but for sustainable desalination, and not for 'let's desalinate like crazy and have swimming pools everywhere'. Probably because of their environmental concerns, participants whose perspectives align with the idea that desalination should be the option of last resort do not believe that cheap natural gas from offshore wells will improve energy security and lower the prices of desalinated water in Israel (#23: – 2**). When it comes to the financial aspects of desalination, Factor 1 is neutral about the idea that desalination should remain funded only from water prices and therefore disconnected from government budgets (#24:0**). This is consistent with a certain degree of confidence this factor has in the ability of the government to resist the influence of powerful private desalination companies and make independent water policy decisions (#19: – 2**).

Respondents in this factor were neutral on the idea that desalination poses a major risk to marine biodiversity (#13:0**). This may be surprising, considering that this factor is certainly the most concerned about environmental protection and sees desalination as 'the option of last resort'. A reason for this apparent neutrality is most likely linked to the way in which this statement was formulated, particularly the first part, in which desalination is said to pose 'a *major* risk to marine biodiversity' (emphasis added). Some respondents indicated that the environmental risks are real, but they probably do not pose a major risk to the marine ecosystem. Despite this apparent neutrality, this factor still ranked this statement higher than the other factors, all of which assigned negative rankings to it.

Factor 2: desalination is moving us to an infinite resource

Factor 2, which accounted for 19% of the variance and included eight sorts from diverse groups except the public sector (Table 4), is confident in the advantages of using desalination as a new water source. All three participants employed at a desalination facility aligned with this factor. The Mediterranean Sea is seen by respondents in this factor as an unlimited desalination water source (#15: + 3**). They agree, though, with the statement that indicates that the increasing use of desalination technology may have hampered water conservation efforts in Israel (#6: – 3**). This situation is not necessarily due to lack of information or public awareness, and they see no need for more public education on water conservation before building more desalination plants (#21: – 3**). However, this perspective is not against public education on water issues; rather, as one participant (DES01; F2 = 0.7311) argued, while calling the attention of the interviewer about the fact that he was drinking desalinated water during the interview, there is a need do 'both, not either'. He went on to say that

> '… *it's not 'or' but 'and', it's not either educate people or build a desalination plant, it's do both: educate people [on water conservation] and build the desalination plant. We have to conserve water, we have to save on all aspects … [we have] to do desalination as efficiently as possible … having a lower carbon footprint, using less electricity, doing it with less chemicals*'.

An interesting distinctive feature of this perspective is that, more than any other factor, it believes that desalination can serve as a bridge for peace in the region (#25: + 4**). This is probably aligned with their essentially techno-optimistic approach to water management and their clear reliance on the private sector as the engine of a more efficient water management. In fact, the 'infinite resources' perspective strongly disagrees with the idea that desalination allows the private sector to accumulate too much power, suggesting extreme confidence in the private sector to efficiently and transparently operate desalination facilities (#43: – 4*). Respondents in this factor ranked statement #28 higher than any other factor (+2**) and therefore believe that desalination facilities, once built, are no longer an issue because they are tapping into a virtually infinite resource. Due to

confidence in the private sector, respondents in this perspective support market instruments such as water tariffs to fund desalination, instead of government budgets (#24: + 2**). In line with this financial and managerial approach, this perspective coherently argues that civil society should not push for stricter regulation, inspections, and deterrents for the desalination industry (#10: – 2*).

Confidence in the desalination industry is also consistent with a strong belief that the environmental impacts of desalination to the marine environment are low (#13: – 4**). It is important to highlight here, as indicated above for Factor 1, that a negative ranking for this statement could be linked to the adjective 'major' associated to the risk to marine biodiversity. In fact, a participant affiliated with this perspective indicated that the risk posed by desalination to marine biodiversity does exist, but 'I don't think it's a major risk' as implied in statement 13 (PUB04; F2 = 0.6784). Other respondents where more explicit about the environmental impacts of desalination. For example, DES02 (F2 = 0.6661) argued the volume of desalination wastewater being discharged into the ocean is not significant: '… at the end of the day, it is a drop in the ocean, whatever effect it has, it's very, very local'.

