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ANALYSIS

Bridging decision networks for integrated water and energy planning

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ABSTRACT

Integrated policy and planning is needed to effectively meet the challenges of growing water and energy inter-dependencies in many regions. Joint consideration of both water and energy domains can identify new options for increasing overall resource use efficiencies. In order to identify and realize such opportunities, however, detailed knowledge of current and emerging water–energy couplings is needed along with a nuanced understanding of key actors and agencies engaged in decision-making. In this paper we develop a systematic, analytical approach based on quantitative analysis of water and energy couplings, identification and characterization of key actors and groups using concepts from stakeholders theory, and employing notions from organization theory of boundary-spanning agents that can serve to bridge inter-organizational networks for water and energy planning. We apply this approach to conduct an in-depth investigation of water and energy resources in Jordan, a country that is at the cusp of developing new infrastructure that will enmesh its water and energy future. We find that oil-shale development (a strategic objective of the Ministry of Energy and Mineral Resources) will create new water requirements and new sources (such as desalination of seawater and greater reuse of wastewater) will help in fulfilling demand. There may also be opportunities for creating water savings in the agricultural sector and using wastewater from the municipal sector for partially fulfilling water needs in the energy sector. Realizing such arrangements however will require joint cooperation across a number of different agencies such as the Water Authority of Jordan, Jordan Valley Authority, the Natural Resource Authority and municipal water management companies. This coordination can be facilitated through boundary-spanning agencies, such as international donor agencies and The Ministry of Planning that are already locally well positioned for such a role.

1. Introduction

1.1. Overview

The inter-dependent relationship of water and energy [1], also referred to as the water–energy nexus, is of growing interest in resource planning and policy [2]. Water is needed for extracting fossil fuel, refining petroleum products, and cooling power plants for electricity generation. Energy is needed for water purification and desalination, pumping and conveyance, end-use (e.g. heating and cooling in buildings), and wastewater treatment [3]. In the Middle East and North Africa (MENA) region, this inter-dependency has become particularly important as new water supply augmentation strategies (such as desalination) are more energy intensive than traditional sources, and some non-conventional energy sources (such as shale oil and gas, solar thermal power plants) require more water [4]. The need to better understand these intensifying inter-dependencies has begun to be noted at high levels [5,6], and a number of efforts are underway to improve the knowledge base of the water and energy couplings in different regions of the world [7]. In addition to understanding the physical connections, however, it is also important to assess the social and political system within which the resource policies are made. An understanding of key stakeholders and a strategic linking of decision-

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making institutions are ultimately needed to allow for improved decision-making processes [8] needed to achieve higher resource-use efficiencies. Toward this goal, we present a systematic approach in which the water and energy resources of a region are first assessed, and the physical inter-linkages are identified (both for the present as well as future trends). We then conduct a holistic assessment of the major stakeholders in the water and energy sectors, followed by an analysis of possible strategies for linking decision-makers and enabling the design and implementation of integrated resource policies.

In this work, we apply our methodology to study Jordan, a country in the MENA region that faces acute water shortages and has limited domestic energy supplies, but is poised for significant changes that are likely to enmesh its water and energy futures. Furthermore, it has separate agencies for water and energy planning – a case that is common for many other countries in the region. Jordan, therefore, serves as a useful first case study. In on-going work, however, we are applying this approach to investigate other countries in the region that have different natural resource availability, socio-economic conditions, and institutional arrangements such as the United Arab Emirates (UAE), Oman, Iraq, and Kuwait.

1.2. Literature review

The water–energy nexus has been a subject of increasing research in recent years [9–11]. In some MENA countries, the inter-dependencies are already being manifested. For instance, in Saudi Arabia almost all of the natural gas currently produced is consumed domestically, primarily in the petrochemical industry and in seawater desalination [12]. Policy makers have taken note, and there is increasing desire for reducing per capita water and energy use in countries such as Saudi Arabia, UAE etc. [13].

While recognition of the inter-connected nature of water and energy has been an important first step [14], real change and a shift from traditional silos of domain-centric planning will only occur when there are decision-making structures bridging water and energy domains. From an organizational perspective, the planning, development, and management of water and energy systems has been historically under the control of different agencies [15,16]. Water and energy have been treated as separate 'sectors' for management in most countries. In some cases there may be overlap at a sub-sector level—for instance, water and power agencies that deal with water and electricity generation [17]. However, in most cases there are separate agencies that deal with petroleum and natural gas. While such arrangements may have functioned reasonably well in the past, the demands emerging from decreasing water availability in middle latitudes and semi-arid low latitudes [18] along with the desire to reduce per capita energy use in the MENA region [13] now necessitates an integration from an organizational and management perspective. The inclusion of the organizational dimension within the water–energy nexus research has been discussed in the past [19]. However, systematic analyses that use current and emerging physical couplings (within a region) as a basis to identify strategic organizational linkages are largely absent in existing literature. In this research, we make a first attempt in developing a framework wherein assessment of the physical (and engineered) systems is integrated with that of the social and political stakeholders. The aim of such an approach is to identify new and strategic opportunities for linking decision-making and ultimately realizing higher resource use efficiencies.

2. Methodology and approach

In this study our approach was based on the following three main components:

2.1. Quantifying physical resource inter-linkages

Water has high local variability, therefore each region and country must develop its own knowledge base relevant to its specific geo-environmental and socio-economic conditions [21–23]. Furthermore, both water and energy sectors encompass sub-sectors (e.g., oil, gas, coal, hydro) and segments (production, distribution etc.) Each region has its own set of specific inter-linkages that need to be characterized at the sub-sector and segment basis in order to identify practical options for improving decision-making.

In the case of Jordan, research from local institutions, strategy documents of government agencies, reports from non-governmental organizations and international donor agencies collectively provide a large amount of information on overall resource availability and use [24–27]. We used a number of these sources to identify current and emerging inter-dependencies between water and energy sectors in Jordan.

2.2. Assessing stakeholder networks

Policies related to resource development are often influenced by an array of complex factors that include not only geo-physical aspects but also economic and socio-political realities. As discussed earlier, the water–energy nexus needs to be considered from an institutional and social dimension, and not just as a set of input–output resource relationships [19]. Thus after investigating the physical inter-linkages of water and energy resources, we explored the social system within which water and energy planning is conducted. We employed concepts from stakeholders theory that are widely used in management research literature [8], and used a classification framework [28] to characterize key stakeholders in the water and energy sectors in Jordan. We augmented this analysis by constructing influence maps (based on our field research and published data) to identify the overall social network

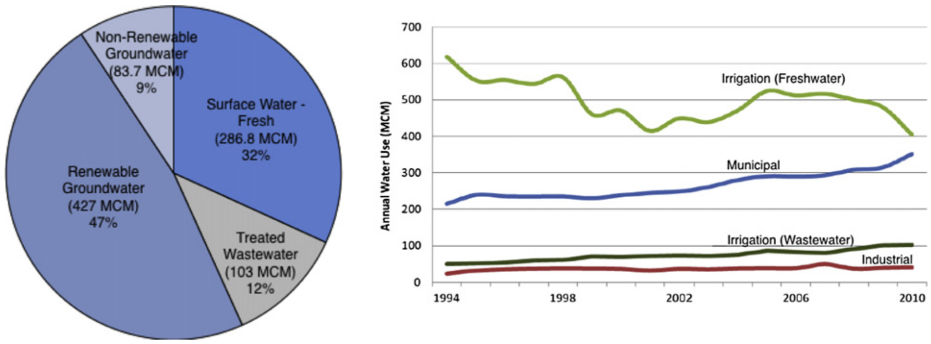

Fig. 1. Water availability (by source type in 2010) and use (by sector) in Jordan. Source: [32].

