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Appraisal of institutional and policy framework conditions for the use of autonomous desalination units in Jordan

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ABSTRACT

Jordan is one of the most water-scarce countries of the world. This scarcity is driven by low rainfall rates and sudden increases in population due to several armed conflicts in the region. Jordan imports almost all of its energy needs. More attention is being currently given to renewable sources of energy especially with the concerns about climate change and volatile fossil fuel prices. Desalination of brackish water is part of Jordan's water strategy. However, autonomous desalination units powered by renewable energy systems represent a new concept in Jordan, albeit, they can have great potential as a decentralized water manufacturing option. Institutional and policy framework conditions in Jordan's water sector are reviewed in order to establish how accommodating the set-up is to the introduction and development of such new technologies. Analysis of pertinent laws and a questionnaire completed by relevant officials and managers revealed the need for a water law to replace the current legal framework and policies, addressing, *inter alia*, the issues of tariffs and embracing new water technologies.

Keywords: Autonomous desalination; Decentralization; Institutional framework; Jordan; Renewable energy; Tariffs; Water policy

1. Introduction

Prudent institutional and policy framework conditions are essential for the success of water resources management. This framework encompasses legal, regulatory and organizational aspects, the comprehension of which is vital, *inter alia*, for the promotion of viable emerging water technologies.

This paper is intended to present an analysis of the stature of institutional and policy framework conditions in the water sector in Jordan. Available literature and information obtained from a completed questionnaire constitute the basis upon which this paper has been built. The questionnaire was completed in February 2006 by well-known professionals in the public and private water sectors, academia, donor agencies and non-governmental organizations in Jordan. This exercise is deemed necessary to accelerate the adoption and implementation of autonomous desalination units based on renewable energy systems (ADU–RES) as an instrument of augmenting water supply. The improvement of framework conditions can only bare results provided simultaneous advancements of technical aspects continue addressing cost, environmental, socioeconomic and integrated plant

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designs considerations. This paper tackles the policy and institutional framework aspects.

2. Water and energy resources in Jordan

Jordan is a predominantly semi-arid to arid country. Its topography and climate vary greatly. It has a warm, pleasant climate, but receives little rain. Desert, in the eastern part, constitutes some two-thirds of the country and is scarcely populated. Annual rainfall ranges from less than 100 mm in the desert regions to about 400–600 mm (Fig. 1) in the western mountains; 93% of rainfall is lost to evaporation. In 2007, Jordan had a total population of 5.7 million with a natural growth rate of 2.2% and with about 70% living in urban areas. On the whole, however, actual population growth was 4.3% due to an influx of refugees resulting from the war in Iraq in 2003. About 38.8% reside in the capital, Amman [1].

2.1. Water scarcity

In terms of actual water resource availability, Jordan is one of the ten poorest countries in the world. In 2007, the annual per capita share of renewable water resources was 149 m^3 [2]. This is well below the World Bank water poverty threshold of 500 m^3. The country has been suffering from a water deficit and will continue to do so for the next decade. The water deficit was estimated at 614 Mm^3 in 2006. Intermittent water supply has become normal practice in the country, particularly during the summer months. The per capita municipal consumption is estimated at 86 L/d at present. Agriculture consumes 63%, municipal use is 31%, industrial 5% and 1% for other uses [2].

According to Jordan's Ministry of Water and Irrigation, the country's water budget can be balanced if and when the proposed Red Sea–Dead Sea regional project is realized [2] (see Fig. 2). This project is still under study and includes investigating the feasibility of constructing a desalination plant and a water conveyance system from the southern shores of the Dead Sea to major cities on the highlands in Jordan [3].

Deteriorating water quality adds to water scarcity in Jordan where in some parts of the country significant quantities of water have been limited to restricted use or rendered completely inapt for any useful purpose. Both natural and anthropogenic sources of pollution contribute to this problem. This is eminent in the natural elevated salinity levels originating from saline springs and drainage from agricultural areas.