Environmental skepticism likely explains the 'infinite resources' perspective's modest support for using renewable energy to run desalination plants (#14: + 1**). The use of renewable energy to run desalination plants and therefore reduce emissions sometimes faces opposition based on the alleged lack of land in a small country like Israel. One aligned respondent (DES01; F2 = 0.7311) indicated that even though he was in favor of renewable energy, he was also worried about the physical footprint of desalination plants located in coastal areas where it would not make sense to 'cover the beach with solar panels'. However, other respondents (e.g., PUB04; F2 = 0.6784) supported renewable energy for desalination. A respondent from Factor 3 (UNI04; F3 = 0.6187) put the issue of the physical footprint of renewable energy in perspective by saying that even though it's true that 'the main issue of land use is the scarcity of land along the seashore, where you put the big plants … electricity you can move much easier than you can move water' and therefore electricity for desalination could be produced elsewhere, even offshore or in other countries.

Factor 3: equating water savings to resources is a dangerous illusion

Factor 3, which accounted for 10% of the total variance and was defined by the sorts of three participants (Table 4), is worried about water insecurity in Israel despite the widespread availability of desalination and water recycling technologies (#48: – 3**). In a stance that parallels the 'technological fix' contradiction presented by desalination (Feitelson, 2018), 'Equating water savings to resources is a dangerous illusion' means that potential water savings in the urban sector should not stop investment in new desalination plants (#45: + 2**). This perspective does not perceive the Israeli water system as sustainable partly because natural water systems do not benefit from the availability of additional water from desalination, which is all being used for domestic or industrial consumption (#47: – 3*). This factor shows a pragmatic approach to water issues, equally supporting desalination, water recycling, and conservation efforts as part of a diversified water management strategy. Respondents aligning with this factor do not have strong opinions on desalination technology and its potential consequences on water systems and consumption patterns. However, they do not see desalination as unavoidable in the face of water scarcity, as suggested by the ranking and significance of statement #8 (–1**) since 'the amount of water on earth stays the same no matter what', in the words of one respondent (WAT04; F3 = 0.7177).

This perspective speaks to the technical and educational aspects of water management. In fact, this is the only factor that strongly highlighted the need for additional efforts in research and development in the water recycling sector (#26: + 4**), and expressed some concern about the training and salaries of the water workforce, particularly in the public sector (#27: + 2**). A respondent working for a municipal water company (WAT03; F3 = 0.7177) was explicit about this problem:

'*We already ran out of people. It's very, very rare that we are able to find an engineer, a water engineer, that agrees to come and work for us, and if they do it's just because they are clever and they want to have some experience in the public sector for one, two years, then they will go for the private sector*'.

In contrast to Factor 2, this factor reflects less trust in the private sector and believes that the government could be manipulated by a few big private companies if the country becomes too dependent on desalination (#19: + 1**; #43: + 1*). This is consistent with its lack of support of a centralized water system that controls all water sources (#16: – 1*). Unlike all the other factors, Factor 3 is clearly skeptical about the potential of water management to be a bridge for peace in Israeli–Palestinian relations (#25: – 3**) (Table 1). Similarly, Factor 3 (together with Factor 4) rejects the idea that desalination will lead to peace in the Middle East or that additional water supply will solve geopolitical conflicts between Israel and the Palestinian Authority (#39; F3: + 3, F4: + 4) (Table 1). Although respondents in this perspective did not elaborate on this issue, during preliminary interviews one participant (WAT03; F3 = 0.7177) seemed extremely concerned about 'some kind of attack on the desalination [facilities] that will shut them down' and also on cybersecurity, because 'somebody can physically get to one of the infrastructures' and sabotage them.

Factor 4: desalination is (risky) electric water

Factor 4, which accounted for 8% of the variance and was defined by three participants from three different sectors (Table 4), is very concerned about the risks and energy aspects of desalination. For this factor, the energy needed for desalination is no different from the energy needed in the past to operate the pumps that uplifted water from the Sea of Galilee. The energy issue is somewhat underestimated by stronger advocates of desalination, such as those in Factor 2 ('Desalination is moving us to an infinite resource'), who seem to focus more on the allegedly infinite character of the sea as a source of water for desalination than on the energy needs of this technology. Respondents in Factor 4 put especial emphasis on the need to educate people to save water (#42: + 3*) since, as participant NON02 (F1 = 0.7928) argued:

'*… we're talking about 'electric water', every time you open the faucet, you're actually also using more electricity … [we have] to make people understand that they need to save water even though we have desalination, because everybody thinks that if we have desalination then … we don't have to save money, and everything is fine*'.

