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WATER ENERGY NEXUS

A PRE-FEASIBILITY STUDY FOR MID-EAST WATER-RENEWABLE ENERGY EXCHANGES

EXECUTIVE SUMMARY

EcoPeace Middle East

Konrad Adenauer Stiftung

THE PROJECT PARTNERS

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Contents

1. STUDY RESULTS

The pre-feasibility study shows that the water-energy exchanges foreseen between Jordan, Palestine, and Israel are technically feasible and potentially offer substantial economic, environmental and geo-political benefits to each of the parties.

In 2030, with expected population of nearly 30 million people, the region will need an additional 574 million cubic meters (mcm) of water annually just to maintain current levels of domestic consumption. The cost of providing this water in coastal areas of Palestine and Israel serving 50% and 70% of population respectively could be provided at a cost of roughly US$0.65 per cubic meter ($m^3$), while the cost of providing water to urban centers in Jordan such as Irbid and Amman serving 80% of population, would range from between US$0.93-1.18/$m^3$, and from a comparative perspective would be the cheapest marginal cost of water currently available to Jordan.

The study also shows that supplying 20% of the region's projected energy demand in 2030 with solar energy could be accomplished at US$0.05-0.07 per kilowatt hour, a cost that is cheaper than the most efficient current fossil fuel production, even without considering the environmental costs of burning fossil fuels. This would enable the countries to meet their Paris commitments at lowest cost and with minimum pressures on open spaces. While Palestine and Israel have limited available open spaces for such projects, Jordan has plenty and production at this scale would require only 0.1% of total Jordanian land area. The project would also have ancillary benefits in terms of reduced local pollutants.

The project has a number of geo-political benefits for each side as well.

The primary potential benefits for Jordan include:

- Achieving water security in a cost efficient manner of $1.1 per cubic meter
- Becoming a major exporter of energy, contributing and thereby reducing demands on foreign currency reserves, and potentially substantially adding to them
- Replacing unilateral dependency on Israel for water and energy with mutual interdependency

Potential benefits for Palestine include:

- Diversifying its energy sources and reducing its reliance on Israel for both energy and water
- Advancing integration into the Arab world
- Achieving renewable energy goals with minimal demands on land resources
- Increasing the likelihood of reaching an agreement with Israel regarding a reallocation of rights to natural water sources

Potential benefits for Israel include:

- Achieving renewable energy goals with minimal demands on land resources
- Advancing its international leadership in desalination
- Diversifying its energy sources
- Promoting regional cooperation, stability, and integration by means of economic development in a regional framework

In addition, the project could benefit all three countries by providing energy and water stability and being a possible springboard for further regional cooperation.

2. BACKGROUND AND STUDY RATIONALE

The Levant area of the Middle East suffers from scarce supplies of fresh water. Jordan, Palestine and Israel are all among the world's lowest in terms of renewable fresh water supplies per capita. Lack of water is a threat to quality of life, an impediment to economic development, and even a source of political instability. The region is also facing rapid population growth, rising standards of living and climatic change, all of which continue to place increasing pressure on these already scarce resources. While there is much potential for water conservation and reallocation of existing water rights, all three countries will need significant additional water supplies to fulfill projected demand. This is likely to come from desalination.

With respect to energy resources, all three countries are highly dependent on imported fossil fuels. This dependency is a serious drain on foreign currency reserves as well as a strategic threat and a source of both local air pollution and global greenhouse gases (GHGs). The region has high potential for renewable energy, and all three countries have signed the Paris Climate Accords of 2015 and committed to reducing GHGs. While all three have goals for increasing the share of energy supplied by renewable sources, currently renewables represent no more than 2% of total energy consumption in any of the countries.

Israel and Palestine (via Gaza) have access to the Mediterranean Sea, and thus a convenient source of seawater input for desalination, whereas Jordan's only access to the sea is in Aqaba, which is relatively far from population centers and other sources of water demand. On the other hand, both Palestine and Israel are densely populated, with a relative paucity of open spaces. Furthermore, development of these limited open spaces is difficult – in the West Bank, both because of Israeli restrictions and hilly terrain,[1] and in Israel, because of existing restrictions on much of the most suitable land in the country's south and because of complex and cumbersome regulatory regimes governing land use planning. This presents a serious challenge to either developing renewable energy domestically. Jordan, on the other hand, is much less densely populated and has vast unpopulated areas that are very suitable for solar energy facilities. Thus, the motivating rationale of this research is to investigate the feasibility of mutually beneficial water-energy exchanges, whereby Israel and/or Palestine would produce desalinated water and deliver it to Jordan and in exchange, Jordan would produce renewable energy and provide it to Palestine and Israel.

Both cooperation on developing water supplies, including desalination, and development and integration of energy systems, including renewable energy, are explicitly stated objectives of both the Palestinian-Israeli Oslo Accords as well as the Jordanian-Israeli Peace Agreement. The envisioned water-energy exchanges could potentially promote such objectives, as well as a diverse range of national governmental objectives including water and energy security, diversification of resource supplies, regional integration, and environmental protection. If successful, it could also serve as an inspiration and basis for wider regional cooperation in other fields.

1 World Bank Group. (2017). Securing Energy for Development in West Bank and Gaza. Summary Report. June 13, 2017

As a pre-feasibility study, this study outlines various scenarios of future water and electricity demands, evaluates technologies available for supplying anticipated demand, presents initial cost estimates doing so, and provides an assessment of the geopolitical pros and cons of such an arrangement. The following section briefly presents the methodology of the report including scenario assumptions and data sources. Section 4 presents technical and social assessments of future water needs in the region. Section 5 presents technical and social assessments of energy needs and solar energy generation potential and distribution requirements. Section 6 offers an initial economic assessment of the costs of the water-energy exchanges. Section 7 highlights some of the major environmental benefits of the proposed project. Section 8 presents an overview of the geopolitical challenges and opportunities entailed in such a project. Finally, Section 9 presents conclusions and outlines potential directions for further research.

3. METHODOLOGY

The first stage in the pre-feasibility study was to establish working assumptions and develop possible scenarios for the scale and structure of possible water-energy exchanges. We chose a base year of 2030, as the nature and scale of the project will take at least a few years to study and to implement. This year also gives us perspective regarding future populations, as well as water and energy demand growth over time.

3.1. Population Growth

In order to evaluate future water and energy needs the study first evaluates anticipated population growth. Population estimates used in this study, taken from official government estimates, are given in Figure 1.