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Table 1
Water resources use (in MCM) for 2010.

Source	Domestic	Industrial	Irrigation	Livestock	Total Uses
Surface water (Fresh)	120	5.05	154.77	7	286.82
Treated wastewater	0	1.5	101.49	0	102.99
Renewable ground water	203.88	22.02	200.99	0.3	427.19
Nonrenewable ground Water	27.81	11.88	44.01	0.01	83.71
Total	351.69	40.45	501.26	7.31	900.71

Source: Ref. [32].

that can potentially be leveraged to identify and implement integrated policies.

Stakeholder analysis is widely used to identify new options and strategies for implementing policies. We have used this approach in our work, while recognizing that policy development is a complex process that frequently takes place in unstable and changing environments [8].

2.3. *Identifying possible boundary spanning intermediaries*

In order to implement mechanisms for integrated planning, we explored the concept of boundary spanning intermediaries (or agents), a notion that has been developed in the context of using knowledge to enable action and policy across different levels of decision-making [20,29]. Boundary spanning organizations are considered to be at the interface of communities of experts and communities of decision makers that can effectively bridge the two groups such that knowledge created within the expert community can be effectively utilized in policy and regulation [30]. This role stems from the definition of boundaries in organizational theory as "the demarcation line or region between one system and another, that protects the members of the system from extrasystemic influences and that regulates the flow of information, material, and people into or out of the system" [20]. While the notion of boundary spanning roles has long been explored in regards to organizational structures [31], in this paper we consider the specific use of such intermediaries for informing and integrating water and energy policy decisions. To the best of the authors' knowledge this is the first application of the concept of boundary spanning intermediaries to decision making across different areas of policy that have traditionally been administered separately in many countries.

Using the approach described above, we focused on three main questions for Jordan: (a) What are the existing key inter-linkages between water and energy resources; (b) what is the current inter-organizational network of energy and water sectors; and (c) what are potential interlinking organizations or boundary spanning actors that can serve to bridge knowledge generation and decision-making activities for the two sectors?

3. Analysis

3.1. *Water and energy resources in Jordan*

3.1.1. *Water availability and use*

Water resources in Jordan are extremely limited. The per capita annual availability was estimated to be 145 m^3—which is well below the water scarcity threshold of 1000 m^3 per person per year [25]. As of 2010, the total water availability in Jordan was estimated to be 901 million m^3 (MCM). Fig. 1 shows the sources that contribute to the overall availability and the evolution of water use by sector over time.

It can be noted that 68% of the supply is based on pumping groundwater or treating wastewater—both of which are generally more energy-intensive than securing surface water supplies. The water resources in the country are fully tapped, with the agricultural sector (irrigation and livestock) using 56%, the domestic (municipal) sector using 39%, and the industrial sector using the remaining ~5% of supply (see Table 1).

From Table 1, it can be noted that irrigation has ~49%, municipalities have ~66%, and the industrial sector has ~84% of its supply based on groundwater. This large dependence on pumped groundwater puts significant demands on energy.

Historically, agriculture has had the highest share of water use in the country, but with rising population the domestic (municipal) sector has increased its share over time (see Fig. 1). A number of reports suggest that there remain opportunities for water savings in agriculture through adoption and a number of reports suggest that there are opportunities for water savings through adoption of efficient irrigation methods as well as through switching cropping patterns [33]. In the municipal sector, it has also been noted that there are opportunities for water savings through reduction of leaks in the distribution infrastructure, and a number of such efforts are currently underway in the country [34,35].

3.1.2. *Energy availability and use*

Jordan is almost entirely dependent on imported oil and gas to meet its primary energy needs. In 2011, 1000 tons of crude oil and 6.4 billion cubic feet of gas were produced that together contributed to only 3% of the overall energy consumption in the country [27]. The imports of oil and refined products largely come from neighboring Arab countries through the port at Aqaba, and some processing of the crude oil is done at the only Jordanian oil refinery at Zarqa. Natural gas, which supplies all the major electric power plants, is imported from Egypt and is delivered through a pipeline (owned and operated by the Egyptian Fajer company) [27,36]. Fig. 2 shows primary energy production and use by sector in Jordan for 2011.

While local crude oil and gas production is limited in Jordan, the country is considered to have some of the largest oil shale reserves in

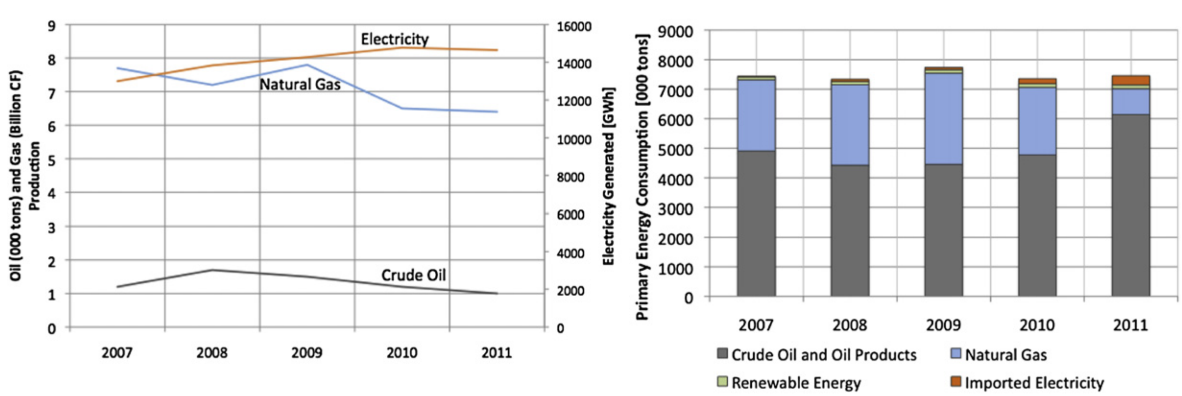

Fig. 2. Local energy production (by source type) and total use (by sector) in Jordan. Source: [27].

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the world [37]. Oil shale is a rock – containing an organic substance called kerogen – that can be retorted (heated) to form crude shale oil and gas. Four of Jordan's best known deposits (El Lajjun, Sultani, Jurf, Ed-Darawish, and Attarat Um Ghudran) are located about 100–120 km south of Amman (close to the town of Qatrana) and contain more than 22 billion tonnes of raw oil shale. It has been estimated that at an average oil yield of about 9.0% (roughly 22 gallons of oil per ton of raw oil shale), the oil that could be extracted from these deposits is approximately 14 billion barrels, which could satisfy Jordan's liquid fuel and electricity needs for centuries [36]. New estimates indicate that up to 40 billion metric tons of raw oil shale maybe present in the country [37]. With high oil prices in the world markets, some oil shale development options now seem economically feasible to some, even though the cost of accessing these resources in the past has been prohibitive, and there are growing efforts within the country to harness this resource [37]. One of the stated strategic objectives of the Ministry of Energy and Mineral Resources, as outlined in its most recent annual report, is to "develop and utilize the local conventional and renewable sources of energy, oil shale, and uranium" [27]. It remains to be seen how successfully the shale deposits in Jordan can be commercially harnessed at a large scale.