Combating water scarcity remains a strategic challenge that Jordan faces. Efforts are made to balance increasing demands from the various sectors but naturally domestic demands are given highest priority. On the demand side,

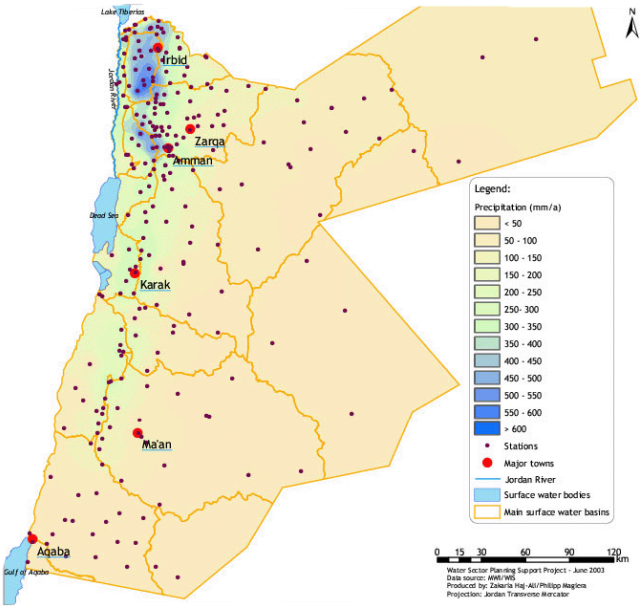
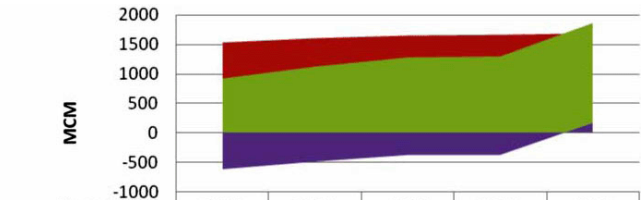


Fig. 1. Rate of precipitation in Jordan (1963–2002).



Year	2006	2010	2015	2020	2022
Population, Million	5.6	6.08	6.64	7.14	7.36
Demands	1539	1613	1658	1671	1696
Supply	925	1127	1283	1298	1862
Deficit	-614	-486	-375	-373	166

Fig. 2. Water demand and supply (2006–2022) [2].

efforts have been directed at water conservation by means of leakage reduction, water reclamation and through the application of more efficient irrigation techniques. On the supply management side, water desalination and construction of more reservoirs have been the major efforts to augment available resources.

2.2. Desalination

Employing desalination to augment the scarce water resources has been modest in Jordan. This is perhaps due to the relatively high costs entailed. However, as the country is trying persistently to decrease the water deficit, desalination seems rather inevitable. While the country is known to have brackish water reserves, the Gulf of Aqaba is the only potential seawater source. It is far from population centers; it is some 350 km from the capital Amman, which is also some 1000 m above mean sea level.

There are 21 privately owned desalination plants in the Jordan Valley. Located north of the Dead Sea, they have been mainly established for irrigation purposes. The average brackish water salinity is about 3000 ppm, with the maximum ranging from 7000 to 8000 ppm. Some studies have revealed the presence of up to 80 Mm^3 of water that can be used in the Jordan Valley. A relatively large project, with an estimated annual capacity of 9–15 MCM, is that known as the Hisban project, which is likely to be finished by 2015. On the highlands in the second largest city of Zarqa, there is a 600 m^3/h desalination plant that has been in operation since 2004.

The largest surface water reverse osmosis (RO) desalination effort in Jordan is the Ma'in, Zara and Mujib project. This is a Design-Build-Operate project whereby the Ministry of Water and Irrigation (MWI) and Water Authority of Jordan (WAJ) have contracted the private sector to execute and hand it over after 2 years of operation. The annual capacity is 55 MCM with a salinity of 1500–2000 ppm. The project includes a conveyor and will serve Amman with 38 MCM annually. Water is pumped approximately to a height of 1500 m. Brine is to be conveniently disposed of into the Dead Sea. Cost of production is estimated at 0.4 JD/m^3. WAJ reported an operational cost ranging from 0.18 and 0.22 JD/m^3 [2].