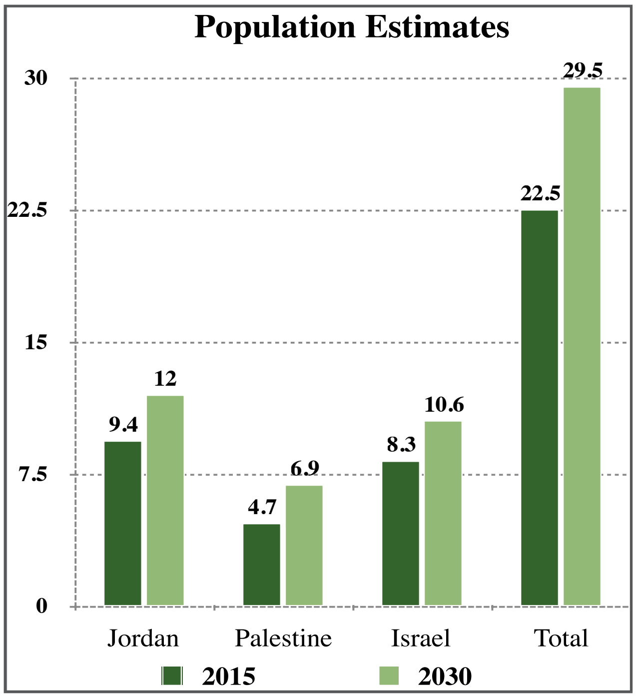

Figure 1. Current Populations and Future Population Forecasts (in millions)

Sources: [2,3,4]

Note: Current Jordanian figures are for people residing in Jordan, including nearly 3 million refugees, immigrants and other non-citizens.

As can be seen from the projected population figures, all three countries are anticipating significant population increases. The region's population is expected to increase by roughly 7 million, or over 30% between 2015 and 2030. As such, providing adequate supplies of water and energy will be increasingly challenging.

3.2. Scenario Development

In order to determine the scale of water demand for the envisioned project, this study assumed a scenario in which annual domestic consumption for Jordan and Palestine remains at current (2015) levels, while Israel's is capped at 80 cubic meters per capita per year (m^3/c/y), in line with its masterplan for the water sector.[5] The additional supplies necessary to supply this amount sustainably (i.e., without pumping renewable water sources at beyond recharge rates), without necessitating reductions in current allocations to agriculture and industry, are assumed to come from desalinated sources.

2 Department of Statistics, 2016, *Population Projections for Kingdom for the Period 2015-2050* (In Arabic). Note: Figures for Jordan are somewhat uncertain, especially regarding the number of non-Jordanian residents. Other estimates, by the same source, as well as by the UN's World Population Prospects (2017), give a range of figures for the 2015 population from 9.1-9.5 million residents. Figures for 2030 were taken from the medium range estimate for population growth.

3 State of Palestine - Prime Minister's Office of Population & UNFPA, 2016. *Palestine 2030*. http://palestine.unfpa.org/publications/palestine-2030-demographic-change-opportunities-development

4 Israeli Central Bureau of Statistics. 2013. http://www.cbs.gov.il/www/hodaot2013n/01_13_170t1.pdf Figures for 2030 were based on the medium range estimate for population growth.

5 In the full pre-feasibility study, an additional scenario was evaluated, in which all parties' domestic needs are supplied at the 80 m^3/c/y level. This was done in order to evaluate a socially equitable outcome. Projected water needs were significantly higher under this second scenario and both Jordanian and Palestinian water officials and experts who gave feedback to early drafts of the report indicated that such a scale of supply is not being considered by the relevant regulatory agencies and are not in line with their strategic planning. Therefore, we do not consider this scenario in this Executive Summary.

In terms of energy, two scenarios are examined. Both of these examine the potential for solar energy production in Jordan. The first scenario considered herein is one in which the amount of renewable energy supplied to each party is exactly equal to the energy needs of providing the projected additional water needs via desalination; that is, the amount of renewable energy needed to make such a water-energy exchange carbon neutral. The second one takes as a given that each party will produce 20% of its total projected electricity consumption from renewable sources produced in Jordan.

The study recognizes that there is much opportunity for conservation of both water and energy. In the case of water, reduction of leakages, reallocation among parties and among sectors, various technological standards, conservation campaigns and desalination of brackish water can all contribute towards more efficient water use and can reduce the amount of desalinated seawater needed. These measures should be promoted irrespective of this project. Given the scale of population growth forecasted, however, the working assumption of this study is that such measures would be insufficient to supply the needs of the populations and that desalination is a reasonable means of achieving this goal. Similarly, in the case of electricity, all three parties have potential for developing renewable energy domestically, including solar, wind, biomass and other sources. The study looks at solar in Jordan as a potentially efficient means of supplying additional renewable energy to the region. In both the cases of water and energy, the proposed project envisions actions complementary to, and not in place of conservation measures and local sustainability policies.

4.WATER

4.1. Background

Jordan, Palestine and Israel share common surface and groundwater basins, including the Jordan River system and several aquifers. Given this physical interdependence, coordinated management of the shared resources is necessary in order to ensure they are used in a sustainable manner. While issues of water rights and joint management of shared water have been and continue to be contentious political issues, recent agreements on water swaps and other joint projects demonstrate that cooperation, though not easy, is possible.

Annual renewable freshwater supplies among the three countries collectively are less than 3000 million cubic meters (mcm).[6] Distributed across a population of over 22 million, this means that the region's population has less than 150 cubic meters per capita annually (m^3/c/y) available for all purposes. For reference, the commonly used Falkenmark index of water stress, indicates that countries with annual supplies of less than 1000 m^3/c/y suffer from water scarcity and those with less than 500 suffer from chronic water scarcity.[7,8] Thus, the region as a whole (and each of the countries individually) must deal with severe chronic water scarcity. The situation is most severe in Gaza, where over 90% of the available supplies is not suitable for consumption and most of the water comes from unsustainable overpumping of the very limited aquifers. But even Israel, even when including its large quantities of water from desalination and reclaimed sewage, does not come close to reaching the 500 m^3/c/y threshold.

As mentioned, pressures on existing water supplies are expected to increase over time due to rapid population growth. In addition, as a result of projected climate change, rainfall is predicted to decrease, and temperature and resulting evaporation are predicted to increase. Thus, with greater demand and reduced natural supply, additional sources of water will be needed, especially for the municipal/domestic sector, which needs high quality potable water.

4.2. Calculating Scenario Needs

Table 1 shows the municipal consumption levels for each country as of 2015, both overall and on a per capita basis. It also shows how much of that water is assumed to be unsustainable, based on official government estimates. The column labeled "2030 Municipal Supply Needed" shows the amount of water needed in order to maintain current per capita supplies in the cases of Jordan and Palestine, and to supply 80 m^3/c/y in the case of Israel. The final column shows the additional amount of water that would be needed to achieve this supply.

6 Allan, J.A., A.I.H. Malkawi, and Y. Tsur. 2014. Red Sea–Dead Sea Water Conveyance Study Program Study of Alternatives *Final Draft Report* Executive Summary and Main Report.

7 Falkenmark, M. and Lindh, G. (1976). Water for a Starving World. Westview Press: Boulder, CO, USA.

8 Lawrence, P., Meigh, J. and Sullivan, C.. (2002). The Water Poverty Index: an International Comparison. Keele Economics Research Papers 2002/19. Keele University. UK.