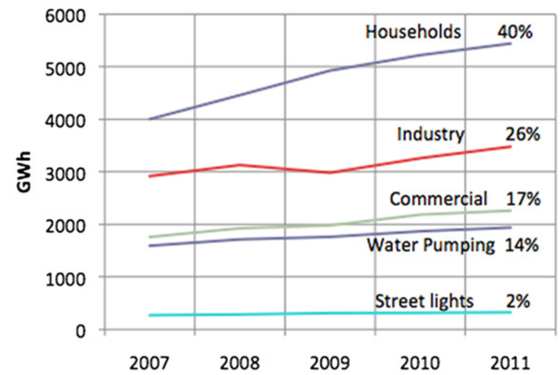

Fig. 4. Total electricity consumption by sector (2007–2011). The percentages indicate the share of total use by sector in 2011 (Source: [27]).

Based on the overall low levels of local oil production and processing and type of electric power plants, our first order quantitative estimates show that the energy sector does not currently pose large demands on water supplies in Jordan.

3.2. Jordan's water and energy inter-dependencies

3.2.1. Water use in energy sector

Jordan has ~2900 MW installed operational capacity of electric power plants. We reviewed the generation type and cooling technologies of the power plants using a database that provides unit-level details of power plants around the world [38]. Our results (see Fig. 3) show that steam and gas turbines comprise the bulk of the power generating units with small levels of hydropower and wind generation in the country. In terms of power plant cooling technologies however, where water use typically is largest, most of the plants either use air (dry) cooling or sea-water cooling (in the case of plants at the port city of Aqaba). Most of the electricity generation is from gas turbines that are not using a water-based cooling system (which forms the N/A case shown in the right in Fig. 3). Thus, unlike some other regions (such as in the US where 41% of water withdrawals are for electric power plants [39]), there is little dependence on freshwater for electricity generation in Jordan.

Jordan seemingly has a small oil production water footprint. We estimate that the modest crude oil production (of 1000 tons in 2011) does not account for significant water use (assuming that conventional oil recovery methods are used) [4]. The comparatively large refining operation in Jordan (processing 3157 tons in 2011) also does not appear to be a major user of water. Based on reported water use data (250 m^3 per hour) by the Jordanian oil refining company [40], we estimate a maximum water use of ~2 million m^3 annually, which represents 5% of industrial water use (of 40.45 MCM) in the country.

3.2.2. Energy use in water sector

Energy consumption within the water sector is largely in pumping operations that are used for accessing groundwater supplies as well as for delivering it through pipelines across the country. The pumps, operating on electric power, are attributed with 14–15% of total electricity consumption in the country (see Fig. 4). This constitutes a sizeable portion of electric power use, and is highlighted by the fact that 'pumping' is considered separately in the sector-wise breakdown of electricity use data in annual reports [27]. The Jordanian government is making concerted efforts in collaboration with international development agencies such as USAID and GIZ to increase pump efficiencies, thereby reducing energy use [34,35]. However, given the nature of water supply and distribution – where groundwater makes up 56% of the overall supply – it can be expected that even if these efforts succeed, a significant amount of energy will continue to be used for water provision and distribution.

Another key segment within the water system where energy use has often been found to be large is water used in households. Operations for cooling and heating water can be energy intensive [41]. In Jordan, however, based on low values of per capita consumption as discussed earlier in Section 3.1.1, we expect that the amount of growth in energy (electricity and gas) use within this segment can be checked through recent steps toward promoting solar water heating [42].

Wastewater treatment also requires varying amounts of energy that depend on the level of treatment and technologies used. In Jordan, most of the treatment can be assumed to be at primary or secondary levels, in which typical energy intensity ranges from 0.2 to 0.5 kWh/m^3

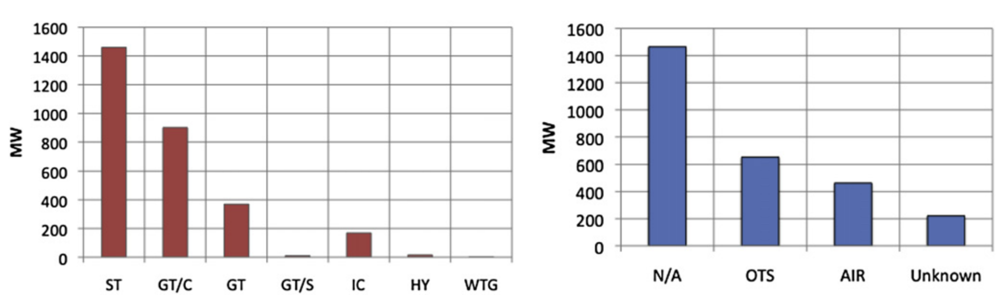

Fig. 3. Left – Operational capacity (by type) for electricity generation in Jordan. Right – Cooling technology in electric power plants in Jordan (Source: Platts database, 2010 [38]). Abbreviations – ST: steam turbine, GT/C: gas turbine with combined cycle, GT: gas turbine, GT/S: gas turbine with steam send off, IC: internal combustion (diesel) engine, HY: hydroelectric turbine, WTG: wind turbine generator, N/A: not applicable, OTS: once-through seawater, AIR: air (dry) cooling.

[43]. Using this assumption, and based on the reported total treated volume of 103 million m^3 for 2011 (see Fig. 1), we estimate that annual energy consumption for water treatment ranged from 20.6 to 51.5 GWh. In comparison to energy for water pumping (2000 GWh in 2011 as shown in Fig. 4), this represents a small fraction.

In summary, we find low dependence of water use in energy (both for oil production and processing as well as in electricity generation). However, energy use for water pumping is appreciable, at approximately 14% of total electricity consumption. The overall coupling is thus asymmetric with low dependency on water for energy, but higher dependency on energy for water. While the specific quantitative assessment made here is for Jordan, the general result (of an asymmetric nexus) is in line with recent studies we have conducted for other MENA countries [9].

3.2.3. Future water–energy couplings

While understanding the current state of water and energy interdependencies is useful, the more important question is how the coupling is likely to evolve over time. In order to address this question, we reviewed existing strategies and planning documents of the two sectors in Jordan.

In the water sector, while current deficits are being covered by exploiting non-renewable fossil groundwater, in the future (*i.e.*, by 2022), it is expected that large-scale desalination of seawater (from Aqaba) will be required (see Fig. 5). Additionally, current plans indicate that wastewater recovery and reuse will be expanded for use in irrigation and industry. Overall, it is expected that desalinated water supply will increase to 520 million m^3 and will constitute one third of the total water supply for the country. Treated wastewater volume will increase to 247 million m^3 (from currently 103 million m^3). Finally, there are plans for long-distance transfers (such as the Disi pipeline) [25] that will require pumping over higher elevations. The transfer will rely on energy-efficient water conveyance systems using energy recovery systems to reduce energy use.

If the options for developing new water supplies are realized as currently planned, then the significant shift toward desalination will impose new energy requirements. For a conservative lower bound estimate, if we assume that the energy (electric) intensity of desalination may range from 2.5 to 3 kWh/m^3 in the future desalination system [44], then the energy requirement for desalination and wastewater treatment (in 2022) can be expected to range from 1423 to 1745 GWh. This represents 10–12% of current total electricity generation in Jordan – in other words, a 10–12% increase in current generation will be needed by 2022 just for desalination and wastewater treatment.

The strategy, as described in Ref. [25], calls for using nuclear power plants for generating electricity and producing desalinated water. Nuclear power systems, however, require—and are likely to continue to require—very large capital investments (for construction) [45] and trained personnel (for operation). It is unclear how effectively these requirements can be met in the near future in the country.