In the Aqaba Special Economic Zone (ASEZ), desalination is expected to provide 10 MCM/y to be introduced in two phases of 5 MCM/y in 2013 and 2019 [4]. Over 150 million JD in capital investment is needed over the 25-year planning period. RO has been assumed to be the desalination technology for pricing capital and operation costs and brackish water wells were assumed as the raw water source. The MWI, WAJ and Aqaba Special Economic Zone Authority (ASEZA) formed a limited liability company, the Aqaba Water Company (AWC), of which WAJ owns 85% and ASEZA 15%. ASEZA is to grant AWC the right to manage and develop a water transmission and distribution network, wastewater collection network and treatment facilities and the rights of first refusal to develop and operate seawater desalination facilities.

A noticeable number of desalination plants are being constructed in the country and more are under planning—most of which are RO plants with a few electrodialysis reversal (EDR) plants. The latter is seen to have potential for small-scale applications in remote areas. This is because EDR necessitates fewer pretreatment requirements. Also, more recently some local pilot studies have been conducted to establish the viability of multi-effect distillation (MED) applications [5]. Nonetheless, all existing desalination plants in Jordan utilize conventional energy sources except for some small solar desalination plants in Aqaba, which are intended for research purposes and as pilot projects.

2.3. Energy sources

Volatile international oil prices are having a significant impact on Jordan's economy and population as the country has to import all of its oil needs. This has prompted policy makers to seek alternative energy sources like natural gas and oil shale of which great reserves are believed to exist in the country. Table 1 clearly indicates the enormous increases of energy imports in the last 3 years. This will surely increase consumers' hardship as prices are likely to be subjected to further increases. Annual investments in conventional energy amounted to 150 million JD during 1998–2003. On a business-as-usual scenario, this has been estimated to increase to 195 million JD/y during the years 2004–2015. Annual expected growth till 2020 is estimated at 3.5% in energy and 4.6% in electricity [6].

Currently, Jordan consumes about 6 MTOE, and this is expected to double every 15 years. This will certainly increase Jordan's economic burden. Alternatives are being sought in order to reduce dependence on imported sources of energy. Jordan has reserves of oil shale estimated at 40 billion tons. Currently, there are serious plans to make use of these reserves. Natural gas and oil resources are being explored. Gas is currently utilized for power production and is expected to be used to produce all electricity needs from local reserves in the long run. Jordan's generated electricity is estimated at 1660 MW while the peak load is 1255 MW. Electricity coverage is practically complete. The tariff follows a tiered pricing system. Conservation of energy has been promoted, especially in the industrial and commercial sectors.

2.4. Renewable energy

At present, Jordan has two wind farms: a 1.125 MW in the north of the country at Hofa and another at Al-Ibrahimiah with a capacity of 320 KW. Solar thermal

Table 1
Cost of energy imports in Jordan relative to GNP [6]

Year	Imported energy	
	Cost (million JD)	Cost relative to GNP (%)
2000	568	9.6
2001	566	9.0
2002	610	9.3
2003	764	10.9
2004	1153	14.5
2005	1830	21.6
2006 (estimated)	2110 (7.3 MTOE)[a]	23.0

[a]Million tons of oil equivalent.

energy has been widely used in Jordan in the form of solar wter heaters for residential and industrial uses.

With an estimated solar radiation of 5.6 kWh/m^2/d, Jordan is considered to be rich in solar energy. All solar energy-driven technologies have, therefore, great potential for application in the country. There are many photovoltaic (PV) energy-driven installations serving various purposes in remote rural areas of Jordan. Applications include 24 systems (108,026 kWp) for water pumping, 13 installations for telecommunications (18,601 kWp), 41 for electricity generation (25,180 kWp) and other applications, making the total peak power 178,307 kWp. There have also been some efforts to utilize biogas in Jordan. A biogas pilot plant was constructed on a municipal waste landfill site in the city of Ruseifa. This plant started production in the year 2000 with a rated capacity of 1 MW. The annual power production from this pilot plant is 7 million kWh due to burning of 2.14 Mm^3/y of methane gas. The total municipal waste is around 1.5 million tons/y, which is equivalent to 25,000 TOE [6].