Table 1. Future Water Needs

	2015 Population (millions)	2015 Municipal Supply (mcm)	2015 Per Capita Consump-tion (m^3/y)	Declared Overdrafts of Renewable Sources[9]	2030 Popula-tion (millions)	2030 Municipal Supply Needed (mcm)	Additional Water Needed (mcm)
Jordan	9.4	4,36[10]	46.4	1,60[11]	12.0	556.6	280.6
Palestine	4.5[12]	214.9	47.9	107.2[13]	6.9	330.5	222.8
Israel	8.3	777.8	93.7	0	10.6	848	70.2
TOTAL		**1,428.7**	**76.3**	**267.2**	**29.5**	**1,735.1**	**573.6**

Sources: [14,15,16]

The figures in Table 1, summarized in Figure 2 below, present the additional potable water supplies needed. As permanent water rights between Israel and Palestine are still unresolved and contested, the above figures are relevant only for Jordanian and total water needs. The relative distribution of joint Israeli-Palestinian needs, including the relative shares of supplies provided by natural and desalinated sources, likely will be determined by a permanent status agreement. Regardless of the allocation of natural water rights among the parties, however, the total figure for the region would remain the same.

The working assumption in this study is that these additional supplies come from seawater desalination. For purposes of perspective, the figure of 573.6 mcm annually is roughly equivalent to the total yearly output of all of Israel's current desalination plants. The largest desalination plant currently operating in Israel has a capacity of approximately 150 mcm/y. Thus, the additional amount of water needed would be on the scale of roughly four large desalination facilities. This does not imply that four facilities would actually be built, as capacity at current facilities could be expanded, which would lower overall capital costs. These facilities could be located in Israel or in Gaza, where one large-scale desalination plant is currently already being planned.[17]

9 Figures for declared overdrafts are taken from official government reports, and may or may not reflect all actual unsustainable pumping. The figure for Palestine is based on supply for Gaza minus the estimated safe-yield of 60 mcm/y. Israel did not declare any overdraft, and thus, none is listed herein

10 The Jordanian figure is based on estimated supplied by officials at the Ministry of Water relating only to residential consumption, as the official figures for municipal water consumption include industrial supplies as well.

11 Represents the amount listed as overdraft according to the National Water Strategy (see footnote 56). Notably, it does not include withdrawals from non-renewable aquifers, which the Ministry includes as "Sustainable Resources".

12 The population figure for Palestine differs from the official national population figure as it includes only the population receiving water supplies via Palestinian utilities. The figure for water supplies does not include those Palestinian residents of Jerusalem who are supplied via Israeli utilities. In calculations of water needs in 2030, these residents are included in the Palestinian population projections.

13 Represents the calculated overdraft beyond safe yields from the Coastal Aquifer in Gaza as of 2015. Safe yield was assumed to be 60 mcm/y. It must be noted that over 90% of water supplied in Gaza is not of potable quality, and thus, even the "safe yield" of Gazan water may be insufficient for supplying all municipal needs.

14 Israel Water Authority, http://water.gov.il/Hebrew/ProfessionalInfoAndData/Allocation-Consumption-and-production/20156/1998-2015.xls

15 Palestinian Central Bureau of Statistics. http://www.pcbs.gov.ps/Portals/_Rainbow/Documents/water/water-E-main.htm , Tables 6 and 8.

16 Hashemite Kingdom of Jordan. Ministry of water and Irrigation. National Water Strategy 2016 2025. Dec. 2015.

17 Initial capacity for the Gaza plant is 55mcm/y, eventually to be expanded to 110-120 mcm/y. Source: Office of the Quartet, Report for the Meeting of the Ad-Hoc Liaison Committee, May 3-4 2017, Brussels.

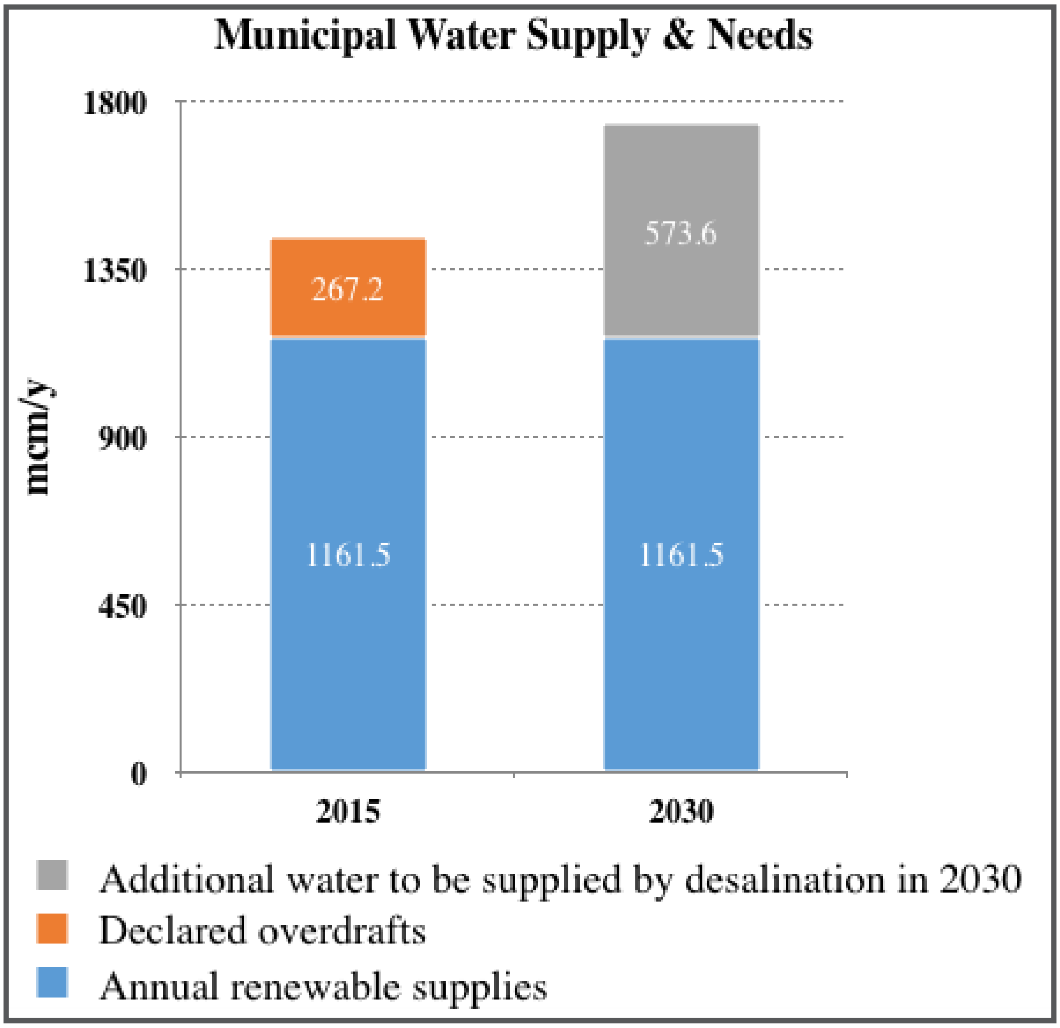

Figure 2. Estimated Municipal Water Supply & Needs

5. ELECTRICITY

5.1. Background

All of three countries are hugely reliant on imports of fuels for energy production. In the case of Jordan, 96% of its energy sources are imported.[18] In Palestine almost all of its fuels are imported via Israel, as is nearly 90% of its electricity (with Jordan and Egypt supplying an additional 4%).[19] Israel also imports most of its energy sources, though it has begun to develop large offshore natural gas reserves in the Mediterranean and hopes to become a net energy exporter in the coming decades. Natural gas reserves have also been identified off the coast of Gaza, but have yet to be developed. All three countries have set goals of increasing domestic energy production and diversifying sources of imports.

