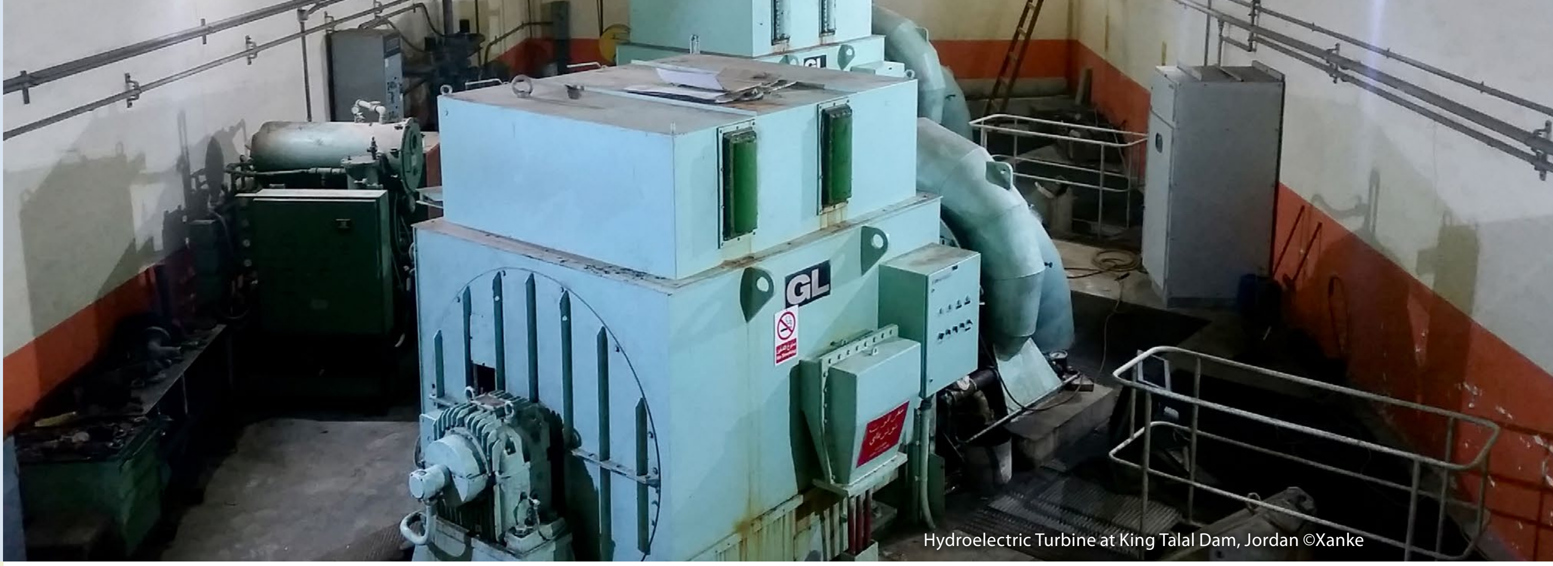

Hydroelectric Turbine at King Talal Dam, Jordan ©Xanke

Techno-Economic Assessment of Water Infrastructure Projects

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KEY FINDINGS

Specific water costs, which are the costs of providing one cubic metre of water at desired quality to the point of demand, are computed for all water infrastructure projects and are used to measure their relative economic efficiency.

In the infrastructure projects studied in SALAM, energy costs are the major cost drivers for seawater desalination and subsequent transfer.

From an economic point of view, it would be advantageous to supply water to the West Bank from desalination plants in Netanya and Ashdod. Desalination at Aqaba and Haifa and transfer to the Jordanian demand centers would be a cost-efficient solution to cover their water needs.

MOTIVATION

Due to the large set of possible technological solutions and the spatial extent of transboundary water infrastructure projects in the SALAM project region, the design of decision alternatives is a complex task. The water infrastructure system consists of seawater desalination plants and respective energy supply systems, water transfer pipelines and electromechanical equipment such as pumping stations. Furthermore, the topographic conditions in the region could favour hydropower generation. If a desalination site near Haifa in the north of Israel is chosen, the desalinated water could be transferred to the Lake Tiberias (Sea of Galilee) through a tunnel which would serve as a regional water storage reservoir, used for electricity generation before being transferred down the Jordan Valley and to the regional water demand centers [Large-Scale Hydropower Plant at Lake Tiberias in the Context of Transboundary Water Transfer, p. 50].