In what at first sight may appear as a contradiction, participants who loaded on this factor ranked negatively the idea that desalination plants should run on renewable energy (#14: – 2**). However, interviews demonstrated support for the use of renewable energy in general, but also a concern:

'*The biggest question is energy … water security through desalination, it's really about energy security as much as it is about water security. And here the question is, you know, what is my energy source, am I increasing CO_2 emissions, am I contributing to climate change through these big factories …. So, energy and water here are very, very tightly coupled when it comes to desal (UNI01; F4 = 0.7122)*'.

Further developing the energy security concern, this respondent stated that '… one of the problems is that, in terms of maintaining these technologies, it's really a matter of a stable energy supply. So, the fact that Israel has now been investing heavily in offshore natural gas more or less removes the energy piece as a potential threat to water security'. Renewable energy is perceived as less reliable than other sources, because, in the view of one

respondent, water supply would suffer 'if we have two weeks without sun, without wind …' (PRI02; F4 = 0.5658). Thus, instead of using renewable energy to run desalination plants directly, 'it's more about diversifying the national grid (UNI01; F4 = 0.7122)'. Moreover, UNI01 noted the relationship between energy sources and the price of water: '… desalination is no longer expensive, it's affordable, it's only going to get cheaper over time. The energy questions are being effectively addressed … [desalination plants] are becoming more energy efficient and that's also driving the price down'.

Other potential risks to desalination and water recycling include sewage discharges, which may affect desalination facilities by potentially contaminating desalination water sources. Solving this problem is urgent enough as to constitute one more reason to solve the political situation with the Palestinian Authority, as sewage discharge from the Gaza Strip into the Mediterranean may impact Israeli desalination activities (#18: + 3*). This perspective is worried about direct potable reuse and decentralized grey water (re)use because these practices carry potential health risks (#12: + 1**; #5: − 1*). Respondents from other factors also raised this point, saying that '… health authorities … are afraid that people will [make] illegal connections between grey water and fresh water and pollution will start' (PRI03; F1 = 0.4749). Long-term financial commitments tied to the establishment of large-scale desalination plants are also a concern for Factor 4 (#22: + 2**). Participants aligned with this perspective see no major contradiction between water conservation and desalination (#6:0*) but, in agreement with Factor 1, see water recycling as preferable to seawater desalination on economic grounds (#11: + 2*). Their acceptance of desalination may be partly based on the idea that the Mediterranean Sea guarantees ample access to seawater, as suggested by the positive value assigned to statement #15 (+1**). In terms of governance, this perspective argues government control over the private desalination sector is needed (#34: − 4**), although some degree of decentralization is also desirable (#16: − 2*) because water management is 'very much a context specific type of issue' (UNI01; F4 = 0.7122). Similar to Factor 2, this perspective sees civil society's main role as not to push for stricter regulation, inspections, and deterrents for the desalination industry (#10: − 4). During the semi-structured interview, respondent UNI01 (F4 = 0.7122) indicated that 'civil society, the public, should simply know I'm getting water 24/7, it's good quality water, and therefore I'm prepared to pay my tariff'.

Similarities and differences between factors

Despite the differences described above, and some partial agreements between pairs of factors, there were also interesting similarities across all factors, as revealed by the eight so-called 'consensus statements' (Supplemental Material, Table S5). In Q-method jargon, 'consensus' simply means that different factors assigned relatively similar values to certain statements although, strictly speaking, this may not necessarily mean that respondents of different factors really agree fully on these issues. All factors strongly agree on the idea that water is an economic good and therefore someone has to pay for it (#1) and that water security and political security are tightly connected (#2). Even though environmental protection was not a unifying issue, all factors agree that the public health risks of water recycling can be counteracted by adequate monitoring and control of decentralized wastewater treatment systems (#46), and that water recycling is, to a certain extent, positive for stream rehabilitation (#36). All factors slightly disagreed that water should be kept affordable for farmers who may be affected by rising prices due to large water infrastructure projects (#38). The results of our study also show that all factors downplay the potential environmental impacts of desalination, with F2 and F4 strongly opposed to the claim in statement #13 that 'Desalination is a major risk to marine biodiversity, because the accumulated impact of so much brine on the marine environment is a great unknown' (F1:0**, F2: − 4**, F3: − 2, F4: − 2) (see Table 1). A respondent from Factor 3 (UNI04; F3 = 0.6187), for instance, complained about '… those very green people that object to anything … and are against desalination' while, according to him, the scientific evidence shows that desalination has small and 'very, very local' environmental impact.