Electricity consumption has been increasing rapidly in the region, especially in Jordan and Palestine, as the parties experience both population and economic growth (see Table 4 below). Israel's consumption has been growing at the slowest rate, but because of the relative size of the market, it has increased the most in absolute terms and dominates the local market.

In terms of electric grids, Jordan is connected to a pan-Arab grid, including by land to Iraq, Palestine, and Syria, and via sea to Egypt. Palestine itself has minimal control over its electricity grid, and is almost completely dependent on Israel for transmission and distribution. Currently, the Palestinian Authority is in the process of inaugurating four substations and will control some of the distribution grid. One power plant in Gaza produces electricity, but supply is limited and irregular. The Gazan grid is connected via Rafah to Egypt's and the West Bank is connected via Jericho to Jordan's, however, these supplied only 3.3% and 0.7% respectively of total Palestinian consumption as of 2015.17 Israel is an effective "electricity island", not connected to other countries, other than Palestine.

Currently, all parties are highly reliant on fossil fuels. Renewables sources supply only roughly 2% of total electricity production in the region. All three have established more ambitious policy and all three countries have signed and ratified the 2015 Paris Accord committing to reducing emissions of GHGs. To date, however, progress in developing renewables has been modest across the board.

5.2. Calculating Scenario Needs

In calculating the future energy needs for the scenarios examined in this study, for the carbon neutral scenario (henceforth Scenario 1) we calculated the energy consumption needed to produce 573.6 mcm/y of desalinated water outlined in Table 2 and to deliver them within Israel and Palestine and, in the case of Jordan, to deliver 280.6 mcm/y of water to the Jordan's King Abdullah Canal, the primary national water carrier. We did not consider the energy needs of distribution of water within Jordan.

18 El-Katiri, L. (2014). A Roadmap for Renewable Energy in the Middle East and North Africa. Oxford Institute for Energy Studies. OIES Paper MEP 6.

19 Palestine Central Bureau of Statistics. Energy and Energy Balance Tables 2015. http://www.pcbs.gov.ps/Portals/_Rainbow/Documents/tables%202015.xlsx

For this study, we assume that desalination facilities will use reverse-osmosis technology. This is because reverse-osmosis technology is the most energy efficient of the currently commercially viable desalination technologies, and because it is the primary technology currently used in Israel and thus, the one with the most relevant technical and economic data available for analysis. We assume consumption of 3.4 kWh per cubic meter, based on the most efficient facilities currently operating in Israel. For the electricity needs of pumping water, we use 1.26 kWh per cubic meter,[20] which is somewhat higher than current average energy consumption of water delivery in Israel.[21] This produced a figure of 4.66 kWh/m^3. The total amount of energy needed annually is 2,672 GWh. We also took into consideration 14% transmission losses, which gives a total demand of 3,108 GWh/y. These figures are summed in Table 2 below.

Table 2. Energy Needs of Desalination and Delivery

Parameter	Value
Scenario 1 – Desalination needs	
Additional water supply needs, total for the region (mcm)	573.6
Electricity need per 1 m^3 water desalination (kWh/m^3)	3.4
Electricity need per 1 m^3 water transmission (kWh/m^3)	1.26
Electricity transmission and distribution losses (%)	14
Electricity consumption needs in 2030 (GWh annually)	2,672
Electricity consumption needs with transmission and distribution losses in 2030 (GWh annually)	3,108

In calculating the energy needs for producing 20% of the region's overall 2030 consumption via renewables, we relied on data from official governmental sources both for current consumption and projected future consumption. These figures, shown in Table 3, show that consumption is projected to grow by nearly 5%.[22] Accounting for transmission losses the needed amount of electricity is 34,830 GWh per year. This is over double the entire current consumption in Jordan.

20 The calculated figure of 1.25 kw per cubic meter was based on the following formula: TC = 4.2(ME+CE), where TC is total consumption in watts per cubic meter, ME is meters in elevation and CE is compensating elevation to cover the effects of friction. CE was calculated as 2.5 meters per kilometer distance. The study used an elevation of 150 meters (Eshkol Reservoir) and a distance of 60 km (the distance from Hadera to the Eshkol Reservoir, a large water reservoir in Israel, from which water could flow largely by gravity to the Jordan River Basin, and from there to Jordan

21 The average figure of 1kWh per cubic meter was taken from Hoffman, D. 2014. "Potential for energy savings in the Israeli water sector." Water Engineering, 91: 27-34. (In Hebrew).

22 The official figures for projected Israeli consumption growth are much greater than average growth over the past decade, and as such are likely an overestimate. Because of the relative size of the Israeli market, this dominates the calculated regional future needs. We, however, do not make our own estimates of future consumption, and rely on the official estimates cited herein.

Table 3. Current and Estimated Future Electricity Consumption (in GWh per year)

Demand	2015	2030	Implied Average Annual Growth Rate	Average Annual Growth Rate 2005-2015	20% of 2030
Jordan	16,177	42,419	6.6%	6.4%	8,484
Palestine	5,768	12,850	5.5%	7.1%	5,570
Israel	52,700	94,500	4.0%	1.9%	18,900
Total	**74,666**	**149,769**	**4.8%**	**2.6%**	**29,954**
Total Including transmission and distribution losses (14%)					**34,830**

Sources: [23,24]

