Assessment of Freshwater Strategies and Recommendations for Implementation

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KEY FINDINGS

The most cost-effective water strategies consist of a combination of different water transfer projects and rely on seawater desalination at selected locations.

The assessment of alternative water strategies based on a performance matrix shows that there is a need for further improvement, e.g. with regard to the integration of renewable energies and environmental impact minimization.

Several issues still remain to be addressed before implementing a water strategy at the regional and national levels, including the issue of the resilience of water resources systems in facing the adverse effects of climate change and transboundary management of groundwater systems.

MOTIVATION

The purpose of this policy brief is to discuss the strengths and weaknesses of alternative water production and transfer strategies, as expansion options for the regional water resources system to match projected freshwater deficits until 2050. Thus, the focus is on the options developed under the SALAM initiative with respect to the positioning of seawater desalination (SWD) plants and distribution to demand centers in Jordan and Palestine, and the design of the required water infrastructure. Basic information was provided in the following specific policy briefs: [Future Freshwater Deficits in Palestine and Jordan, p. 18], [Water Production and Transfer Strategies, p. 22], [On- and Offshore Solutions for Large-Scale Seawater Desalination at the Mediterranean Coast, p. 26], [Renewable Energy for Seawater Desalination in the Middle East: Case Study Aqaba, Jordan, p. 30], [Water Conveyance System for Freshwater Deficit Coverage in Jordan and Palestine, p. 37], [Techno-Economic Assessment of Water Infrastructure Projects, p. 72], [Regional Macro-Model for Transboundary Water Resources Planning, p. 76], [Multi-Criteria Analysis of Water Resources Planning Options, p. 80]. Direct comparison of the project alternatives is intended to provide further decision support to regional decision makers and stakeholders with respect to the implementation of a regional water strategy. Finally, reference is made to the overall project, providing recommendations with regard to further studies to provide a sound decision-making basis for the implementation of water and wastewater reuse strategies on a national and regional level. Special attention should be given to the sustainable development of irrigated agriculture as well as the rehabilitation of regional ecosystems.

METHODOLOGY

A performance matrix is set up in order to better identify the strengths and weaknesses of the alternative water production and transfer strategies. The project alternatives are compared with the relevant decision criteria (indicators), including both quantitative and qualitative criteria. A comprehensive comparison of decision alternatives is achieved by considering economic, environmental and technical criteria.

The alternatives are characterized by the total length of the pipes of the transfer network, total positive elevation difference of the transfer pathways and energy demand. These indicators are not mutually independent as length and elevation difference directly impact the energy demand. The total length of the water allocation network of each option is a good indicator of the time needed to build the additional hydro-infrastructure. Qualitative technical indicators are the degree of connectivity with the existing water hydro-infrastructure and the technical feasibility of the water transfer strategy, based among others on the proximity to existing roads or power lines [Water Conveyance System