The large oil shale reserves in the country are considered an integral part of future energy supply mix in current energy plans (see Fig. 5). It is projected that oil shale development will contribute 14% of energy supply, while nuclear energy is expected to supply 6%. Local energy supplies are expected to make up 39% of the total mix overall. It is worth noting that the water intensity of *in situ* oil shale extraction is significantly larger than that for conventional petroleum extraction [46,47].

The new shift toward oil shale has important implications in terms of water use: oil shale facilities will use water in mining, retorting, upgrading, refining, power generation, waste disposal, and site reclamation. Additionally, water will be needed in the cities where workers and their families will live. A study reported in Ref. [36] has assessed potential water sources for oil shale and has noted that there is essentially no surface water in the oil shale areas, except during flash floods. The groundwater supplies are already an important water source for cities, farms, mines, and existing industries in the area. The study estimates that if an oil shale industry emerges in Jordan, it will probably use surface mining and heated aboveground retorts, and the average net water usage could be approximately 3.2 barrels of water per barrel of upgraded shale oil produced. Thus, a 100,000 barrel per day industry might consume approximately 18.9 million m^3 per year which is as much as 0.5 million Jordanians – equal to the population of the city of Zarqa.

The water use for nuclear energy could also be significant, unless the nuclear power plants are built in Aqaba and seawater is used in cooling operations. If this is the case, freshwater impacts will be limited, but there may be ecological impacts associated with brine discharge in the Red Sea [48].

In summary, our combined review of water and energy strategies for Jordan finds that desalination and development of oil shale will intensify mutual inter-dependencies of the two sectors in the country within the next decade.

The current energy strategy notes the need for addressing the water access problem [49]. While the acknowledgment of physical resource inter-dependencies is an important initial step, it does not necessarily mean that the current system will improve the integration of water and energy resource management. Such integration may eventually occur in an *ad-hoc* manner over time. To increase the probability of improved and integrated resource use, it is important to specifically architect and institute inter-sectoral planning efforts. To design and implement such an effort, it is important to first understand the important

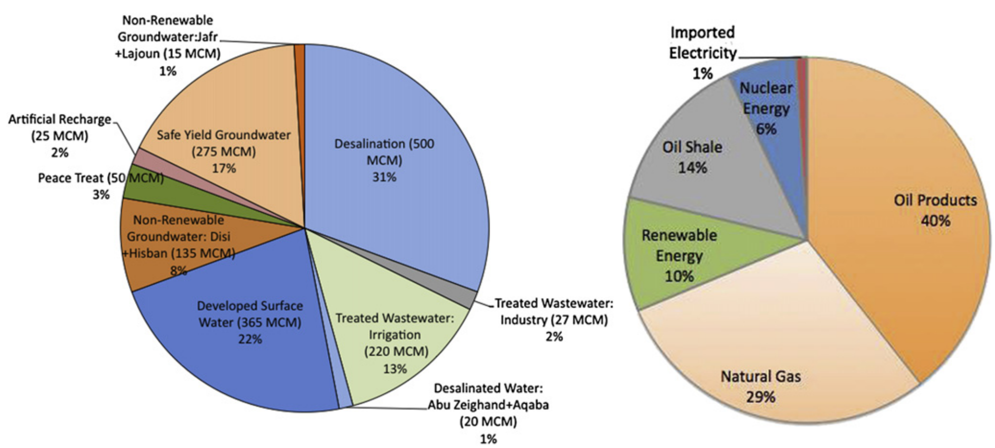

Fig. 5. Left – Expected water supply in 2022 (Source: [25]), Right – Expected energy mix in 2020 (Source: [27]).

decision-making organizations within both sectors. The following sections provide a detailed overview of the important stakeholders in the water and energy sectors of Jordan.

3.3. Water sector stakeholders

In the water sector in Jordan, the key decision-maker is the Minister of Water and Irrigation, who oversees the Ministry of Water and Irrigation (MWI), the Water Authority of Jordan (WAJ), and the Jordan Valley Authority (JVA). The minister is primarily advised by the Secretary General of the MWI, who provides both technical understanding and long-term sector experience in strategic thinking. Although the majority of long-term planning now falls to the MWI, it effectively serves as a policy planning organization over the JVA and WAJ, two older agencies that were created in the 1970s and 1980s to oversee access and delivery of water to specific economic sectors.

The Jordan Valley Authority (JVA) was created in 1977 to manage the water supply in the Jordan Valley through dam construction, irrigation and drainage water management for farmers, and the bulk supply of water to municipal and industrial users [32]. At that time, the JVA was also responsible for land management and distribution outside of municipal boundaries and the development of touristic infrastructure around the Dead Sea. It currently acts primarily as a bulk water supplier to farmers in the Jordan Valley with localized distribution and management increasingly ceded to local Water User Associations.

The Water Authority of Jordan (WAJ) was created in 1988 to focus on municipal and industrial water supplies as well as wastewater collection and treatment, and continues to be responsible for these services in addition to supervising and regulating the construction of public and private wells outside of the Jordan Valley. The laws governing WAJ were amended in 2001 to allow for private sector participation in the water sector. The utility sector was subsequently corporatized through management and service contracts, but currently remains nationally owned [32].

As mentioned previously, the primary decision-making power in the water sector rests with the Minister of Water and Irrigation, however, there are additional important and influential actors and groups that place both institutionalized and influential demands and ultimately impact decision-making. Most prominently, the King and Royal Council wield political influence and power (although sporadically rather than systematically), while the Prime Ministry (comprised of the Prime Minister and the appointed Cabinet) also has political influence and executive authority [50]. Table A1 in the Appendix provides a summary of the key institutions and their role in the water sector in Jordan.

In our work, we employ the widely used definition of a stakeholder as "any group or individual who can affect or is affected by the achievement of the organization's objectives" [28]. The list of actors (individuals) and agencies that collectively have some stake in the water sector (Table A1) was compiled through the combination of field research in Jordan and review of published literature. Our field research included ~15 primary qualitative interviews with stakeholders in government, aid agencies, the NGO community, the private sector, and academia, and were conducted in September and October 2012.

After compiling a broad list of stakeholders in the water sector, we systematically assessed their salience and comparative roles by using theoretical constructs and a classification scheme described by Mitchell et al. in Ref. [28]. According to this scheme there are three key attributes that a stakeholder (in relationship to a focal organization) can possess: power, legitimacy, and urgency. Power is defined as "a relationship among social actors in which one social actor, A, can get another social actor, B, to do something that B would not have otherwise done." Such power can be based on coercive ability (through force or threat), utilitarian (material) incentive, or on normative (symbolic) influence. The legitimacy of a stakeholder is defined as "a generalized perception or assumption that the actions of an entity are desirable, proper or appropriate within some socially constructed system of norms, values, and beliefs". The third attribute, urgency, is defined as "the degree to which stakeholder claims call for immediate attention". The urgency may be based on time sensitivity or potentially on the criticality of the claim from the stakeholder.

These three attributes collectively allow for classifying the salience of the stakeholders for a focal organization. In Mitchell's framework, a stakeholder is classified as a 'definitive stakeholder' if it possesses all three attributes (of power, legitimacy, and urgency). A stakeholder with power and legitimacy is deemed to be a 'dominant stakeholder', one with legitimacy and urgency is 'dependent', and one with power and urgency (but no legitimacy) is 'dangerous'. Stakeholders that have only one attribute are called 'latent stakeholders'. Those that only possess power are classified as 'dormant', those with only urgency are 'demanding', and those with only legitimacy are 'discretionary'.