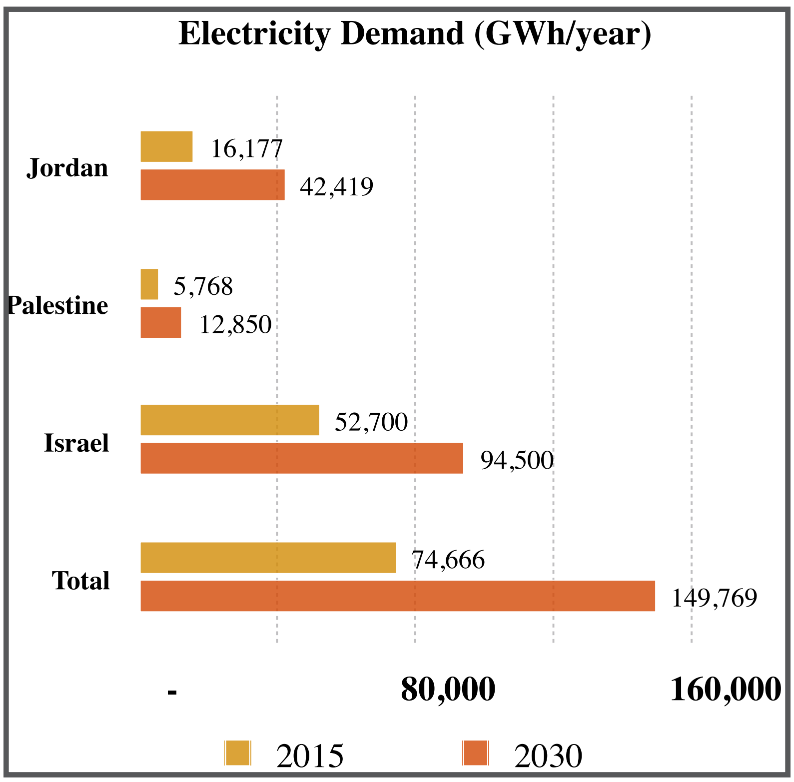

Figure 3. Current and Estimated Electricity Demand

23 NEPCO annual report, 2015. http://www.nepco.com.jo/store/docs/web/2015_en.pdf

24 PENRA (undated). "Energy Situation in Palestine.".

5.3. Choice of Technologies

In evaluating renewable energy potential in Jordan we evaluate only solar technologies. While there is much potential for other renewables, especially wind energy, in Jordan, we limited our focus to solar, as previous studies found that Jordan's solar generation potential far outweighs that of wind and is more cost efficient per unit of land.[25] Jordan has some of world's best conditions for producing solar energy and has high levels of irradiation potential. Southern Jordan has the highest such potential, at levels up to 2800 kWh/m^2, levels much higher than even the highest of the world's top installed facilities. Furthermore, it has a short concentrated rainy season, and thus, the timing of the irradiation over the course of the year can be predicted with a high level of confidence.

In the study we examine two types of solar energy technologies, photovoltaic (PV) and concentrating solar power (CSP). PV systems dominate the market and tend to be much cheaper than CSP systems, but CSP systems can be built to integrate storage capacity, and thus mitigate somewhat the related problems of intermittency and lack of dispatchability which characterize renewable energies such as solar and wind and limit their usefulness.[26] We also examine each technology under specific conditions: PV with and without tracking systems, and CSP trough and tower designs, with various storage capacities. We find PV with a one-axis tracking system to be the most cost-efficient, and for reasons of brevity, in this Executive Summary we present results only for this technology.

The effectiveness of current PV systems declines over time. In order to ensure that Scenario 1 was in fact carbon neutral for the life of the project (assumed to be 25 years), we add additional production to the estimates for Scenario 1. Based on current technologies, we assume a reduction rate of 0.5% of output annually. Thus, instead of the figure of 3,108 GWh calculated in Table 3 above, we use a production capacity of 3,372 GWh for 2030, meaning that actual production will be greater than the 3,108 GWh demand in the early years of the project and less than actual demand in the later years.

25 German Aerospace Center (DLR) 2005. Concentrating Solar Power for the Mediterranean Region http://www.dlr.de/tt/Portaldata/41/Resources/dokumente/institut/system/publications/MED-CSP_complete_study-small.pdf

26 Intermittency refers to the fact that power is not produced at all hours of the day, while dispatchability describes the ability to tailor production to meet specific demand at any given time of day. In the case of solar, it may overproduce relative to demand during mid-day, and not produce at all at night.

6. ECONOMIC ANALYSIS

6.1. Water Economics

For the purposes of this study, we assume a Build Operate Transfer (BOT) financing model, in which upfront costs are born by the private sector, and costs to the governments are spread out over a period of 25 years – the financing system currently in place in Israel's large seawater desalination plants. Currently desalinated water costs from existing Israeli plants range from $0.55-$0.80 per m³. Taking the low-end estimate, assuming cost savings due to economies of scale and technological improvement over time, gives an annual cost for desalination of $315m for the region as a whole. Adding the cost of pumping (assuming a cost of US$0.082/kWh – the cost currently paid in Israel), results in another US$0.103/m³, or US$59m annually.

In the case of Jordan's share of the water, given the quantity, an additional pipeline may be needed.[27] The shortest distance from the Mediterranean to the Jordan River is roughly 80 km, via Israel. The shortest distance from Gaza is roughly 120km. Based on estimates from the Israeli Water Authority,[28] capital costs would range between US$440-840 million. Annualized over the course of the project, this amounts to an additional US$0.06-0.08 per cubic meter for Jordan. We also add an additional pumping cost of US$0.077 as an estimate for the costs of pumping from the western bank of the Jordan River system to the King Abdullah Canal (KAC), Jordan's primary national water carrier.[29]

It is difficult to calculate the cost of delivering the water throughout Jordan, however, assuming the same pumping coefficients as in Israel, pumping from the King Abdullah Canal to Amman, for instance, with an elevation difference of 1000m and a distance of approximately 100km would entail an extra 5.25 kWh per cubic meter. The cost of electricity in Jordan is variable and subsidized making direct calculations complicated. According to a "Master Strategy for the Energy Sector in Jordan for the Period 2007 – 2020," prepared by the electric utility NEPCO the marginal cost of electricity in 2030 is projected to be US$0.071.[30] Using this cost would entail a delivery price of US$0.37/ m³. Adding this to the cost of delivery up to the King Abdullah Canal gives a total cost of supply of US$1.10-1.18/ m³. This is very similar to the lowest-end costs estimate for the Red-Dead canal examined within the context of the World Bank sponsored feasibility study,[31,32] as well as to the costs of bringing water from the Disi Aquifer in

27 It is not clear that a dedicated pipe of this scale would be necessary, as increased allocations from the Jordan River system could supply Jordan, with the reduced supply in Israel being replaced with desalinated water.

28 Capital costs would be in the range of US$5,500-7,000 per meter. Israel Water Authority. 2017. Personal correspondence.

29 This figure is based on the low-end estimate in Shaham, G. 2015. Options for Supply of Additional Water to the Kingdom of Jordan. The Kinneret Drainage and Rivers Authority – Sea of Galilee Administration. This study examined the costs of pumping from the Sea of Galilee to the KAC. The low-end estimate is justified given that the original calculations were for a much smaller scale pipeline, and there are known economies of scale.

30 Coyne-Et Bellier, Tractebel Engineering and Kema. 2014. Red Sea - Dead Sea Water Conveyance Study Program
Feasibility Study Draft Final Feasibility Study Report Summary.

31 Ibid 2014 and Allan, J.A., A.I.H. Malkawi, and Y. Tsur. 2014. Red Sea–Dead Sea Water Conveyance Study Program Study of Alternatives *Final Draft Report* Executive Summary and Main Report.

32 One need be careful regarding comparisons of costs from this project with those of the Red-Dead Canal, as they are not designed to achieve the same purposes and therefore include different types of infrastructure and calculations were undertaken with somewhat different assumptions. Thus, the comparison is for illustrative purposes only.

southern Jordan (a major source of current water supply),[33] and is significantly lower than the high end estimates of such sources. In contrast to water from Aqaba or Disi as a source, the actual distance water would need to be pumped in this project would be less, and so would associated costs, as much of Jordan's population is located in the North, closer to the King Abdullah Canal. Pumping the water to Irbid, Jordan's second most populous metropolitan region, for instance, would entail only an additional US$0.20/m^3 for pumping, or a total cost of US$0.93-1.01/m^3. A summary of estimated costs for water supply is given in Figure 4 below.