Differences across all factors are suggested by Q-Sort values sorted by consensus versus disagreement, as indicated by the variance across Factor *Z*-scores. Disagreement means that different factors assigned different values to the statements, not that they disagree with the meaning of particular statements. As highlighted by Huaranca *et al.* (2019), information on consensus and disagreement across social perspectives on a given issue is important to focus debates, reach compromises, and overcome apparently irreconcilable positions. Our results show that the link between desalination and peace in the Middle East was not a point of consensus among the social perspectives identified, suggesting that optimism on the potential of desalination as 'a game-changer in transboundary hydro-politics' (Aviram *et al.*, 2014) may not be as prevalent as it was in the past. In fact, the issue of Israeli–Palestinian relations did not help define any social perspective, even though the management of shared groundwater resources, particularly the Israeli–Palestinian case and the broader issues of water and peace in the Middle East, has been extensively discussed for decades in international forums and research and policy circles (Isaac & Shuval, 1994; Feitelson, 2000; Feitelson & Haddad, 2001; Brooks & Trottier, 2010; Katz, 2021). In our study, factors assigned very different values to statement #39 ('The idea that desalination will lead to peace in the Middle East is not true. Additional water supply will not solve who controls the Temple Mount or where the Palestinian capital will be'.) (F1: − 2, F2: − 2, F3: + 3, F4: + 4) (Table 1). Similarly, the potential of water management to be a bridge for peace in Israeli–Palestinian relations was also an area of disagreement, as indicated for statement #25 ('In the past, the water shortage has been a pretext for war. Today, in our region the subject of developing new water sources like desalination can serve as a bridge for peace'.) (F1: + 2, F2: + 4**, F3: − 3**, F4: + 1) (Table 1). Respondent UNI01 (F4 = 0.7122), for instance, was skeptical about the power of water to bring a solution to the Israeli–Palestinian conflict:

> '*Israel won't release the water if the Palestinians link it to sovereignty, and the Palestinians won't approve a project if Israel doesn't give them some kind of … political recognition or control. So, people go without water*'.

Other areas of disagreement across factors were the need to decentralize the water system to give municipalities more control over water (#26), the use of renewable energy to run desalination plants (#14), and the ability of desalination technology to be the ultimate solution for Israel's water problems (#15 and #31). On the other hand, some of the commonalities and differences across the factors are also tied to issues at the edges of contemporary Israeli policy for water security, as we will discuss in more detail in the section 'Emerging issues'.

Salience

Salience ascribed by the different factors to the nine themes of this study was consistent with the description of each factor. As seen in Table 5, all themes received relatively high mean scores, which provides empirical validation of their inclusion in the study. The highest normalized mean *Z*-score for all factors was assigned to theme 'Water Security' (1.05) followed by 'Promoters and Facilitators' (0.96). On the other hand, the lowest normalized mean *Z*-score was assigned to themes 'Barriers and Risks' (0.60) and 'Water Systems' (0.71). This is in line with the general findings of the study and the opinions gathered during interviews, with respondents from all factors worried about water availability and the need to keep a diversified water portfolio to ensure a reliable water provision throughout the year. We also found interesting differences between factors that align well with the descriptions provided above. First of all, themes with highest salience were different across the factors, which is reasonable if factors are truly different. Factor 1 assigned the highest salience to 'Cost–Value–Nexus' ($Z = 1.12$) (Table 5). Relatively high salience was also assigned to 'Water Security' and 'Promoters and Facilitators' (*Z*-scores = 1.02 and 0.96, respectively). These findings seem consistent with the concern expressed by respondents in this factor about the high costs of desalination and its potential environmental impacts (see, for

Table 5 | Salience of different themes for the four factors identified.