Geothermal energy is another source of energy believed to be of potential. Jordan has thermal and mineral waters scattered in various locations in the country, e.g. the Zarqa Ma'in and Zara hot springs. The potential of these sources is under investigation. Also, if accomplished, the Red Sea–Dead Sea project has the potential of hydro-power generation of 600 MW of electric power through a 400-m head difference between the two seas [6].

3. Current legal framework, policies and strategies

The main legal framework of the water sector in Jordan is synchronized mainly by three laws: WAJ Law 18 of 1988, Jordan Valley Authority (JVA) Law 30 of 2001 and MWI Law 54 of 1992. MWI issued its water strategy and policy in 1997 and 1998, which was published in 2002 [7] to satisfy the relevant legislative requirements of Article 5 of WAJ Law 18 of 1988, which stipulates that a water policy be set. The relevant issued documents are:

- Jordan's water strategy [8]
- Water utility policy [9]
- Irrigation water policy [10]
- Groundwater management policy [11]
- Wastewater management policy [12]

The strategy duly recognizes pressures imposed by population increases due to natural growth as well as to sudden waves of immigration that Jordan encountered. The fact that population is concentrated in distant locations from water resources resulted in higher costs for water supply projects and associated services, prominent among which is the high annual cost of operation and maintenance, of which energy is responsible for 55%. Increasing water demand has necessitated over abstraction from groundwater aquifers. Relaxed controls on drilling wells and lack of controls on abstraction rates resulted in some ground water aquifers being depleted and others salinized.

The policy documents mentioned above were issued with the aim of detailing the government's policy and intentions pertaining to water sector and respective subsectors. Highlights of the most relevant aspects to serve the purpose of this paper follow.

3.1. Resource development

Water is and shall be always considered as a national resource. Economic feasibility and social and environmental impact are to determine the extent to which surface and ground waters may be exploited. A periodic assessment of potential water resources and their respective uses should be conducted, including marginal and brackish waters. An overall far-reaching water resources development plan is to be formulated from which a revolving and dynamic 5-year plan shall be drawn in line with other economic sectors. Concurrently, an investment plan is to be drawn. Economic, social and environmental considerations should dictate the priorities of project implementation and for additional water allocation. This has to be considered within the context of the sustainability pertaining to national water balance and socio-economic and environmental factors. At any rate, foremost priority should be given to satisfying basic human needs: 100 L/d per capita is the priority amount allocated to domestic water supplies. Priority is then for municipal purposes, followed by tourism and industrial purposes. No mention of agriculture here.

3.2. Resource management

Sustainability of use of already developed sources is given priority. Exploitation of renewable groundwater aquifers should be reviewed, brought under control and extraction rates made sustainable. A dynamic demand and supply management approach is to be pursued making use of instruments of advanced technology. Persistent efforts shall be exerted to improve efficiency of conveyance, distribution, application and use. Water requirements for future industrial, commercial, tourism and agricultural projects should be included into the cost of production.

3.3. Legislation and institutional set-up

Existing institutional provisions and legislature are to be subjected to frequent review and subsequent adjustments as deemed appropriate, in particular, to respond to emerging needs. Legislation shall allow for stakeholder participation and ensure public–private cooperation.

3.4. Financing

Cost recovery of utilities and service provision shall be sought out. The standard practice shall be the cost recovery of operation and maintenance. However, capital cost recovery shall be approached with care. Cost recovery shall be set while accounting for the cost of living and per capita share of the gross domestic product. Also, in setting water tariffs, the need for and requirements of private investment shall be taken into consideration. On the other hand, non-domestic users shall pay a fair cost. Project financing will depend on loans, private borrowing and/or Build Operate and Own (BOO) and Build Operate and Transfer (BOT) arrangements. This is to remain till the cost recovery is full and the domestic savings become capable of local financing development projects.

3.5. Research and development

Efforts shall be exerted to promote indigenous water research in various fields, e.g. resource management and economics. Forging partnerships with international research institutions shall be encouraged in order to keep current with technological advances and to facilitate technology transfer and adaptation.