Water subsidies in Jordan are extensive. Between 2005-2011 they were estimated to be 0.4% of Kingdom's total GDP.[34] This is a serious drain on government coffers, and phasing out of these subsidies is a significant part of the Jordanian Ministry of Water and Irrigation's strategic plans.[35] Therefore, attaining water in a cost efficient manner is an important economic and national priority of Jordan.

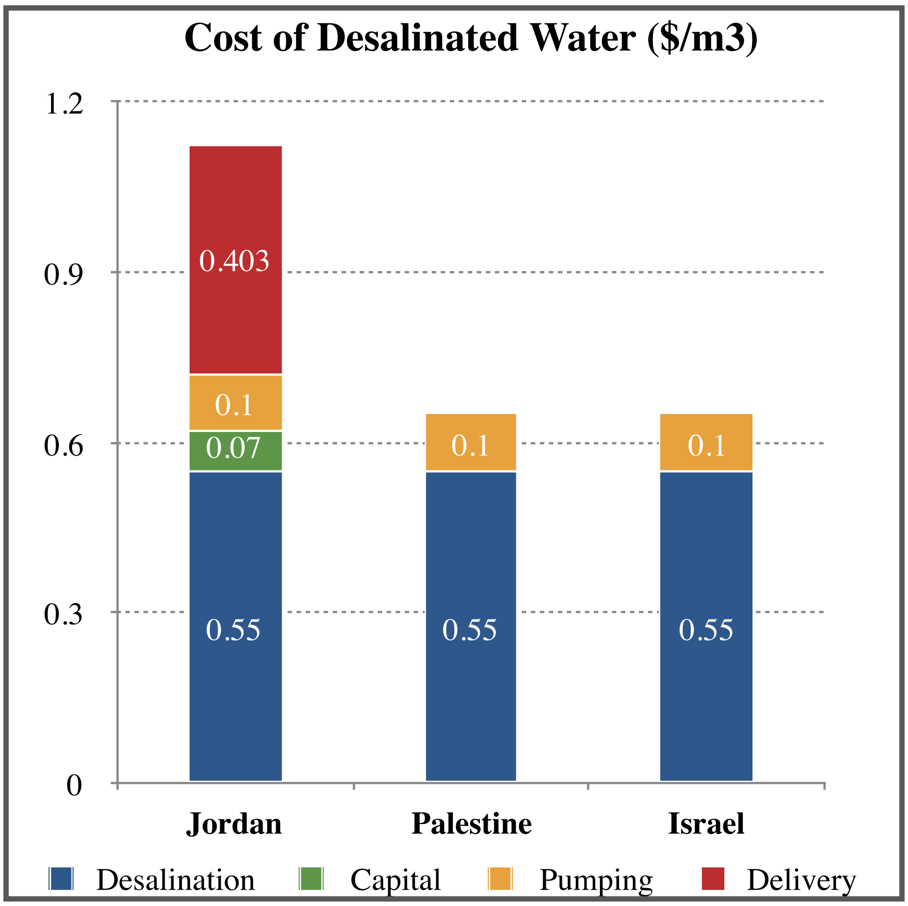

Figure 4. Estimated Costs of Desalinated Water per Country

33 USAID. 2012. Review of Water Policies in Jordan and Recommendations for Strategic Priorities.

34 Ibid, 2012.

35 Jordan Ministry of Water and Irrigation. 2016. Water Sector Capital Investment Plan – 2016-2025.

Table 4 shows annualized costs for the three countries, assuming an average cost (including delivery) in Jordan of US$1.10/m³. Again, the costs for Palestine are based on current sources, but would be substantially reduced should a reallocation of rights to natural water be agreed upon. Table 5 shows the net present value of costs for 0, 5%, and 10% discount rates.[36]

Table 4. Annualized Costs of Desalination and Pumping

	Additional Water Needed	Desalination Costs	Pumping Cost	Total
	(mcm)	(million US$)	(million US$)	(US$/m)
Israel	70.2	38.6	7.2	45.8
Palestine	222.8	122.5	22.9	145.5
Jordan	154.3	154.3	280.6	308.7
Total	**573.6**	**315.5**	**184.5**	**500.0**

Table 5. Net Present Value of Water Project Costs (in billions of US$) (25 year time frame)

Applied Discount Rate	**0%**	**5%**	**10%**
NPV	12.5	7.4	5.0

6.2. Electricity Economics

Estimates of capital costs, operating costs and land use costs for producing a PV system at the scale envisioned are presented in Table 6. Cost estimates were based on discussions with experts currently working on solar energy in Jordan, on academic literature,[37] and on data from the International Renewable Energy Agency (IRENA).[38]

36 This assumes no additional infrastructure is needed in Jordan. A full feasibility study should evaluate in depth the capacity of Jordan's existing infrastructure.

37 For example, Fthenakis_et al. 2016. New prospects for PV powered water desalination plants: case studies in Saudi Arabia. *Progress in Photovoltaics: Research and Applications*. 24:543–550. And K. Zweibel, J. Mason & V. Fthenakis, January 2008, "The Solar Grand Plan," *Scientific American*, 298(1), 64-73.

38 IRENA. 2014. https://www.irena.org/DocumentDownloads/Publications/IRENA_RE_Power_Costs_2014_report.pdf

Table 6. Capital, Operations & Maintenance, and Land Use Estimates for PV

	Scenario 1	Scenario 2
Installed generator capacity, MW	1,513	16,957
CAPEX, low & high estimates, US$/Wp	1.1-1.6	1.1-1.6
CAPEX, low & high estimates, million US$	1,665-2,421	18,65327,131
Land use needs (km²)	9	92
Land use cost (annual), million US$	1.5	16.8
Land use cost (rent for all period), million US$ (undiscounted)	37.4	418.9
Operation and maintenance (O&M), c/kWh	1.5	1.5
Annual O&M, million US$	50.6	522.5

One important finding from the analysis is that land costs represent a relatively minor share of total project costs. This indicates that lower land use costs in Jordan, relative to Palestine and Israel, are unlikely to be a factor in locating the facilities. More important are the lack of available open spaces for such facilities in Palestine and Israel and the regulatory and bureaucratic obstacles to obtaining approval for construction of such facilities there.

Capital investments, however, are not the only, nor the most representative measure of project costs or preferability. Levelized cost of electricity (LCOE) measures the per unit costs of electricity production over the lifetime of a project. As such, it allows for comparison of projects of different technologies, scale, duration, capital costs, etc.[39] Estimates for the LCOE of a PV system with a one-axis tracker using a 5% discount rate ranged from US$ 0.0525 per kWh using the low-end assumptions to US$0.0685 using high-end ones. These values are comparable to current state of the art renewable energy projects. The low-end cost estimates are similar to recent winning bids from Israeli government solar tenders,[40] and are believed to be close to the costs of production in the existing PV facility in Maan, Jordan.