		Aggregated *Z*-scores				Normalized *Z*-scores				
Themes	***n***	**F1**	**F2**	**F3**	**F4**	**F1**	**F2**	**F3**	**F4**	**Mean**
(a) Water Security	5	5.1	4.7	7.8	3.4	1.02	0.94	**1.55**	0.67	**1.05**
(b) Water Systems	7	5.8	4.6	4.3	5.3	0.83	0.66	0.61	0.75	0.71
(c) Governance-Regulatory Environment	5	3.2	5.0	2.1	6.6	0.63	1.00	0.42	**1.32**	0.84
(d) Barriers and Risks	6	3.2	4.2	3.4	3.6	0.53	0.70	0.57	0.60	0.60
(e) Promoters and Facilitators	4	3.8	5.6	2.9	3.0	0.96	**1.39**	0.73	0.75	0.96
(f) Technological Transitions and Pathways	5	3.7	2.8	4.6	3.4	0.74	0.56	0.91	0.68	0.72
(g) Cost–Value–Nexus	5	5.6	3.8	4.0	4.5	**1.12**	0.77	0.80	0.91	0.90
(h) Climate Change and Sustainability	6	5.4	4.6	4.3	4.8	0.90	0.77	0.71	0.80	0.80
(i) Emergent: Israeli–Palestinian Relations	5	4.7	3.0	5.1	6.2	0.93	0.60	1.01	1.24	0.95

Note: Highest normalized *Z*-score bolded for each theme and for the overall mean.

instance, statement #11: + 3*). Factor 2 was more worried about 'Promoters and Facilitators' ($Z = 1.39$) and 'Water Security' ($Z = 0.94$), which aligns with the idea that climate change and population growth leave Israel with no alternative other than desalination to cover its water needs (statement #8: + 4*). Highest salience for Factor 3 was assigned to 'Water Security' ($Z = 1.55$). In fact, this factor believes that Israel is not a water-secure country despite the use of desalination and recycling technologies as indicated, for instance, in statement #48 (−3**). Finally, Factor 4 highlighted theme 'Governance-Regulatory Environment' ($Z = 1.32$). This factor has strong opinions on the role of civil society (see statement #10: − 4*) and government (statement #34:–4**). It is interesting to note that even though theme 'Emergent: Israeli–Palestinian Relations' obtained a relatively high mean normalized *Z*-score (0.95), none of the factors considered this theme as the most salient, which is congruent with the description of the factors based on individual statements and the differences and similarities among all factors described above.

Discussion: emerging issues

Two major issues emerged among the social perspectives identified. First, desalination is necessary for a water-secure Israel, but desalination should not be the only source of drinking water in Israel. As one participant (NON02, F1 = 7928) put it,

> '*[Desalination] is considered like the best thing that ever happened to Israel, and only now, [we] are starting to talk about it more and more … in order to show that there's … a darker side of this … We're not against desalination … We're not against. We want it to be managed better*'.

Several participants articulated the idea that Israel should not 'put all its eggs in one basket', a reference to perceived over-emphasis on desalination (UNI01, UNI03, WAT02, and PUB07). This idea highlights a difference between water sector stakeholders and the state strong focus on desalination. In response to statement #7 ('Desalination gives people a false sense of water security and abundance, and Israel has put conservation on the backburner as a result'), one participant gave a representative response: 'You know you don't want to put all your eggs into one basket, which is, to some degree, what Israel is doing' (UNI01, F4 = 0.7122). This same participant also noted that investment in desalination 'pushed us from an insecure to a secure [water system] … you

still always want to ensure and manage and keep as a reservoir your freshwater supply'. Numerous participants across the factors made similar observations that 'there should be a balance of all options' including conservation and desalination (DES01, F2 = 0.7311), to have 'a spread between [different water sources]' (DES02, F2 = 0.6661), and retaining a backup supply of 'natural water' (UNI04, F3 = 0.6187). Several participants also noted the over-reliance on desalination as a potential geopolitical threat by offering a small number of desal plants as 'strategic targets' for 'missile attacks' (WAT02, F1 = 0.7235).

Second, civil society involvement in Israel's water governance received attention across social perspectives. Several participants highlighted civil society's role of 'watchdog, both for industry and government' (PRI05). One public sector worker (PUB03, F1 = 0.6236) explained, 'There are things that we as civil workers can't really say out loud because our bosses are the politicians. So sometimes you need the NGOs to come and say the things out loud'. Another explained that civil society's role is 'to keep everyone honest' for 'policy and advocacy' (NON01, F1 = 0.8393). Participants noted that many NGOs in this role focus on the environmental impacts and costs of unconventional water production. As a public sector employee explained,

> *'[NGOs] come and they complain that this stream didn't get enough water this year and please fix it … [or] there are sometimes spills of sewage treatment sent to the sea and we need to treat that' (PUB07, no Q-sort).*