3.6. Public awareness

It is recognized that water administration alone is insufficient to confront the water problem. Educating the public about the need for water to be used in a sustainable manner and underlining its importance for economic and social development is equally important.

3.7. Health standards

National water standards shall be set and enforced. Water quality testing laboratories shall be maintained and properly equipped.

3.8. Private sector participation

The role of the private sector shall be expanded. Management contracts, concessions and other forms of private sector participation in water utilities shall be considered and adopted as appropriate. BOT and BOO concepts shall be considered. However, these are to be subjected to continuous assessment to identify and mitigate negative implications. The Government of Jordan has been carrying out economical restructuring enabling the private sector to assume a more significant role. In this, water and wastewater services management are considered of priority in regard to private sector participation [13].

4. Water administrative structure

Water resources were managed and regulated by WAJ, JVA, Ministry of Agriculture and Ministry of Health until 1988 when the MWI was established. The major objective of establishing the MWI has been to centralize water sector activities in an endeavor to improve their management. This made MWI the official institute in charge of water sector activities that include planning, setting of strategies and policy and research and development.

There are three Secretary Generals within MWI: one for MWI itself, one for WAJ and another for JVA. They are required to answer to the Minister. MWI contains eight directorates, namely Legal Affairs, Water Resources Development, Deep wells and Drilling, Water Resources Planning, Environment, Public Information Affairs and Awareness, Financial and General Affairs and Project Directorate.

According to the Ministries and Public Institutions and Departments Linked Organization By-Law No.16 of 1988, WAJ and JVA are linked with the Minister of Water and Irrigation. Nonetheless, WAJ is an autonomous corporate body, with financial and administrative independence. It is responsible for public water supply and wastewater services. It is also in charge of the overall water resources planning, construction, monitoring, operations and maintenance. The WAJ Secretary General has five assistants for Technical Support, Planning and Investment, Maintenance and Workshop, Financial Affairs and Administrative Sectors. WAJ has been undergoing reform according to an improvement plan.

Private sector involvement and decentralization in the water sector are being promoted in the Government's reform plans. This is in line with overall government policy directed at the promotion of private sector participation in various governmental sectors. A Project Management Unit (PMU) was established within WAJ in 1996 to regulate water and wastewater utilities under private management; for example, the Greater Amman water supply management contract which was introduced in 1999. The PMU is mandated to initiate and follow-up privatization contracts. Management contracts and BOT systems have been set up for the construction of water conveyance and water supply projects and wastewater treatment plants. The establishment of public water companies is another emerging form managing the water sector. Such a company has its own board of directors with representatives from MWI, concerned ministries and authorities.

MWI embarked on an ambitious restructuring program in order to increase efficiency in the water sector. Decentralization has been at the center of such efforts. This has been epitomized by delegating management responsibilities from WAJ to regional units operating on a

commercial basis with private sector participation (PSP). An example is the Northern Governorates Water Administration (NGWA) founded in 2001. NGWA is comprised of the four northern governorates of Irbid, Jerash, Ajloun and Mafraq (including North Badia). It started operation in January 2002, and provides water supply and wastewater disposal services to more than 1.4 million people living in a predominantly rural service area. The PMU of WAJ is managing the transition period with support from an international aid agency.

Established in 1977, JVA has been entrusted with the social and economic development of the Jordan Rift Valley, Jordan's major agriculture region. It has also been delegated the responsibility of developing, maintaining and protecting water resources. In addition to the 110 km King Abdullah Canal, JVA is also responsible for all dams and reservoirs in the country. JVA has a Secretary General who has six assistants for Planning and Environment, Southern Ghors and Wadi Araba, Lands and Urban Development, Administration, Finance and Tenders, Northern and Middle Ghors, and Studies and Projects.