A techno-economic assessment is essential to identify, design and select possible projects. When upgrading or building new water infrastructure components, the associated costs are to be approximated at an early planning stage with reasonable effort in order to be able to differentiate between technical variants and evaluate them regarding their economic efficiency.

The objective of this Key Product is to assess the economic viability of water infrastructure projects considered within the scope of SALAM. We applied methods of fluid mechanics and cost estimation methods for the techno-economic assessment of integrated water resources management infrastructure projects. To judge and compare the projects economic viability, specific water costs were determined and used as a benchmark. Sensitivity analyses were conducted to cope with the inherent uncertainty due to the early planning stage and the underlying assumptions. Furthermore, Decision Support tools have been developed and are provided to the regional decision makers to provide support beyond the scope of the SALAM project.

METHODOLOGY

The specific water cost in US Dollar per unit of water ($/m^3) is used as a benchmark and defined as the cost of providing one unit of water to the point of demand at desired quality. It includes the cost of desalination and the cost of transfer with subcomponents as depicted in Figure 1.

The cost of desalination includes direct capital costs for materials and construction work as well as indirect costs, e.g. for insurance or project management, and operating costs with fixed and variable components. It is assumed that required capital is raised entirely through loans under a build-operate-transfer scheme (BOT), which means that capital costs are incurring as a constant annuity.

The transfer system's capacity was determined based on the expected water deficits per demand cluster in Jordan and Palestine by 2050 [Future Freshwater Deficits in Palestine and Jordan, p. 18]. The topography of the region was considered for the design of the transboundary freshwater transfer network from desalination plants at the Mediterranean and Red sea to the points of demand and the determination of the cost of water transfer. The topography impacts the required pumping power capacity as well as the design of routing and selection of pipeline types and diameters.

Within the cost assessment procedure, the power capacity required for a pumping station was determined for each section of the transfer network, taking elevation gains and head losses into account.

The resulting cost of water transfer therefore consists of pumping station installation, maintenance and operating costs, as well as pipeline installation and maintenance costs proportional to the total amount of supplied water.

Furthermore, desalinated water from Haifa could be used for electricity generation, which in return could be used for seawater desalination. To assess the economic benefit of incorporating hydropower into the network, a cost benefit analysis was conducted. The total cost of the hydropower plant includes annualized construction and installation cost, as well as operation and maintenance cost. In turn, benefit is obtained through energy proceeds. Energy generation capacity mainly depends on the inflow from desalination plants, as well as the effective head and energetic efficiency of the turbine. The net benefit of the hydropower plant was determined by relating the total annual costs and the estimated annual energy proceeds to the annual inflow of desalinated freshwater and would lower desalination cost. To account for uncertainty in the underlying assumptions, especially for the price of electricity, sensitivity analyses were conducted.

RESULTS

Five alternatives for covering the freshwater deficits up to the year 2050 in Jordan and Palestine were examined. Water production and transfer strategies were detailed in [Water Production and Transfer Strategies, p. 22].

Results, as summarized in Table 1, indicate that the cost of desalination is of minor importance when comparing alternatives. The specific transfer costs, on the other hand, vary considerably between alternatives. The most economical alternative for supplying the West Bank from Netanya and Ashdod is associated with specific transfer costs of 0.43 $/