Although some participants see this role as important for Israel's 'level of transparency', several participants – particularly representing private sector interests – noted concerns that such organizations often take 'an extreme position' (PRI05, no Q-sort), which, as one NGO representative argued, is because 'we bother them. We're putting at risk big money and demanding more inspection that makes more work for them, because really there's minimal demands from the government and we're causing more, so it's a hassle and it's a pain in the butt' (NON02, F1 = 0.7928). Other respondents saw weaknesses in the actions of civil society organizations. One participant (UNI02, F4 = 0.7122) argued that civil society should 'raise the awareness of the public … and demand from the government to take an action' but concluded that 'NGOs in Israel are not powerful enough … and therefore they're not really doing their job unfortunately in that respect'. Another (UNI07, no Q-sort) saw civil society involvement as 'the weakness in the Israeli case … on the one hand, the water sector is very successful, but on the other hand, it's outside of the public realm. And actually, major decisions are being made with literally no public input and so the civil society is relatively weak when it comes to water'. Although a council for WA includes two government-appointed public representatives, some participants noted that efforts to create 'a true water board or commission' as mandated in the 1959 Water Law have been unsuccessful (UNI07, no Q-sort).

Concerns for environmental impacts of desalination are present among several respondents, but not in an individual factor. Stakeholders loading on different factors demonstrate concerns over environmental topics such as energy use, specifically greenhouse gas emissions and renewable energy development and use. Several participants, particularly loaders on Factor 3, also cited the 'water for nature' narrative, positing that water supply augmentation via desalination will actually benefit natural systems by reducing extraction and returning water to aquifers and surface water bodies. However, as indicated by McEvoy (2015), without an appropriate and effective institutional and regulatory framework, surplus water from desalination facilities will not contribute to a more sustainable water augmentation strategy and better resource conservation, but will instead promote further urban growth and water use. Similarly, concerns regarding the presence of personal care and pharmaceutical products in recycled wastewater also complicate earlier narratives presenting water recycling as uniformly environmentally beneficial (Malchi *et al.*, 2014; Fu *et al.*, 2019).

Basic water policy challenges such as the public acceptance of desalination and recycling technologies were crucial in the past. This issue, that may be seen as a 'first-order' challenge, seems to be less relevant now in

Israel, where these technologies have been in use for several years. This high degree of technological penetration makes Israel a relevant case study by highlighting 'second-order' policy challenges: those issues that only arise in water policy environments containing established desalination and water recycling systems. Several concerns arise in this respect, such as power supply, workforce, the role of civil society, water and political security, political independence, hydro-diplomacy, the footprint of renewable energy, micro-pollutants, and minerals in recycled and desalinated water, and, above all, the need to keep a diversified water portfolio. Even though some, if not all, of these concerns may not be entirely new, our study is the first to point out, based on empirical and rigorous social data from Israel, that these more complex concerns gain prominence in the public opinion after first-order social and environmental impacts are addressed or overcome. In other cases that are earlier in desalination or water recycling technological adoption trajectories, first-order challenges such as public acceptance or evident environmental impacts may overshadow some or all of those secondary concerns.

Some of the new concerns identified in our study seem to be more related to the political, economic, and social dimensions of desalination, and the alleged 'contradictions' of desalination, than to the more technical and managerial aspects addressed in most of the desalination literature so far (Williams, 2022). Feitelson (2018), for instance, identified an environmental contradiction owing to brine discharge and increased energy use and emissions, and a second contradiction whereby desalination has actually decreased water conservation and boosted household consumption. Several respondents raised concerns consistent with desalination's environmental contradiction. For instance, UNI03, a university professor and researcher who did not load significantly on any factor but had more affinity with factors 1 and 3, stated that 'we don't know enough about the environmental impacts of desalination, there aren't that many studies that have looked at this, especially on a long-term basis … in hindsight, every desalination plant that is supposed to be installed should have environmental impact studies, should have monitoring regulations in place from day zero'. The environmental contradiction can also be used, however, to boost support for desalination. Respondent WAT03 ($F3 = 0.7177$) expressed frustration at statement 13: 'How can someone say that [desalination] is very risky and, in the same phrase, say [that the impact is unknown] … I'm sure that at certain level the amount of salt can be a problem, but I don't [think] it's a very big thing'. Similar contradictions have been highlighted in other case studies where enhancing water supply reliability by desalination may introduce new vulnerabilities, compound the water–energy nexus, and change the social relations of control over water (McEvoy & Wilder, 2012; Wilder *et al.*, 2016; Williams, 2018; Fragkou & Budds, 2019). The contradictions of desalination have also been discussed by Swyngedouw (2013, p. 268), who argues that