The water sector is known to increase government debt problems. This is attributed to the annual subsidies paid to WAJ and JVA. About 25% is known to go for interest payments on external loans contracted for investments in hydraulic infrastructure. WAJ consume 75% of this amount. On the other hand, there are the indirect energy subsidies given out to farmers. Only half of the water sector expenditures are recovered though levies and associated charges. It is worth mentioning that the total water quantities billed by WAJ amount to about 50% of the water quantity produced. This has been attributed to "technical and financial losses" caused by the unaccounted for quantities of water. While this is for municipal water, water for irrigation in the Jordan Valley is sold by JVA at 11–12 Fils/m^3 (JD is 1000 Fils; 1 JD equals 1.41 USD), which is considered rather low as farmers in the highlands put up with a 50 Fils/m^3. The low water tariffs are seen somehow justifiable because JVA's main mission is to promote social and economic development in the Jordan Valley. Nonetheless, full cost recovery is targeted for 2020. It is estimated that 30% of the "cost recovery gap" can be achieved through improvements in operational efficiency and a further 30% by the institution of better integrated investment planning.

The Government of Jordan has been persistent in decreasing debt. Every economic sector in the country is expected to play its role in this policy. The water sector is no exception. To achieve this, three main areas of action have been identified in the water sector. These are increasing WAJ and JVA efficiency through technical and administrative measures including privatization, increasing water tariffs and intensification of the investment planning process. However, it is believed that about 40% of the financial deficit of the water sector would have to be covered through tariff increases. Further still, the average cost of production and conveyance will be on the increase due to more costly investments and environmental requirements. Nonetheless, in doing that, it is recognized that tariff reviews should take into account socioeconomic implications. For non-residential uses, 1 m^3 cost 1 JD (1.41 USD) plus an additional 0.56 JD for sanitary discharge for those connected to the sewerage network. The water tariff follows a tiered structure such that the greater the volume of water consumed, the higher the price per cubic meter. Water bills are issued on a quarterly basis.

Regulatory aspects: In accordance with MWI strategy and policies, national health standards are to be promulgated and enforced. This is particularly so for the municipal water supply. Compliance to these standards ought to be ensured regularly by utility owners through laboratory testing. Records of tests should be maintained and be available for inspection by the governmental agencies. National drinking water standards are listed in the Jordanian Standards for Drinking Water No.286 of 2001. There are also guidelines for microbiological water quality of raw water intended as a source for treatment to drinking water levels (unpublished). Other relevant standards include Jordanian Standards for Reclaimed Domestic Water No.893 of 2002, Jordanian Standards for Industrial Wastewater No.202 of 1991, and WAJ's Regulations for the Quality of Industrial Wastewater to be connected to the Collection System. Each of the WAJ Central Laboratories in Amman, JVA Laboratory in the Jordan Valley and Ministry of Health Laboratory has separate surveillance and monitoring programs for water and wastewater. The Ministry of Environment does not have its own laboratories, but nonetheless contracts out to others to execute its monitoring legislative duties.

5. Discussion

The following is a summary of the findings obtained from analyzing the questionnaire which was completed by water professionals in Jordan's water sector. The objective of this questionnaire has been to assess the extent to which existing laws and policies are implemented and to evaluate their appropriateness.

Jordan's water policy is substantially affected by the country's agricultural, economic, environmental, social and human development and financial policies in descending order. However, inter-sectoral water use prioritization is percieved differently by the various consumer sectors. While municipal usage is undoubtedly first priority, second place varied from industrial to tourism to agriculture. Environmental usage was perceived to be receiving least priority. The driving forces behind this prioritization are the state of water resources followed by

economic factors and then equity considerations. Also, the determining factors in project selection varied greatly. Sometimes it is the meeting of increasing demand that determines projects selection. Other assertions are that it is the donors who decide. Other attributions ascribe this to socioeconomic considerations while others expressed the opinion that it is the vested interest of decision makers that determines how projects are selected. The varying perception is a sign of ambiguity in the water sector. On the whole, project selection is highly influenced if the project is funded locally or from international aid agencies.

Water tariffs are regularly reviewed for municipal water while it is irregular for agricultural and industrial waters. On the whole, tariffs are partially subsidized for municipal and agricultural waters while they are based on a cost recovery basis for industrial usage. The government is the only side that determines and controls water tariffs. Existing policies do encourage water sector privatization; however, it is still in the middle to early stages for the municipal urban sub-sector, while it is in the early stages for the municipal rural, agricultural and industrial sub-sectors.