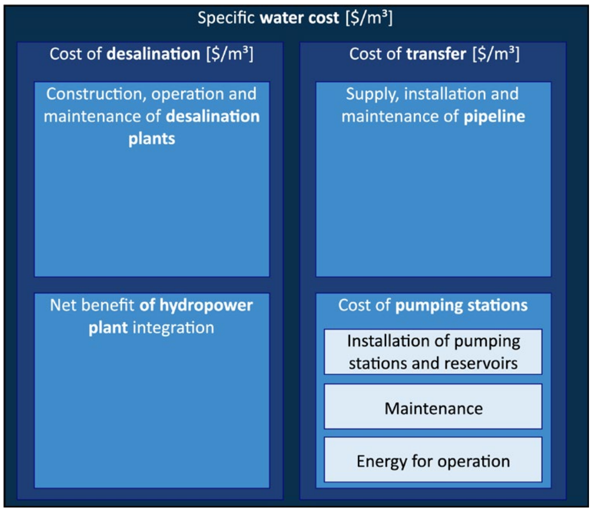

Figure 1: Cost components of the specific water cost. Specific water costs comprise the cost of desalination plant construction and operation, transfer cost and possible benefits of hydropower generation.

m^3, whereas exclusive supply via Haifa to the West Bank clusters incurs transfer costs of 0.89 $\$/m^3$. For demand clusters in Jordan, a combined supply via Haifa and Aqaba, as in Alternatives 3d and Cost Min, is the most economical solution. Given the higher share of supply from Haifa (563 million m^3/a) than from Aqaba, the Cost Min Alternative comes out to be slightly more advantageous than Alternative 3d (412 million m^3/a from Haifa). For alternatives with desalination in Haifa, a net benefit of 0.05 $\$/m^3$ through hydropower generation has been considered in the calculation of the specific water cost.

The higher transfer costs are mainly caused by energy requirements for transfer. At least two thirds of the transfer cost, depending on the alternative under consideration, are related to pumping stations and energy for operation, so that installation and maintenance of transfer pipelines represent the lesser cost factor. Additionally, transfer costs are highly sensitive to changes in energy prices, e.g. due to a different electricity generation mix or rising CO2 certificate costs.

The nominal power of the potential hydropower plant at Lake Tiberias ranges from 19.4 to 34.6 MW for considered flows. Thus, an annual flow of 412 million m^3 (Alternative 2b + 3e) yields an energy output of around 163 GWh/a. For alternatives with annual flows of up to 735 million m^3, the output increases up to 291 GWh/a.

Assumptions for the capital and operation expenditures were based on the global database of the International Renewable Energy Agency (IRENA 2021) and revenues from energy proceeds were assumed at 0.14 $/kWh. Since the costs of hydropower projects are highly dependent on specific local conditions, e.g. site access, extreme scenarios have been evaluated. Based on these assumptions, positive net present values ranging from 212 to 378 million $ were determined, which suggests that the project is economically advantageous. The resulting levelized cost of

ALTER-NATIVE	PRODUCTION POINT	SUPPLY [MILLION M³/A]	COST OF DESALI-NATION [$/M³]	COST OF TRANSFER PALESTINE [$/M³]	COST OF TRANSFER JORDAN [$/M³]	SPECIFIC WATER COST PALESTINE [$/M³]	SPECIFIC WATER COST JORDAN [$/M³]
1b	Netanya	735	0.64	0.53	1.09	1.17	1.86
	Aqaba	300	0.66	-	1.37		
2 + 4	Gaza	323	0.62	0.84	-	1.46	2.06
	Aqaba	712	0.66	-	1.41		
3d	Haifa	735	0.63	0.89	0.86	1.47	1.68
	Aqaba	300	0.66	-	1.35		
2b + 3e	Gaza	185	0.62	0.80	-	1.23	1.72
	Netanya	138	0.64	0.34	-		
	Haifa	412	0.63	-	0.91		
	Aqaba	300	0.66	-	1.37		
Cost Min	Netanya	138	0.64	0.34	-	1.07	1.63
	Ashdod	185	0.64	0.49	-		
	Haifa	563	0.63	-	0.92		
	Aqaba	149	0.66	-	1.46		

Table 1: Summarized results of the techno-economic assessment. If a region is supplied by multiple production points, the costs are allocated accordingly on the basis of the volume flow.

electricity (LCOE) range from 0.037 to 0.070 $/kWh and is comparable to the state of the art of other renewable energy generation projects as depicted in Figure 2.