It should be noted that the attributes are a matter of perception and are a constructed (rather than objective) reality. Also, the attributes may change over time and should not be considered to always remain in a steady state. In our analysis, the MWI was identified as the focal organization for policy making in the water sector, and attributes of its stakeholders were assigned based on our review of published materials as well as on the primary interviews.

From the perspective of MWI, our analysis shows that the definitive stakeholders are the King and Royal Council, the Prime Ministry, and both the Highlands and Jordan Valley farmers (Fig. 6). It is interesting to note that the powerful role of the agricultural sector is brought forth here. Moreover, the international development agencies (such GIZ and USAID) are dormant stakeholders, as they possess power (largely through monetary incentives), but as external actors lack the legitimacy of state institutions.

The stakeholders' classification serves to clarify the comparative salience and dominance of the different players. However, it does not specifically illustrate all of the inter-organizational relationships, the space they occupy within the societal spectrum, or the type of input or influence they exercise in the decision-making process. In order to develop such a perspective, we have created a map (Fig. 7) of the key stakeholders in the water sector based on our field research and literature review [25,26,32]. The vertical axis characterizes the

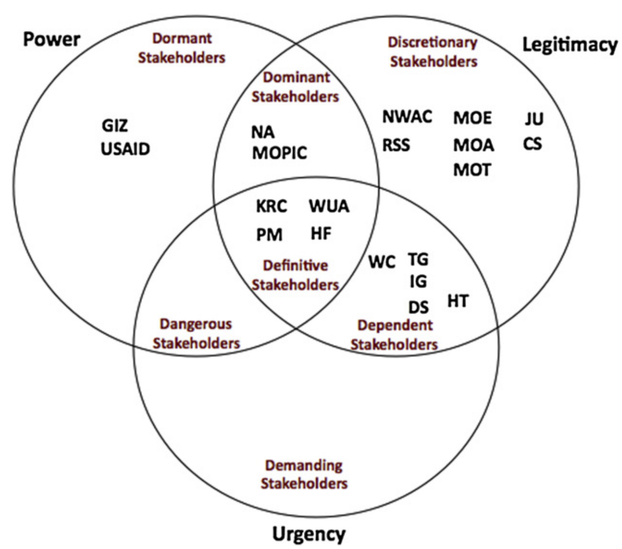

Fig. 6. Ministry of Water and Irrigation (MWI) stakeholder attributes and classification. Abbreviations: KRC: King and Royal Council; PM: Prime Ministry; WUA: Water Users Associations (of farmers in the Jordan Valley); HF: Highland Farmers. Please see Table A1 for other abbreviations.

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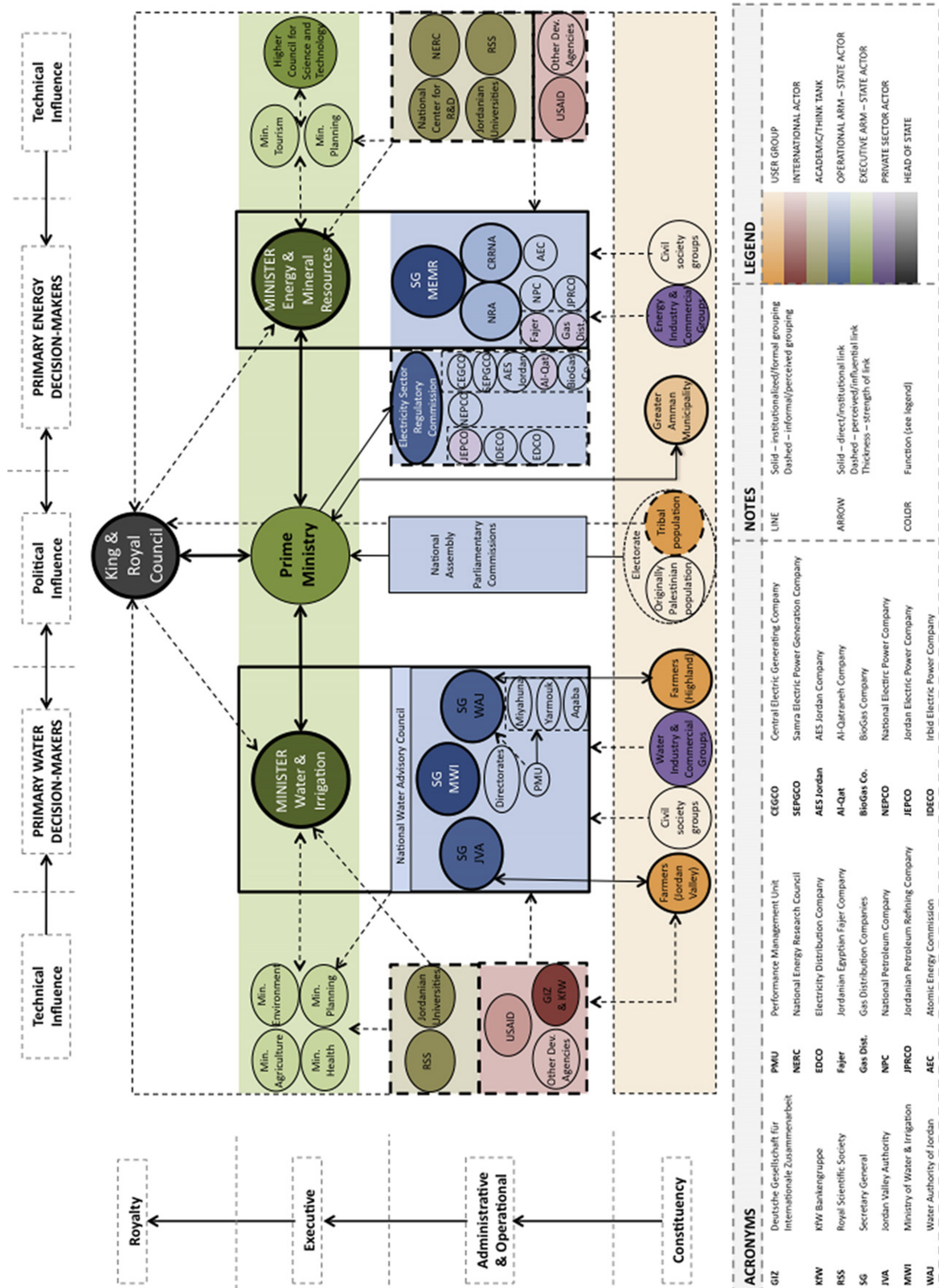

Fig. 7. Water and energy sector stakeholder map.

different actors in the water sector based on societal (or decision-making) level, while the relative positioning on the horizontal axis delineates the nature of the role or type of input each actor has on the decision-making process. The water sector stakeholders are shown on the left and the energy sector stakeholders (discussed in the next section) are mirrored on the right of the map.

As described in further detail in the legend in Fig. 7, the solid lines indicate formal or institutionalized links, while dotted lines indicate perceived links. Similarly, the solid boxes indicate formal groupings (*i.e.*, the JVA, WAJ and MWI are under the leadership of the Minister of Water and irrigation) while the dotted boxes indicate more informal groups. Finally, the depth of color indicates the level of perceived influence that each actor or organization was perceived to have based on our field interviews. Most significantly, the Minister of Water and Irrigation is clearly depicted as the central decision-making figure, although advised by the Secretary General of the MWI and, to a lesser degree, the secretary-generals of the JVA and the WAJ. The Prime Ministry and the King and Royal Council both play an overseeing role, while the GIZ and KfW are the most relevant actors among the donor agencies. Finally, at the constituency or user group level, the influence of the Jordan Valley and Highland Farmers is highlighted, as are the Jordanian tribes as a subsector of the total population.