These estimated costs are already competitive with even the cheapest fossil fuel produced

39 Calculations were made using the LCOE Calculator of the National Renewable Energy Laboratory of the U.S. Department of Energy https://www.nrel.gov/analysis/tech_lcoe.html, and its Cost of Renewable Energy Spreadsheet Tool (CREST) https://financere.nrel.gov/finance/content/crest-cost-energy-models

40 Globes. 2017. “Revolution: Solar energy is the cheapest alternative in Israel” 20 March, 2017 (In Hebrew).. http://www.globes.co.il/news/article.aspx?did=1001181744

electricity, relying completely on natural gas. Direct cost comparisons between solar and conventional power systems, such as natural gas, using parameters such as LCOE are problematic, given solar energy's limitations of intermittency and lack of dispatchability.[41] However, this problem is somewhat mitigated by the fact that a) peak solar production would correlate highly with peak demand, especially in summer months, and b) total production is limited to 20% and thus should not result in unneeded production. In addition, when one adds in the costs of environmental externalities from fossil fuels (currently estimated at US$0.028 per kWh in Israel[42]), solar energy is almost certainly advantageous.

Data on the cost of transmission infrastructure were difficult to attain, however, using parameters given by experts in the electricity field in Jordan the calculation of transmission infrastructure costs for Scenario 1 was roughly US$44 million for a line from Maan to Israel and US$106m for a line from Maan to Palestine, via Jericho. It was assumed to consist of extra high-voltage alternating current (EHVAC) overhead lines and one substation. We assumed transmission capability for EHVAC to be 500-700 MW per circuit. For Scenario 2, the relative share of Palestinian electricity could be served by the same infrastructure, and thus, the costs remained US$106m, while the portion of Israeli electricity was calculated to necessitate 7 double circuit overhead lines and 7 substations, and would cost US$305m. In both cases, transmission infrastructure represents a relatively modest share of overall project costs.

It is important to note that these costs are based on very rough estimates, in-depth detailed studies would be needed both on transmission infrastructure costs, integration costs, and actual transmission costs. Furthermore, the cost assessments here were undertaken only for a single facility in Maan, however, given the scale of electricity produced, especially in Scenario 2, production should be distributed geographically rather than concentrated in a single area, both to reduce loads on any given line and to distribute potential risk across the system.

6.3. Water-Energy Exchanges

As mentioned, without detailed data on the costs of transmission and distribution infrastructure, both for water and for energy, it is difficult to estimate the actual costs of the water-energy exchanges that this study is examining. What can be done, however, is to compare production costs. For the purposes of comparison, we assume that regardless of whether the envisioned exchanges occur, the parties would consume the quantities of water and electricity as detailed in Sections 4 and 5. Therefore, this analysis evaluates only the cost of the exchange; that is, it compares the costs to Jordan of importation of desalinated water from Israel and/or Palestine with the revenue it would receive from selling electricity to Israel and Palestine.

Because the issue of water rights between Palestine and Israel is still contested, and the location of the proposed desalination is as yet undetermined, for this section we treat Palestine and Israel as a single water exporter for Scenario 1. In the case of Scenario 2, each party is assumed to pay Jordan for 20% of its anticipated electricity consumption (plus losses). For this analysis, the water and electricity are sold at cost. Water costs are those taken from Table 4 above, while electricity prices are based on the LCOE for the low and high end estimates of one-axis PV systems, multiplied by relative shares of electricity consumption in each of the scenarios. The results are presented in Table 7.

41 See, for example, Joskow, P.L. 2011. "Comparing the Costs of Intermittent and Dispatchable Electricity Generating Technologies." *The American Economic Review* 101(3): 238–41. Or Edenhofer, et al. 2013. "On the Economics of Renewable Energy Sources." *Energy Economics* 40: S12–23.

42 Based on figures provided in: http://www.sviva.gov.il/subjectsEnv/SvivaAir/Pages/AirExternalCost.aspx

Table 7. Annual Net Revenue for Jordan

Scenario		Quantity	Revenue (million US$/y) (at US$0.0525/kWh)	Revenue (million US$/y) (at US$0.0685/kWh)
1	Jordanian Water Imports & Pumping within Jordan	280.6 (mcm)	-$309	-$309
	Jordanian Electricity Exports	1587.6 (MWh)	83	$109
	Net Revenue for Jordan		**-$225**	**-$200**
2	Jordanian Electricity Exports*			
	To Palestine	3,000 (MWh)	$158	$206
	To Israel	22,000 (MWh)	$1155	$1507
	Total	25,000 (MWh)	$1,313	$1713
	Net Revenue for Jordan		**$1,004**	**$1,404**

* Values round to nearest 100 MWh

While the figures above are merely illustrative, they indicate that the net costs to Jordan of water importation would be reduced significantly under Scenario 1. Under Scenario 2, because of the large scale of electricity production, Jordan would become a major energy exporter. Revenues from exports of electricity under the latter scenario are estimated at between US$ 1.3-1.7 annually. To put this in perspective, this is several times the magnitude of annual revenues from the Arab Potash Company,[43] Jordan's largest factory. In fact, it is 3-4% of Jordan's total 2016 Gross Domestic Product (GDP) of US$ 38.6 billion,[44] and would be the equivalent to 11-15% of industry's share of 2016 GDP.

For both Palestine and Israel, the financial benefits are more difficult to estimate. Revenues from water will depend on who supplies what quantity. In terms of electricity, both countries have capacity to develop their own renewables, theoretically at rates similar to those calculated for Jordan, given the similar climate. The major economic incentive for both countries is the availability of land in Jordan. Restrictions and regulatory impediments to changes in land use for both countries are likely to be significant, and could lead to substantial regulatory costs as well as delays in project implementation.

6.4. Project Finance

Several options exist for project finance. Jordan and Palestine, as developing countries, are eligible for financial assistance on favorable terms from institutions such as the World Bank and other development banks, while Israel, as a member of the OECD, has a relatively high credit rating which can attract lower cost financial terms on the

43 Annual revenue for the Arab Potash Company in 2016 was roughly US$ 460 million. Source: Arab Potash Company. Annual Report 2016. (Calculated using an exchange rate of 1 US$ = 0.7 Jordan Dinar (JD)).

44 The World Bank. 2017. https://data.worldbank.org/indicator/NY.GDP.MKTP.CD?locations=JO

open market. In addition, various carbon finance instruments may be available, both through development banks and various private carbon markets.

There are several reasons to involve the private sector in such a project. BOT project finance models, for instance, have the advantage of deferring upfront costs and much of the risk away from the government and on to the private sector. It also galvanizes private sector knowledge and experience. Finally, private sector led projects may face less political resistance than government led ones, which is particularly important in the context of Middle East regional cooperation.

Regardless of the source of funding, certain information is critical to investment decisions, most importantly a detailed assessment of project risks. There are political and security risks, e.g., that the partner countries cease or impede project development, or that project infrastructure becomes the target of attacks or is damaged during the course of violent exchanges between parties or citizens of the various parties. There are also technical risks, e.g., that technologies do not work as anticipated. And finally, there are real issues of economic risk, including construction cost overruns, purchase commitments and ability to pay. These are especially relevant considering that the electricity sector in all three countries is in deep arrears and many of both the water and electric utilities suffer from difficulties with cost recovery from their consumers.