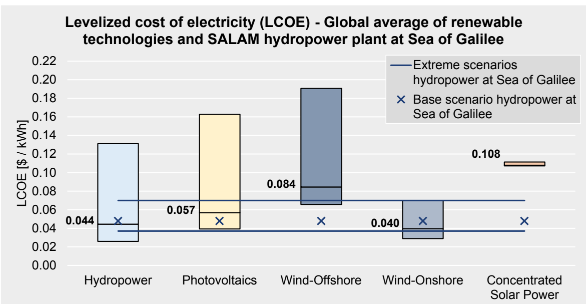

Figure 2: Levelized cost of electricity (LCOE) of the SALAM hydropower plant at Lake Tiberias compared with the global average LCOE of renewable technologies from the database of the International Renewable Energy Agency (IRENA).

CONCLUSION

The conducted techno-economic analysis provides decision support for the design of transboundary water infrastructure projects in Israel, Palestine and Jordan. The economic implications of different options for siting of seawater desalination plants and design of the water distribution network were highlighted and substantial differences between options became apparent. Due to the high flow volumes, the topographical conditions in the region and the long operating life of the infrastructure components, operational expenditures, especially for energy, have a stronger influence on the water cost than capital expenditures. This should be taken into account when planning water transfer routes, but also in the selection of energy technologies and sources.

Furthermore, results also show that the incorporation of a hydropower plant at Lake Tiberias can be economically advantageous in view of the large freshwater flows from desalination. Building on this study, the underlying assumptions for cost and revenue items can now be refined by including market specific data and tax effects within the framework of a detailed project study for selected alternatives.

The results of this study can be incorporated into the multi-criteria decision support procedure to rank the presented alternatives according to the preferences of the decision-makers. While the work presented here focuses on the economic performance of different water infrastructure projects, the methods of multi-criteria analysis furthermore allow to incorporate objectives from the social, political, ecological and technical domains to evaluate the performance of these alternatives.

SALAM ECONOMIC TOOL

The SALAM Economic Tool is a decision support tool that is linked to the SALAM IES with the goal to provide decision support for water resources planning and water management beyond the scope of the SALAM Initiative [SALAM Information and Expert System, p. 86].

The tool is organised in a modular approach that allows for an economic assessment of different types of hydroinfrastructure considered within SALAM. As of now, cost estimation for seawater desalination projects, determination of economic key data based on a reference project database and cost calculation for freshwater transfer networks are supported. Figure 3 illustrates the Graphical User Interface (GUI) and input scheme of the desalination module.

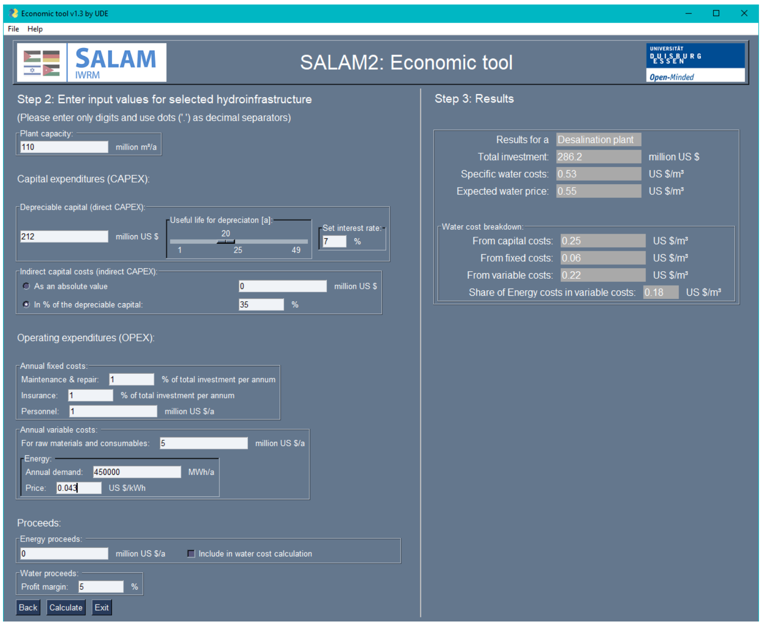

Figure 3: GUI and input scheme of the Economic Tool. Here, the desalination module is depicted.

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