3.4. Energy sector stakeholders

In the energy sector, the primary decision-making agency is the Ministry of Energy and Mineral Resources (MEMR). Within the Ministry, there are a number of agencies dealing with the regulation, licensing, and operation of energy supply services. The agencies tasked with regulation and monitoring are the Electricity Regulatory Commission (ERC), the Natural Resources Authority (NRA), and the Commission for Regulation of Radiation and Nuclear Energy (CRRNA) for the electricity, oil and gas, and nascent nuclear sectors, respectively.

The MEMR is the main organization charged with developing an energy supply strategy. However, a number of other ministries and stakeholders (both public and private organizations) influence final decision-making. As mentioned earlier, Jordan is almost entirely dependent on imported oil and gas for its primary energy needs. International energy companies and international donor agencies are thus important stakeholders in the sector. A detailed list and description of key organizations and actors is provided in Table A2 in the appendix.

Using an approach similar to that described in the previous section, we systematically classified the key stakeholders based on our assessment of their attributes of power, legitimacy, and urgency (from the perspective of the MEMR). We found that the definitive stakeholders for the MEMR are the King and Royal Council, the Prime Ministry, and the Fajer Gas Company that delivers gas from Egypt for powering the electric power plants in the country (see Fig. 8). As described earlier, a stakeholder with all three attributes of power, legitimacy and urgency is classified as a 'definitive' stakeholder. The Fajer Gas Company holds significant utilitarian (material) power, since it is the dominant supplier of natural gas that runs the electricity-generating infrastructure. It can be also be deemed to have legitimacy and urgency as viewed from the perspective of the MEMR, and is thus found to be a definitive stakeholder.

The dominant stakeholders—in addition to the National Assembly that has normative (symbolic) power—are the Electricity Regulatory Commission and the Ministry of Planning and International Cooperation (MOPIC). The MOPIC is considered to have power (based on material/financial control) over channeling funds from donor agencies. The remaining stakeholders are classified in the discretionary and dependent categories. There are additional stakeholders, such as the Ministry of Finance, Ministry of Municipal and Rural Affairs etc. [32], that we have not included here based on our perceived relevance in energy planning. Once again, it should be noted that the attributes are a constructed perception based on our research (and not objective

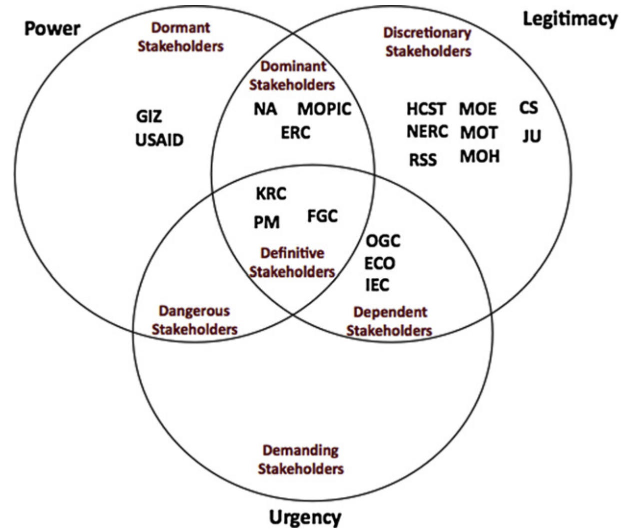

Fig. 8. Ministry of Energy and Mineral Resources stakeholder attributes and classification (see Table A2 for abbreviations).

reality) and can change with time. We expect that a shift in salience could occur for international oil companies if they become involved in extensive development of oil shale in the future in Jordan.

Following the classification, we also developed an influence map for the energy sector (shown on right side of Fig. 7). The central role of the minister of MEMR is depicted along with other actors. The main difference in this case (as compared to the water sector map) is that there is greater decentralization with more companies (in the electricity sub-sector as well as in oil exploration) as well as more regulatory authorities (ERC, NRA, CRRNA).

3.5. Bridging water and energy decision-making

The analysis of the water and energy decision-makers provides the necessary elements for constructing an integrated view of the inter-organizational relationships (see Fig. 7). The map visually highlights the bridging role that the stakeholders with political influence, *i.e.*, the King and Royal Council, the Prime Minister and National Assembly can play in any effort aimed at facilitating and mandating integrated resource policy development. However, these actors can only provide high-level direction, but do not necessarily have the domain expertise and technical know-how to propose detailed plans. While it is likely that the ministries (MWI and MEMR) have (or could develop) this expertise and know-how, the two sectors of water and energy have been administered separately. Thus, if a shift toward integrated decision-making is desired, then boundary-spanning intermediaries will be needed to provide necessary linkages for coordinating future resource development strategies.

In general, there are three possible options for realizing a boundary-spanning function: (1) leveraging existing links (communication channels), agents (*i.e.*, individual actors), and organizations to serve this purpose; (2) creating new boundary spanning roles within existing organizations or forming new organizations dedicated for this role; and (3) restructuring and merging existing organizations of different domains to create a new, integrated entity. There are other possibilities that encompass a hybrid combination of these approaches, however, in our study we discuss these three cases.

1) Leveraging existing networks

The inter-organizational network for each sector allows us to identify opportunities for leveraging existing agencies to perform a boundary-spanning role. In this work, we examined this possibility by

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identifying the common stakeholders between the two sectors, and considering first joint actors from the most salient categories (*i.e.*, those that include the 'power' attribute).

Our analysis shows (see Figs. 6 and 8) that the definitive stakeholders (with power, legitimacy, and urgency) common to both sectors are the ones already discussed above (*i.e.*, the King and Royal Council and the Prime Minister). The dominant stakeholders (*i.e.*, those with power and legitimacy) that are common across the water and energy sectors are the National Assembly and the Ministry of Planning and International Cooperation (MOPIC). Additionally, the international aid agencies also form a common group.

We observe that international aid agencies can play an important role toward facilitating integrated water and energy planning in the country. These agencies have a prominent role at the administrative and operational level within these sectors (Fig. 7), and they not only possess technical expertise on the water and energy sectors in Jordan and elsewhere, but also integrate some knowledge of the politics and constraints at the constituency and executive level. This ability to bridge technical and political knowledge and to span both sectors makes them clear boundary-spanning intermediaries. However, these donor agencies do not have legitimacy in the same way that users or national decision makers have legitimacy over water and energy planning as a whole. In this context, the presence of MOPIC as a common and dominant (Figs. 6 and 8) stakeholder is relevant. The MOPIC, already in charge of channeling donor funds to respective organizations in the country, is well positioned to serve as a boundary-spanning entity that can coordinate and integrate water and energy planning efforts. It can effectively function as the bridge that provides legitimacy to the input from donor agencies as well as play an important role in synergizing resource development strategies for the country.

Another common group of stakeholders (that possess legitimacy but not power in water and energy decision making) are research organizations: the Royal Scientific Society (RSS) and Jordanian universities. These organizations already play an important role in knowledge creation relevant for local needs. The RSS and national research universities can be employed for providing important input. There are organizations such as the Higher Council for Science and Technology (HCST) that also provide opportunities for such activities. The Council, in addition to having high-ranking officials that include Ministers, also has a few members from the scientific expert community (see Table A2 for more details). Overall, there is real potential for harnessing these groups (beyond their current engagements) toward improving national resource policy.