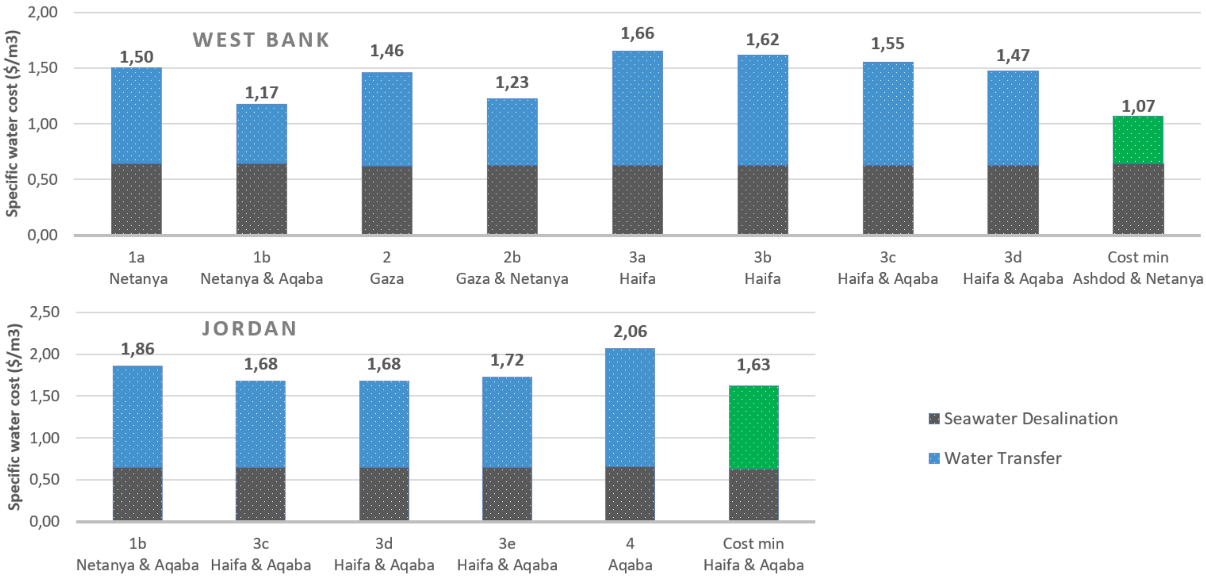

Figure 1: Specific water cost of the set of water production and transfer strategies

for Freshwater Deficit Coverage in Jordan and Palestine, p. 37]. Cost-effectiveness of the alternatives is assessed by the specific water production and transfer costs and the initial financial investment. The former criterion includes all costs including the energy for water production and transfer, which represents the largest share of the total costs [Techno-Economic Assessment of Water Infrastructure Projects, p. 72]. The environmental impact of the strategies is assessed by their CO2 emissions and by a combined criterion entitled adverse environmental impacts. The former is computed from the country-specific carbon footprint (International Energy Agency, 2022) and the energy demand of the strategy. The latter is qualitative and considers impacts during production (brine discharge, impact of construction, seawater intake) and transfer (risk of leakage, pipes productivity).

The set of alternative water production and transfer strategies is evaluated with respect to the relevant decision criteria, including their cost-effectiveness, in a participatory multilateral planning and decision-making process.

The performance matrix allows a direct comparison between the individual alternatives, here as potential expansion variants of the regional water resources system, with regard to their advantages and disadvantages and thus simplifies the decision-making process, especially in communication with political decision-makers.

RESULTS

Strengths and weaknesses of the alternatives, as expansion variants of the regional water resource system, are documented in Table 1.

Figure 1 shows the specific water production and transfer costs for each project alternative. In principle, cost-effective solutions of the regional freshwater deficit problem consist in a combination of several water transfer projects, with seawater desalination both in the Mediterranean Sea and the Red Sea. One option particularly economically attractive to Jordan involves the construction of a large-scale SWD plant at Shavei-Zion, north of Haifa Bay, the transfer of the desalinated water via a tunnel to Lake Tiberias, the construction of a hydropower plant at the lake, to generate renewable energy, and the transport of the water via the Lower Jordan Valley to demand centers in central and northern Jordan.

Option	Option	Freshwater Supply 2050 [MCM/a]	Freshwater Production	Length [km]	Total Positive Elevation Difference [m]	Energy Demand for Water Production and Transfer [kWh/m3]	Technical Feasibility [1-7]	Connectivity to Existing Water Infrastructure [1-7]	Specific Water Costs [$/m3]	Total Investment Needed [M$]	Adverse Environmental Impacts [1-100]	Specific CO2 Emissions [kg CO2 eq./m3]
Supply for West Bank	Alternative 1a	323	Netanya: 323 MCM/a	175	856	8	6	5	1,50	747	66	5
	Alternative 1b	323	Netanya: 735 MCM/a (412 to Jordan, 323 to the West Bank)	175	856	6	5	5	1,17	584	66	3
	Alternative 2	323	Gaza: 323 MCM/a	268	1233	7	4	6	1,47	1022	85	4
	Alternative 2b	323	Gaza: 185 MCM/a, Netanya: 138 MCM/a	211	1631	6	4	3	1,23	634	67	3
	Alternative 3b	323	Haifa: 323 MCM/a	253	2419	8	2	2	1,62	1580	99	4
	Alternative 3d	323	Haifa: 735 MCM/a (412 to Jordan, 323 to the West Bank)	253	2419	7	1	2	1,48	1092	99	4
	Cost-min Alternative - Palestine	323	Ashdod: 185 MCM/a, Netanya: 138 MCM/a	145	1675	5	4	5	1,07	417	60	3
Supply for Jordan	Alternative 1b	712	Netanya: 735 MCM/a (412 to Jordan, 323 to the West Bank)	762	5352	9	5	5	1,86	2980	72	4
	Alternative 3c	712	Haifa: 735 MCM/a (412 to Jordan, 323 to the West Bank)	744	4908	8	3	5	1,69	2965	81	4
	Alternative 3e	712	Haifa: 412 MCM/a, Aqaba: 300 MCM/a	744	4908	8	3	5	1,72	3331	81	4
	Alternative 4	712	Aqaba: 712 MCM/a	679	3214	10	4	4	2,07	3958	100	4
	Cost-min Alternative - Jordan	712	Haifa: 563 MCM/a, Aqaba: 149 MCM/a	883	8338	8	3	5	1,63	2816	89	4

Table 1: Performance Matrix for alternative water production and transfer strategies

By combining this option with a water transfer from a SWD plant near Aqaba, the projected 2050 freshwater deficits in Jordan can be met in a very cost-effective manner.

