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Innovative Water-Energy SWAP Concept between Israel and Jordan

Daniel Janowitz[1], Süleyman Yüce[1], Marco Margheri[2], Hamzeh Yakhoul[2], Jacob Bensabat[3], Bernd Rusteberg[4], Martin Sauter[5]

KEY FINDINGS

A SWAP, i.e. exchange, of desalinated water from Israel for solar energy from Jordan is a viable concept from which both sides benefit

The SWAP concept could be realized even without any financial compensation from either side, targeting on a fair exchange with mutual dependencies.

The SWAP implementation strategy consists of the production of 400 Mio. m^3/a freshwater from large-scale desalination plants North of Haifa, and the transfer to Jordan in exchange for the supply of Electrical Solar Energy by Jordan.

MOTIVATION

Jordan is one of the most water-scarce countries in the world, with a per capita volume of 94 m^3 of renewable freshwater per year. Jordan is heading towards a serious water crisis, facing a freshwater deficit of more than 700 million m^3 per year by 2050 [Future Freshwater Deficits in Palestine and Jordan, p. 18]. The substantial freshwater deficit in Jordan can only be met by the large-scale deployment of seawater desalination (SWD), together with a water transfer to the demand centers. SWD plants could be built at the Red Sea (Aqaba) or on the Mediterranean coast. However, due to significantly shorter distances, water transfer from the Israeli coastline to Jordanian demand centers is more advantageous in economic terms compared to solutions relying on SWD at Aqaba [Techno-Economic Assessment of Integrated Water Resources Management Infrastructure Projects, p. 72]. Therefore, transboundary water production and transfer (WPT) strategies should form the key instrument to face the challenges of the rapidly increasing freshwater deficits in Jordan.

Like all countries in the Eastern Mediterranean, Israel is characterized by substantial solar radiation rates. However, solar energy solely is not a viable solution because it depends on weather conditions, seasons, and sunlight hours, reducing its reliability. This would also require the allocation of large land areas for this purpose, since the Ministry of Energy intents to increase the share of renewable energy in the energy mix to 30% in 2030. But land availability is a limiting factor in Israel (Tal, 2018). In contrast, Jordan has large amounts of land available for solar energy production and higher solar irradiation, which makes solar plants in Jordan even more economical.

These national challenges create a potential synergy for cooperation that is advantageous for the development of Water-Energy-SWAP concepts. In this respect, Israel and Jordan have recently signed a declaration of intent (DoI) that is in line with the concepts described above. The SWAP DoI aims to intensify the cooperation between the two countries through the supply of 200 Mio. m^3/a freshwater from Israel to Jordan in exchange for 600 MW of electricity based on renewables to be produced in Jordan and supplied to Israel (Israel Ministry of Energy, 2021). This Policy Brief takes the approach further and specifies the exchange concept based on the results of the SALAM Initiative.

METHODOLOGY

In order to assess and discuss the feasibility and economic viability of a Water-Energy-SWAP between Israel and Jordan, the following steps were taken: (1) identification of alternative sites for seawater desalination (SWD) on the Mediterranean coast of Israel, (2) identification of optimal