2) Establishing new roles within existing or new organizations

This option can entail the creation of new roles (positions) within existing organizations or establishment of a new organization that is dedicated to serve as an intermediary for the water and energy sectors.

In the first case, there are some existing entities that can potentially include such new roles. For instance, the newly formed National Water Advisory Commission (NWAC), while concerned with water policy and planning, could be given a new role of bridging the planning efforts from the energy sector.

There are also some lessons that can be drawn from other countries in the region. In Dubai, for example, a Supreme Energy Council was created (in 2009) as a regulatory body and independent legal entity. By integrating stakeholders from not only government (*i.e.*, the Dubai Electricity and Water Authority and the Dubai Municipality) but also industrial actors (the Dubai Aluminum Company Ltd., Dubai Petroleum Corporation, and the Emirates National Oil Company), this Council is more effectively able to anticipate and meet energy demands from different actors and based on the Emirate's economic diversification strategy. More importantly, the Supreme Council of Energy is also the government agency tasked with implementing the Dubai Integrated Energy Strategy 2030 (DIES) that aims to ensure the sustainable supply of not only energy but also to enhance demand efficiency of water, power, and fuel. Jordan would greatly benefit from a similar organization tasked with implementation of the Water Strategy 2008–2022, although it is possible that its NWAC could evolve to fit this role.

3) Merging water and energy agencies

In this case, a single agency is tasked with developing, managing, and regulating the water and energy resources. This option is essentially one extreme of the spectrum of possibilities (of which we discuss only three) in terms of setting up boundary-spanning organization. Essentially, it would involve merging the MWI and the MEMR into a single ministry that is in charge of policy and planning of water and energy infrastructure. For practical reasons, however, completely replacing legacy institutional structures can be difficult. Furthermore, the role of such an agency needs to be carefully defined such that a balance is maintained for enabling integrated resource planning, but not at the expense of an over-burdened and large organization that may get difficult to manage efficiently.

4. Conclusions and future work

Water and energy resource challenges are well known in Jordan [24]. However, there has been little integrated analysis of the two resources along with evaluation of their implications for organizational arrangements. In this paper, we attempt to address this gap and discuss the need for joint water and energy planning that may be achieved through boundary spanning intermediaries that bridge decision-making across the two sectors. Our analytical approach is based on three linked components. First, a quantitative analysis of water and energy physical inter-linkages is conducted to determine the key sub-sectors within each of the two domains that currently (or in the future may) have high inter-dependencies. Next, a stakeholder analysis for the main energy and water policy agencies is made in order to identify key actors and organizations. In the third and final step (and using results from the first two analyses) common definitive or dominant stakeholders are identified that can potentially serve as intermediaries for bridging water and energy decision-making.

Our case study on Jordan shows that some traditional policy levers such as increasing water and energy efficiency in domestic water use will not make significant impact. The per capita water and electricity consumption are already very low, however there is potential to reduce water loss through leakages (which would also have beneficial energy saving impacts). Indeed, various international donor agencies have recently been funding efforts to reduce leakage and improve pumping systems [34,35]. While replacing old pumps with more efficient models is one important step, it is also important to investigate alternative energy sources for powering the system. Water pumping imposes significant (15% of total) electricity requirements that are generated by imported natural gas. Renewable sources (such as photovoltaics) should be closely reviewed as an option for powering pumping systems, and on-going research at local universities [51] should be leveraged where possible.

A critical area to consider for policy and action, however, is the challenge of securing future water supplies that will be needed for exploiting the oil shale reserves in which the government appears to be keenly interested. In this case, the first step needs to be collection and dissemination of reliable and accurate data regarding local water availability. While aggregate estimates can be made at a high level, sound data sets will be needed for informing decisions. Adequate and reliable information can help identify locally relevant and practical solutions. For instance, it has been suggested that energy companies, working in oil exploration and development within an area, can cooperate to establish infrastructure, such as a wastewater treatment plant to enable reuse in nearby cities [36]. Such an arrangement could be socially beneficial while also providing adequate water supplies for new industrial operations.

In agriculture (which is still the dominant user of water) there are also opportunities for saving water through use of efficient irrigation technologies that may then be supplied to other sectors. Creative solutions, such as instituting fees to be paid by energy companies for exploring or developing oil fields, could be used to fund the installation of water efficient irrigation systems. The NRA in coordination with WAJ and JVA could potentially work to design and implement such schemes. It should be noted however, that such options and others can only be meaningfully considered and eventually adopted if there are effective boundary spanning entities between the water and energy sectors.

On the whole, given the emerging deeper connections of water and energy in the future in Jordan, it is increasingly important to establish appropriate linkages within the planning and decision-making agencies so that the full implications (of water for energy plans and vice versa) are incorporated upfront. This would allow improved overall resource use efficiencies.

Our field research has indicated that often long-term strategic plans are regarded as 'plans on paper'. The view that strategies are tenuous and do not necessarily shape future actions is not helpful in reducing perception of risks as seen by private enterprises seeking to make large capital investments (and with whom the government wants to engage in developing infrastructure and economic development plans). We argue that jointly developed, integrated strategies of water and energy put forth by the MWI and the MEMR can help create credible (and hopefully long-lasting and eventually implemented) plans. Thus, joint-planning efforts can not only generate new options, but also be crucial to build investor confidence, and ultimately garner private investments.

The focus of this paper has been on Jordan, however, the overall approach that we have used is generally applicable. In on-going work, we are studying other country cases (*i.e.*, Oman, the UAE) experiencing extreme water scarcity but with significant amounts of energy supply. These countries are now experiencing new water and energy challenges due to population growth and socio-economic development. Using our framework, we will conduct a series of in-depth studies of this diverse set of countries in terms of water and energy availability. The collective results will build a sophisticated, multi-dimensional understanding of the resource couplings in the MENA region, and offer approaches for instituting and implementing integrated resource management and policy for meeting societal economic development needs as well as ensuring long-term environmental sustainability.

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Appendix

Table A1
Water Sector Stakeholders in Jordan

Stakeholder	Role in Water Sector
King and Royal Council (KRC)	Provide influence and oversight over decision-making; can influence funding allocation to different regions of the country
Royal Water Committee (RWC)	Convened by the King to produce a Water Strategy for the Ministry that has influenced decision-making within the sector
Prime Ministry (PM)	All decisions made by the Minister of Water and Irrigation must be approved by the Prime Ministry; *i.e.* the Prime Minister and his Cabinet
National Assembly (NA)	An elected body, the National Assembly can receive petitions and complaints from the Jordanian public and can leverage Executive Authority over the Prime Ministry
National Water Advisory Council (NWAC)	Created in 2011, this council includes ministers and secretary generals of the MWI and other government organizations and is intended to serve as a strategic oversight and policy planning body over the Ministry of Water and Irrigation; although, as a new entity, the role of this organization is still evolving
Ministry of Water and Irrigation (MWI)	The central decision-maker in the water sector although influenced by other ministries, the Prime Ministry, and the King
Performance Management Unit (PMU)	Originally created to monitor the Amman Management Contract (that resulted in the creation of Miyahuna), now provides technical monitoring and performance monitoring for the three existing water companies. Technically a body under the MWI, it historically had strong links with the WAJ
Water Authority of Jordan (WAJ)	Supervises the management and service contracts within the water sector, and serves as a bulk water supplier to municipalities and industry in addition to monitoring and regulation of groundwater wells
Jordan Valley Authority (JVA)	Primarily responsible for the development and utilization of water resources in the Jordan Valley; originally served as both a bulk water supplier and local distributor but the latter role has largely been ceded to Water User Associations (WUA) in recent years
Ministry of Agriculture (MOA)	Involved in some data collection regarding irrigated agriculture
Ministry of Environment (MOE)	Key decision-maker in approving new industrial initiatives (particularly involving foreign stakeholders) by requiring the submission of adequate environmental and social impact assessments
Ministry of Planning and International Cooperation (MOPIC)	Responsible for economic planning and also a key contact point for donor organizations in coordinating agreements with other ministries
Ministry of Tourism (MOT)	Relevant in that the tourist sector makes a significant contribution to the economy and tourists are viewed (particularly among the Jordanian public) as putting large demands on precious water and energy resources due to their higher consumption levels