To some extent, the present water policy is seen conducive to public participation and centralization in the management of water consuming sectors. This was seen to be much less conducive in the case of planning and development stages. The effectiveness of private sector involvement in the management of the water sector is seen as good, but to a lesser extent in the planning, funding and execution. International aid agencies are perceived to be more effective in all afore-mentioned stages. Conversely, the involvement of communities and local non-governmental organizations were not seen as effective.

The central government has the greatest influence on managing the water sector. Local municipalities and special authorities have some influence but much less than that of the central government. This is particularly so for the municipal sub-sector and to a lesser extent in cases of the agriculture and industrial ones. Management responsibilities are divided among the various departments. These departments are created mainly on geographical considerations and, to a lesser extent, on political considerations, catchment areas or river basins and utilization patterns.

The allocated water budget is seen to be insufficient in achieving water sector objectives. Private sector participation is not seen highly capable of reducing this deficit. Nonetheless, private sector involvement is seen to have a positive impact on water sector performance.

Water sector data are not easily available, neither to the public nor to the private sector. Such data are available at MWI, WAJ, JVA and some research institutes and centres. Such data are considered safely stored and reasonably easy to retrieve. The cooperation between decision makers and the research community is weak. However, new technologies addressing emerging challenges are on the whole seen to be easily embraced by the water sector.

ADU–RES can be of great potential for Jordan as water transport and supply expenses are rising. ADU advocate decentralized water management, which is conducive to the promotion of subsidiarity and sharing the responsibility. In turn, this can allow for a better participatory approach which can lead to the acceleration of water augmentation and service provision. Such systems are certainly more sustainable and are more environmentally friendly as they use renewable energy sources. This makes them more conducive to water safety and security. Nonetheless, ADU–RES still need to be further developed to render them more robust and less costly. It is important to ensure good practices through acclimatization and further development of ADU–RES. This is in order to address local cost and environmental concerns. It is also necessary to institute procedures to select appropriate types of ADU–RES set-ups. Monitoring and evaluation of the impact of brine disposal are critical to ensure good practice.

6. Conclusions and recommendations

A water law is needed to replace the existing legal framework represented by the MWI, WAJ and JVA laws since these laws were essentially drawn up to regulate the running of these institutions rather than regulating the water sector as such. Fragmentation and overlapping of responsibilities among the three entities have a negative impact upon sector performance. Jordan's water scarcity cannot be abated only by the provision of additional quantities of water but also through proficient management. Technologies and policy tools are both needed to protect existing resources and secure more of them. It is also essential to involve as many consumers as possible in combating the water scarcity dilemma.

ADU–RES is a technology that advocates decentralized water management using clean energy sources. It is conducive to the promotion of subsidiarity and sharing the responsibility for water provision and management. ADU–RES can be of great potential for Jordan as water transport and supply expenses are rising due to the rise in the cost of energy prices. The cost of water to consumers will most certainly increase further in the near future. This is deemed inevitable as new sources are located far from the main residential areas. Also, adding to the cost is the need for more process treatment before water is rendered suitable for various uses. The agricultural and industrial sectors will have to cope with the higher prices as well. New approaches, like ADU–RES, are therefore necessary to cope with this challenge.

However, the introduction and development of such technologies require an embracing institutional and policy framework. The importance of desalination as a water augmentation option has not been reflected in Jordan's water policy, especially using renewable energies. Thus the introduction of legal, regulatory, institutional and policy reforms, with the participation of pertinent stakeholders, conducive to promotion of ADU–RES, is required. Introducing a water pricing policy especially for rural areas rather than just applying national water tariffs seems to be the better approach. Subsidies should gradually be reduced while vulnerable communities are protected. Other essential measures include tax exemptions of renewable energy equipment and encouraging local participation in water planning, development and management. An enabling environment should be created whereby small size industries and local workshops can assemble and/or manufacture parts of ADU–RES that are most regularly used. Easing of administrative procedures encourages water and energy specialists to work more closely together and the creation of public–private partnerships to mobilize funding and investment into ADU–RES.

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