Regarding water transfer to the West Bank, water can be desalinated in Gaza and transported to the West Bank, which would provide Palestine control over water production. This alternative is favoured by the Palestinian stakeholders [Multi-Criteria Analysis of Water Resources Planning Options, p. 80]. A cost-effective solution combines water production near Netanya (new plant) and near Ashdod (expansion of the existing plant) [Regional Macro-Model for Transboundary Water Resources Planning, p. 76]. This latter solution is less expensive than the former given the shorter distance between the SWD plants and the demand centers. The freshwater deficits in the Gaza Strip are to be matched by a local SWD plant regardless of the transfer solution selected.

Significantly higher investment costs are associated with a system expansion on the Jordanian side than on the Palestinian side. This is reflected in the total length of the network of pipelines to be constructed as well as in the topographic height differences to be overcome and the associated energy requirements. It is thus likely that implementing the water production and transfer strategies will last longer in Jordan than in Palestine. However, the pipelines to supply the West Bank must cross Israeli territory, which can significantly delay or complicate implementation due to land property rights. In this regard, there is an advantage for water production near Haifa with water transfer through a tunnel to Lake Tiberias. On the other hand, the solutions involving water transfer from Haifa via Lake Tiberias to the West Bank seem to be significantly less cost-effective. Besides, the construction of the 47 km long tunnel to Lake Tiberias makes strategies supplying water from Haifa more technically complex. Some of the strategies supplying water to the West Bank include a pipeline connecting Jenin and Bethlehem through many Palestinian settlements. These strategies have a good connectivity to the local water distribution networks.

Table 1 shows that further improvement is required with respect to the design of the planning options, e.g. the integration of renewable energies and the minimization of environmental impacts. All strategies need to be further optimized in terms of CO_2 emissions. The strategies with the lowest CO_2 emissions are generally those with the lowest energy demand. However, as the carbon emission factor in Jordan is lower than in Israel, water transfer through Jordan results in less emissions. Sea water intake and brine discharge from offshore plants have fewer adverse environmental impacts than onshore plants. Longer water transfer routes are associated with a higher risk of leakage and lower pipe productivity. This basic environmental analysis should be completed in a future study by an extensive environmental impact assessment.

The performance matrix is integrated to the [SALAM Information and Expert System, p. 86]. Figure 2 shows the user-friendly interface of the tool.

CONCLUSIONS

A wide range of alternative strategies for solving the region's freshwater deficit problem have been delineated, investigated and evaluated by relevant decision criteria, including cost-effectiveness. For the first time, implementable and economically viable transboundary water production and transfer solutions are available to prevent an expansion of the emerging water crisis in the Middle East.

However, as detailed below, several issues need to be addressed before implementing a water strategy at regional and national levels, including the resilience of the alternative water resources systems after expansion to climate change and transboundary groundwater and system management. Special attention should be given to ecosystem rehabilitation via a combined management of conventional and nonconventional water resources. Furthermore, the comparison of alternative water strategies based on a performance matrix shows that there is a need for further optimization of system planning options, e.g. with regard to renewable energies integration and environmental impact minimization.

The methods, concepts and decision support tools developed in the SALAM initiative for sustainable planning of water resources systems based on seawater desalination and water transfer could be transferred to and used in neighbouring countries such as Egypt or comparable regions.

STEPS TOWARDS IMPLEMENTATION

The second phase of the SALAM project initiative focused on regional water resources system planning. Subsequently, different solutions were sought with respect to the necessary expansion of the regional water resources system to meet projected freshwater deficits until 2050. The decision-support tools developed for this purpose, such as the so-called regional macro model, are mostly based on a static (time invariant) approach.