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Table A1 (*continued*)

Stakeholder	Role in Water Sector
Ministry of Finance (MOF)	Oversees budgets and project financing; consequently, also liaises with aid organizations but only in coordinating monetary transfers
Ministry of Health (MOH)	Responsible for drinking water quality
Deutsche Gesellschaft fur Internationale Zusammenarbeit (GIZ)	Engaged in Jordan since 1979, stepped up activities in the water sector in the early 1990s with water and water-related environmental and resource protection becoming a priority area for cooperation in 2001; strongly linked with the MWI
KfW Entwicklungsbank (KfW)	Operating in Jordan since the 1980s within the framework of Financial Cooperation; water resource conservation and security is primary goal
United States Agency for International Development (USAID)	Actively engaged in many different sectors in Jordan, but over the past decade has expanded more on developing and conserving water than in any other non-cash assistance sector. Focused on water policy reform and particularly influential through the Institutional Support and Strengthening Program (ISSP)
Water Companies (WC)	There are presently three water companies operating in Jordan: The Jordan Water Company (Miyajuna, covering Amman), Al-Yarmouk Water Company (YWC, covering the four Northern governorates of Aljoun, Irbid, Mafraq, and Jerash), and Aqaba Water Company (AWC, covering Aqaba). All of these companies operate under slightly different corporatized structures and are monitored by the PMU.
Water User Associations (WUA)	Supported by the JVA and GIZ, water user associations have been created at pumping stations in the Jordan Valley and now cover ∼80% of the total land area. Increasingly responsible for local distribution while the JVA transitions to a bulk water supplier, ongoing policy evolution could soon result in the creation of an "umbrella" WUA that will also provide this group with greater political voice
Royal Scientific Society (RSS)	Effectively a think-tank, also serve as a third-party inspection and monitoring agency within the water sector but have limited decision-making power
Jordanian Universities (JU)	Contain significant academic expertise on water management challenges in the region but have limited capacity to influence decision-making at higher levels

Table A2
Energy Sector Stakeholders in Jordan

Stakeholder	Role in Energy Sector
King and Royal Council (KRC)	Provide influence and oversight over decision-making; can influence funding allocation to different regions of the country
Prime Ministry (PM)	All decisions made by the Minister of Energy and Mineral Resources must be approved by the Prime Ministry; *i.e.* the Prime Minister and his Cabinet
National Assembly (NA)	An elected body, the National Assembly can receive petitions and complaints from the Jordanian public and can leverage Executive Authority over the Prime Ministry
Ministry of Energy and Mineral Resources (MEMR)	The central decision-maker in the energy sector although influenced by other ministries, the Prime Ministry, and the King
Electricity Regulatory Commission (ERC)	A commission involved in determining electricity prices, issuing licenses to generating, transmitting and distribution companies, and monitoring compliance
Natural Resource Authority (NRA)	Issues licenses for prospecting for mineral resources, performs monitoring operations and conducts geological surveys. International energy companies have to work with NRA to get necessary approvals for exploration and development of oil and gas projects
Commission for Regulation of Radiation and Nuclear Activity (CRRNA)	Reports to the Prime Minister (and replaces the older Jordanian Nuclear Energy Commission). It is tasked with regulating and monitoring use of nuclear power to ensure public health and safety
Atomic Energy Commission (AEC)	Formed in 2008 to establish use of nuclear power primarily for electricity generation and desalination in the country
Ministry of Environment (MOE)	Key decision-maker in approving new industrial initiatives (particularly involving foreign stakeholders) by requiring the submission of adequate environmental and social impact assessments
Ministry of Health (MOH)	Involved in coordinating regulations with CRRNA
Ministry of Planning and International Cooperation (MOPIC)	Responsible for economic planning and for securing technical assistance for renewable energy sources. It serves as a key contact point for donor organizations and channels international aid
Ministry of Tourism (MOT)	Tourism is a vital economic sector for Jordan (accounts for 14% of the GDP), and the ministry has worked with ERC to reduce electricity rates for the sector
Higher Council for Science and Technology (HCST)	Established in 1987 as an umbrella institution for all science and technology activities in the country. The council is chaired by a prince and members include the president of the RSS, as well as ministers of planning, finance, higher education, agriculture, energy and mineral resources, and trade and industry among others
National Center for Research and Development (NERC)	Has the objective of developing scientific capabilities in energy, biotechnology and other areas
KfW Entwicklungsbank (KfW)	Operating in Jordan since the 1980s within the framework of Financial Cooperation; water resource conservation and security is primary goal

(*continued on next page*)

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Table A2 (*continued*)

Stakeholder	Role in Energy Sector
Deutsche Gesellschaft fur Internationale Zusammenarbeit (GIZ)	Engaged in Jordan since the last several decades in water and energy sectors Recently promoting energy efficiency measures through financing efficient pumping systems
United States Agency for International Development (USAID)	Actively engaged in energy sector and in particular promoting energy efficiency measures. It is working with ERC and NGOs to raise public awareness and enhance efficiencies across all segments of the energy sector
Electricity Companies (ECO)	There are five electricity generating companies: Central Electricity Generating Company (CEGCO) – it owns the largest generating capacity in the country, Samra Electricity Power Generating Company (SEPGCO), AES-Jordan (a subsidiary of the AES Corporation), Al-Qatraneh Electric Power Company, and bio-gas company owned by the municipality of Greater Amman. There is a single, government owned, transmission company: National Electric Power Company (NEPCO), and three local distribution companies: Jordan Electric Power Company (JEPCO), Irbid Electric Power Company (IDECO), and the Electricity Distribution Company (EDCO)
Oil and Gas Companies (OGC)	National Petroleum Company (NPCO) is a state-owned oil and gas exploration and production company. It works in partnership with international energy companies for oil and gas development in Jordan. Jordan Petroleum Refinery Company (JPRCO) is responsible for crude oil refining and production
Fajr Gas Company (FGC)	The Fajr Company owns and operates a natural gas pipeline that delivers gas from Egypt to Jordan for providing fuel to electric power plants
International Energy Companies (IEC)	BP working with NPCO to develop Al-Risha gas fields, Canadian, Indian and Korean companies at various stages of exploration and development. Estonian, Canadian, and Saudi companies are exploring oil shale development (mainly through mining operations). Shell is attempting to exploit deep oil shale (based on in-situ conversion)
Royal Scientific Society (RSS)	Effectively a think-tank, also serves as a third-party inspection and monitoring agency but has limited decision-making power
Jordanian Universities (JU)	Contain academic expertise and have been doing research on renewable energy systems applicable in the region but have limited capacity to influence decision-making at higher levels

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