> '*the desalination fix inscribes itself in a reworked, expansionary, developmental logic, in which water transfers combine with other modes of water management to produce more water, but a more radical critique has emerged that questions the hegemony of this hybrid mix aimed at sustaining the agro-tourist-urban growth machine*'.

Swyngedouw & Williams (2016, p. 69), in turn, argue that the six contradictions they ascribe to desalination (energy and climate, environmental, governance, growth, cost, and ownership) 'undermine the hegemonic consensus constructed around the desalination fix and its viability as a techno-managerial solution but also form the basis for a repoliticization of water governance more broadly'. In any case, our empirical results clearly show that future debates may arise when unconventional water sources such as recycling and desalination become more entrenched. Assessing the relative importance of second-order concerns and their relevance for future water governance in Israel is beyond the scope of this study, and would require additional technical and sociological research. Future research could also help better understand some of the specific, and usually contested, social and environmental aspects underlying some of the factors (e.g., the energy aspects of desalination, the environmental impacts of different water management strategies, the role of civil society and private

companies, etc.). Nuances observed within and between factors, however, clearly indicate a greater complexity than simple pro- or anti-desalination narratives, with increased focus on both the positive and negative impacts of the widespread adoption of this technology in the framework of a diversified water portfolio that also includes water conservation and recycling. We believe that dialogue with case studies in other areas of the world with similar water needs could help address some of the transversal issues and concerns that arose in this study. In any case, it is our contention that a thorough understanding of local social perspectives on water-related issues will be a key ingredient in a more robust and sustainable policy-making.

Limitations of the study

Although respondents reflect the current composition of Israel's water sector, they do not include end users such as household water customers or farmers, who may have different views on desalination and water recycling and should be the focus of future work. Participants performed Q-sorts remotely during virtual meetings and/or on their own using Q-TIP software. This could have affected participants' understanding of some statements and the sorting task, but we aimed to address all queries and concerns fully. Even though most of the participants indicated that the statements used in this study were clearly taken from current debates on water management in Israel (which provides external validity to our Q-set), it is clear that a different set of statements would generate different factors and therefore lead to different conclusions, as is the case with all studies based on the Q-method.

CONCLUSIONS

We characterized four statistically significant social perspectives on desalination and water recycling in Israel: (1) desalination should be the option of last resort; (2) desalination is moving us to an infinite resource; (3) equating savings to resources is a dangerous illusion; and (4) desalination is (risky) electric water. A common characteristic of the social perspectives is a belief that desalination is necessary for a water-secure Israel, showing agreement with Israel's policy emphasis on deploying desalination technology as the primary source of drinking water. Yet there was also a strong consensus across the factors that desalination should not be the only source of drinking water in Israel, and that the country should not 'put all its eggs in one basket'. Our findings indicate that Israeli stakeholders show more complex and contingent understandings of the pros and cons of desalination and water recycling technologies and the societal risks involved in too much reliance on a limited number of water sources. As Feitelson (2018, p. 65) notes, the very act of 'pursuing the supply augmentation technological fix' promised through desalination decreases the 'incentives to conserve water' which originally drove Israel's earlier policy approaches such as water recycling or its successful water conservation campaign. Our results highlight this tension between supply augmentation and conservation, as demonstrated by Factor 3, for which the idea that 'Equating savings to resources is a dangerous illusion' is a central tenet. Our results could help reassess the role of water-related decision-making processes in Israel and beyond, and revive debates that seem to be overlooked by governmental policy regarding water management and water security. Social perspectives on national-scale water-related issues will be a key ingredient in a more robust and sustainable policy-making. This was explicitly supported by an overwhelming majority of participants, who thought that by better understanding public perception, the government of Israel, private companies, or civil society could make better or more informed decisions in the future.

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DATA AVAILABILITY STATEMENT

All relevant data are included in the paper or its Supplementary Information.

CONFLICT OF INTEREST

The authors declare there is no conflict.

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