With regard to the definition and implementation of a regional water strategy, it is now necessary to investigate how these system planning options have to be managed in order to ensure a sufficient degree of supply reliability, especially for drinking water supply. Intermediate storage of water should be studied to cope with the increasing climate change impacts. This requires a dynamic analysis of the system and its optimal control as well as detailed predictions on the effects of climate change on water resources and drought development and their impact on water availability and supply. The analyses show that in terms of climate neutrality, environmental impacts and cost effectiveness further efforts are necessary to optimize system solutions.

Rehabilitation of the Lower Jordan River and Dead Sea will only be possible through transboundary and conjunctive management of the region's renewable water resources, particularly groundwater, as well as non-conventional water

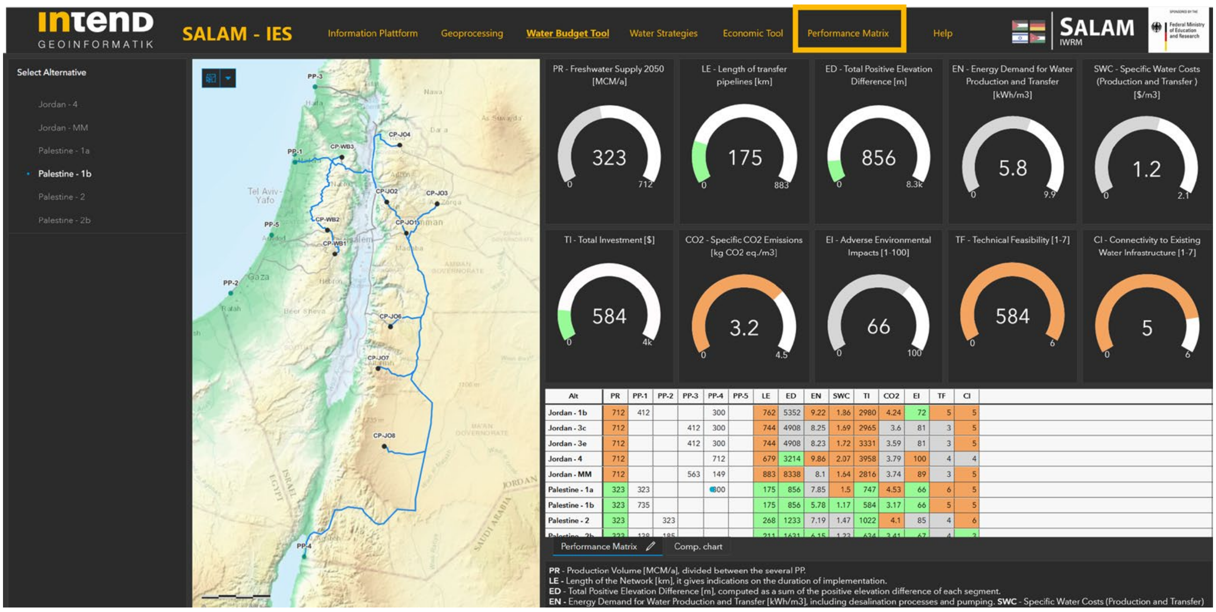

Figure 2: Interface of the Performance Matrix in the SALAM Information and Expert System. Gauges and colours allow the user to assess the relative performance of a strategy against the others.

resources. The latter include, first and foremost, wastewater resources, which must be appropriately treated for reuse. Once the water transfer is implemented, treated wastewater will represent a highly important non-conventional water budget component, together with brackish water resources, and, last but not least, water imports from seawater desalination. Dynamic system management studies and model calculations are also required to optimize the conjunctive management of conventional and non-conventional water resources on the national as well as transboundary level, both on a seasonal as well as interannual time-scale.

The irrigated agriculture sector and its sustainable development will require special attention in the future, not least because of the enormous sectoral water demand as well as the urgent need to meet food demand. In particular, it should be examined whether freshwater demand in agriculture can be further reduced by appropriate IWRM measures and how wastewater reuse for the expansion of irrigated agriculture can be implemented environmentally sound.

Water resources planning and system management are inextricably linked. Therefore, based on the studies on system dynamics and transboundary management of all water resources, important conclusions on system planning and thus on the definition and implementation of a regional water strategy can be expected.

In order to validate innovative SALAM concepts and strategies, including the integration of renewable energy into the process of seawater desalination as well as wastewater reuse, it is recommended to conduct pilot as well as feasibility studies. The latter applies in particular to the water-energy-SWAP concept between Jordan and Israel developed within SALAM.

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References

International Energy Agency (IEA). (2022, Apr 6). “Countries and Regions”. IEA Energy Supply in Israel and Jordan. https://www.iea.org/countries