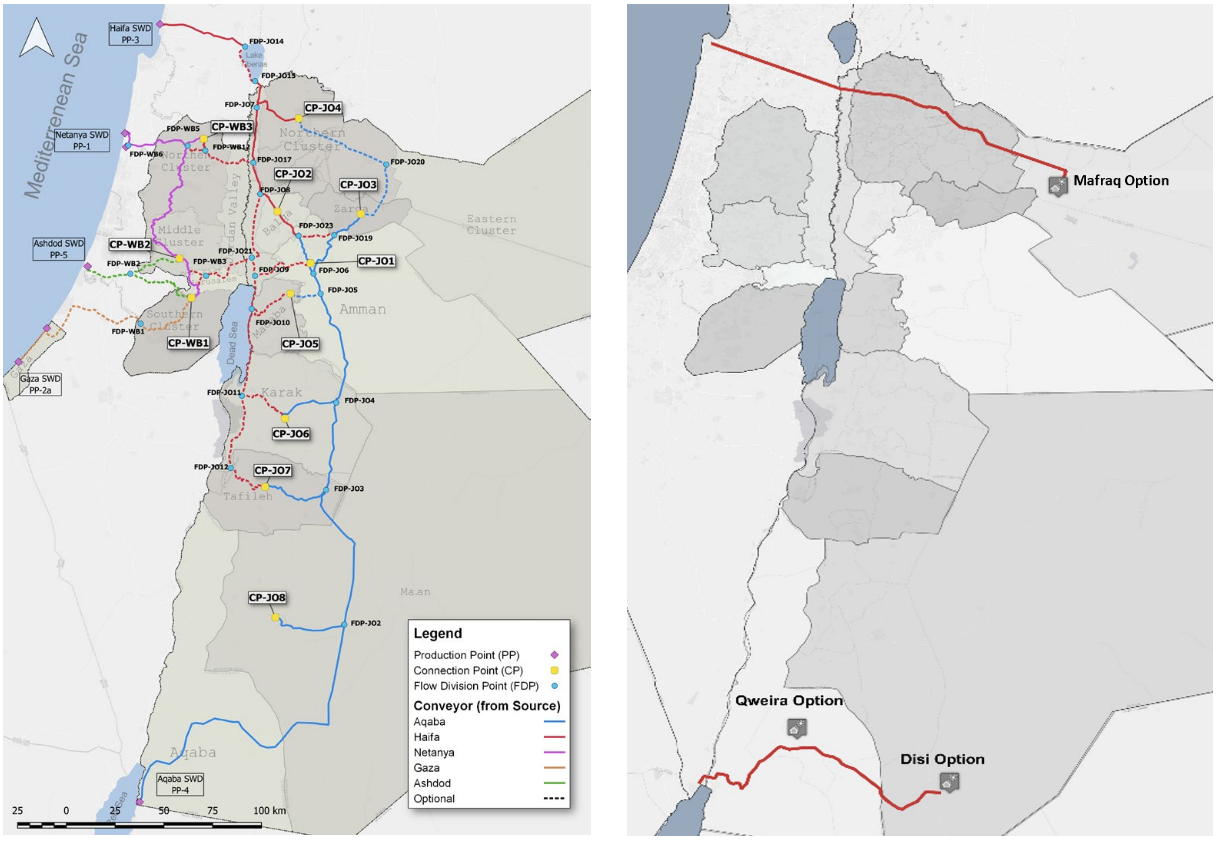

Figure 1: (A) Relevant Water Production and Transport Options (B) Potential sites for the production of electric power in Jordan for transport to Israel

routes for water transfer between the SWD-plants and demand centers, (3) selection of promising strategies for water production and transfer, (4) selection of options for renewable energy production by photovoltaics in Jordan, and (5) analysis of energy transfer to Israel.

Within the SALAM Initiative, we developed 12 water strategies based on seawater desalination at the Red Sea and/or the Mediterranean Sea and water transfer via pipelines to regional demand centers in Jordan and Palestine [Water Production and Transfer Strategies, p. 22]. These solutions are technically feasible and cost-effective. Figure 1A compiles the most technically and economically advantageous options with respect to a regional water distribution network (Rusteberg et al., 2018). It shows potential sites for seawater desalination and the corresponding positioning of pipelines for water transfer. Offshore solutions for seawater desalination were also considered. For the SWAP concept, a highly cost-effective water production and transfer solution for Jordan was chosen, based on a transboundary approach in cooperation with Israel.

After selecting a cost-effective water production and transfer solution from Israel to Jordan, potential sites for renewable energy production in Jordan were investigated. Two selection criteria were established to identify the possible locations for the PV plant: (1) the proximity to Israel's major load centers and / or grid, and (2) the solar radiation level in Jordan. After a first preliminary assessment of possible locations for suitable sites for a large-scale project, three alternatives were selected for further evaluation. Furthermore, energy simulations were conducted using PVsyst simulation software to assess the proposed alternatives' generation potential. This leads to the following location-specific key figures for the production and necessary length of the transmission lines:

- Mafraq Governorate (close to Mafraq city):
  2,165 kWh/kWp, 180km Transmission Line length
- Aqaba Governorate (Qweira):
  2,360 kWh/kWp, 70km TL length
- Ma'an Governorate (Disi):
  2,402 kWh/kWp, 140km TL length

Based on the assumptions in Table 1, the Levelized Cost of Energy (LCOET) for electrical generation by PV, including the transmission costs to Israeli grid was calculated. The LCOET is the average generation cost and transmission costs, including CAPEX and OPEX.

RESULTS

Due to shorter distances, freshwater transfer from the Mediterranean Sea to the demand centers in Northern Jordan significantly reduces the infrastructure investments and the energy required for water conveyance. In particular, the significantly lower energy demand of Mediterranean water production options for water transfer compared to Aqaba options is the basis of the economic advantage of the cooperation between Jordan and Israel under a SWAP

PARAMETER	VALUE	UNIT
PV cost	630	USD/kWp
HV Substations	200	USD/kWp
HV Transmission Line	1,000,000	USD/km.GWp
PV O&M	10	USD/kWp/year
HV TL O&M	2,000	USD/km.GWp/year
O&M Increase	3	%/year
PV Degradation	0.6	%/year
Transmission Losses	7	%/1000km
Financing + Developer Profit	5	USD/MWh

Table 1: LCOE key assumptions

agreement. The construction of a large-scale SWD plant north of Haifa with a production capacity of 400 Mio. m^3/a would cover most of the freshwater deficit in Jordan by 2050, which cannot be covered by the projected new 300 Mio. m^3/a SWD plant near Aqaba.

The analysis of potential sites for solar energy production in Jordan indicates that the Disi Option (Figure 1B) is economically attractive, resulting in an LCOET of 30 USD/MWh.

year has the highest production due to PV system degradation). That amount of energy can be produced by installing a 5.8 GWp PV plant with an area of ~72.9 km^2 in Disi. The swapped renewable energy will allow Israel to increase the renewable energy share in its electrical generation mix significantly. Based on 2019 reports, the contribution of renewables in the energy mix was 2,326 MW of a total of 19,366 MW (12%) in terms of power capacity and 3,300 GWh of a total of 72,500 GWh (5%) in terms of energy. Inclu-

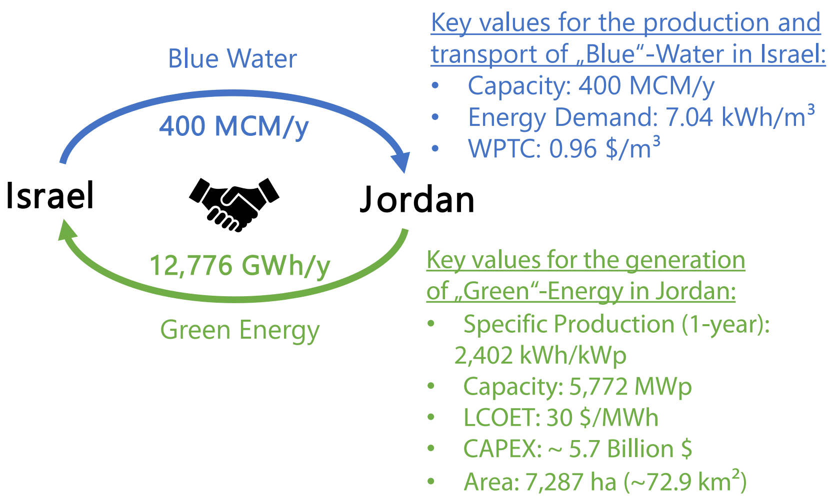

Figure 2: Potential water-energy SWAP between Israel and Jordan based on SALAM findings

In addition, Disi has a large area availability and the best energy yield, which means the highest energy supply reliability and viability. Therefore, the Disi option was selected for the generation of renewable energy for a potential Water-Energy-Swap. Figure 2 illustrates the potential Water-Energy-Swap between Israel and Jordan, including key values calculated by using Equation 1 (see box).

The amount of energy equivalent to the cost of producing and transmitting 400 Mio. m^3/a of freshwater from Israel and Jordan would be 12,776 GWh/y of energy (yearly average of the 25 years lifetime of the PV plant where the first

ding the power and energy required by water desalination and conveyance, the Israeli renewable energy penetration would reach up to 36% in power capacity and 21% in terms of energy based on 2019 figures.

CONCLUSIONS

The mitigation of water scarcity in Jordan and simultaneously covering part of the renewable energy demand in Israel is feasible by conducting a fair Water-Energy-SWAP. A promising bartering strategy could create a win-win situation by exchanging 400 Mio. m^3 of freshwater per year from a large-scale SWD plant located North of Haifa bay for megawatt-hours of renewably generated electrical energy from Jordan. With this approach, a fair exchange is achieved with mutual dependencies without monetary compensation. We recommend carrying out technical/economic pre-feasibility studies for both selected water and energy production and transfer options. The selection of the most suitable SWAP solution with the highest mutual benefit and political acceptance level should be based on a multi-criteria option comparison, considering economic, political, environmental, technical, and social aspects. There are several further research needs to be addressed before implementation. In particular, strategies must be developed to adapt the regulatory framework enabling the production and transmission of renewable electrical energy from Jordan to Israel. It needs to be investigated whether the Israeli grid can handle the additional electricity loads and how it could be expanded. In addition, the land ownership and its availability need to be clarified, including the social acceptance of such large-scale projects. Sustainable implementation of such a SWAP concept requires further research and close cooperation between the water, energy, and environmental authorities on both sides.

BARTERING WATER FOR ENERGY

Aiming at a SWAP concept where money is not part of the deal, the Israeli water production and transport costs need to equal Jordan's energy generation and transport costs. Based on this assumption, the amount of electrical power P_{Swap} for swapping from Jordan to Israel is calculated according to equation (1):

$$P_{Swap}\left[\frac{MWh}{y}\right] = \frac{WPTC\left[\frac{\$}{m^3}\right] * C_{Desal}\left[\frac{m^3}{y}\right]}{LCOET_{PV}\left[\frac{\$}{MWh}\right]}$$

P_{Swap} significantly depends on the water production and transfer costs (*WPTC*) bringing desalinated water from the Israeli coast to the demand center Amman in Jordan. The *WPTC* is calculated using the levelized costs of electricity generation and transfer ($LCOET_{PV}$) bringing the electricity from photovoltaics from Jordan to Israel. In addition, the desalination capacity C_{Desal} and the $LCOET_{PV}$ itself must be considered.

CONTACT

Daniel Janowitz
STEP Consulting GmbH (STEP)
Daniel.janowitz@rwth-aachen.de

Süleyman Yüce
RWTH Aachen; STEP Consulting GmbH (STEP)
yuece@stepconsulting.de

Marco Margheri
Dorsch International Consultants GmbH (DI)
Marco.Margheri@team.dorsch.de

Hamzeh Yakhoul
Dorsch International Consultants GmbH (DI)
Hamzeh.Yakhoul@dorsch.de

Jacob Bensabat
EWRE Ltd (EWRE)
jbensabat@ewre.com

Bernd Rusteberg
Rusteberg Water Consulting (RWC)
brusteberg@rustebergwaterconsulting.com

Martin Sauter
Georg-August Universität Göttingen (UGOE)
Department of Applied Geology, Geoscience Center
martin.sauter@geo.uni-goettingen.de

AUTHORS / FURTHER CONTRIBUTING PARTNERS

STEP[1], DI[2], EWRE[3], RWC[4], UGOE[5]

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