Given these risks careful attention will have to be paid to drawing up clear, detailed and binding contractual relations between the partners, specifying the obligations and rights to each party involved, and perhaps developing some type of institutional framework for conflict resolution and/or instances of abrogation of commitments.

7. ENVIRONMENTAL CONSIDERATIONS

The envisioned project would have clear benefits for the environment. Developing desalination would reduce overdrafts resulting in depletion and contamination of aquifers and pressures on aquatic ecosystems. Desalination, however, is an energy-intensive process, and could be an important source of greenhouse gases (GHGs). Supplying water via desalination as envisioned in this project, would allow for reducing not only GHGs, but local air pollutants as well. Table 8 shows the avoided air pollution emissions for Scenarios 1 and 2 relative to the equivalent amount of electricity being supplied by natural gas. Natural gas is by far the cleanest of the fossil fuels currently used for production, and thus, this is probably a low-end estimate of real emissions savings from such a project.

In addition to the environmental impacts of water and energy production, the project would likely have a positive net impact on wildlife habitat and ecosystems, even if compared to each country pursuing a unilateral strategy of renewable energy production. For Palestine and Israel, the project would allow them to produce renewable energy without adding pressure on their already limited and highly fragmented open spaces, which provide habitat for numerous endangered species of flora and fauna. While it would increase pressure on Jordanian lands, these lands are much more plentiful, over lower ecological value and with much less competition for development. Even producing 20% of the region's total projected energy demand would necessitate only 0.1% of Jordanian territory.

Table 8. Avoided Air Pollution Emissions[45]

		Scenario 1	Scenario 2
Type of Emission	**Emissions (grams/ KWh)**[46]	**Total Avoided Pollution (tons/year)**	
Sulfur Dioxide (SO_2)	0.02	62	697
Nitrous Oxides (NO_X)	0.3	932	10,449
Particular Matter (PM10)	0.01	31	348
Carbon Dioxide (CO_2)	436	1,355,088	15,185,880

45 Avoided emissions are relative to production exclusively from natural gas, and thus, are likely a lower-bound estimate of actual emission reductions

46 Source: Coheh, G. and M. Korner. 2016. Israeli Oil & Gas Sector Economic and Geopolitical Aspects: Distinguish between the Impossible, thePotential and the Doable. Samuel Neaman Institute. Haifa, Israel

8. POLITICAL FEASIBILITY & GEOPOLITICAL CONSIDERATIONS

In addition to potential economic and environmental benefits, the proposed project offers many political advantages to the different parties, including strengthening of regional ties, reduction of reliance on imported fuels, and diversification of water and energy supply sources. In addition, as a regional cooperation project it would likely be eligible for assistance from the international community at terms preferable to those any country would get pursuing a unilateral policy.

The primary potential benefits for Jordan include:

- Achieving water security in a cost efficient manner
- Becoming a major exporter of energy, and thereby reducing demands on foreign currency reserves, and potentially substantially adding to them
- Replacing unilateral dependency on Israel for water and energy with mutual interdependency
- Potential benefits for Palestine include:
- Diversifying its energy sources and reducing its reliance on Israel for both energy and water
- Advancing integration into the Arab world
- Achieving renewable energy goals with minimal demands on land resources
- Increasing the likelihood of reaching an agreement with Israel regarding a reallocation of rights to natural water sources
- Potential benefits for Israel include:
- Promoting regional cooperation, stability, and integration by means of economic development in a regional framework
- Diversifying its energy sources
- Achieving renewable energy goals with minimal demands on land resources
- Advancing its international leadership in desalination

As can be seen from the cursory list above, many of the benefits are in line with primary policy goals of the various nations. For Jordan this includes increasing energy security and lowering the cost of supplying water. For Palestine, this includes reducing its dependence on Israel for basic resources and integrating its infrastructure into that of a fellow Arab country, as, while it its culturally part of the Arab world, physically, it has been largely disconnected from it. For Israel, the project is in line with its declared goal of promoting cooperation via economic development and pursuing political arrangements vis-à-vis its neighbors in a regional framework.

Just as the European Union started as a very limited economic agreement between former enemies focusing on only two resources: coal and steel, this project, if successful, also has the potential to be a springboard for broader cooperation in other fields, thereby further promoting stability and peaceful relations in the region.

The project would, of course, also face certain political challenges, including a preference among some policymakers for self-sufficiency rather than regional interdependencies. It also may face objection by some in Jordan and Palestine to normalization of ties and integration of infrastructure with Israel. In that respect, in must be noted that current agreements for Israel to increase sales of water and natural gas and electricity to both Palestine and Jordan, as well as larger initiatives such as the Red-Dead Canal, indicate that the expected advantages of regional cooperation in these fields can overcome the potential political obstacles. Indeed, as opposed to the unilateral dependency on Israel under the current situation, the proposed project would provide for mutual interdependencies, with each party having strong incentives to maintain cooperation.

9. CONCLUSIONS AND FUTURE RESEARCH NEEDS

The purpose of this pre-feasibility study is to present the project vision and a reasonable approach for how such a project might be developed. This initial analysis indicates that the project is indeed technically feasible and environmentally desirable, and could potentially provide wide-scale economic and political benefits to the three parties. Table 9 presents a qualitative assessment of potential pros and cons of the project for each party relative to a business as usual scenario.

Given these potential benefits, the project deserves to be investigated in greater depth. In conducting a full feasibility study, researchers may wish to alter or expand the assumptions guiding this study as well as the types of scenarios and technologies envisioned. They should also develop the technical and economic analysis to better assess the capacity limitations of current and planned infrastructure, as well as the technical and economic aspects of delivery systems for both water and electricity, including issues regarding integration of these systems into existing infrastructure. While this study is only preliminary and leaves many questions open, it is hoped that the case was sufficiently made for conducting a more in-depth feasibility study supported by the governments themselves as well as the international community.

Table 9. Distribution of Project Benefits

Economic

	Reduced Cost of Water Delivery	Reduced Cost of Achieving Renewable Energy	Reduced Regulatory Hurdles for Reducing Emissions	Income from Selling Electricity	Income from Selling Water	International Financial Support
Jordan	++	–	–	++	–	++
Palestine	*0*	*0*	++	–	+	++
Israel	*0*	*0*	++	–	++	+

Environmental

	Reduced GHG Emissions	Reduced Local Air Pollution	Reduced Pressure on Open Spaces	Reduced Pressure on Freshwater Aquatic Ecosystems	Reduced Pressure on Marine Ecosystems
Jordan	++	++	–	*0*	++
Palestine	++	++	++	+	–
Israel	++	++	++	+	–

Geo-Political

	Achieving Water Security	Achieving Energy Security	Diversification of Energy Sources	Reduced Dependence on Israel	Promoting Regional Stability	Integration with Arab world	Improved International Standing	Improved Chance of Achieving Reallocation of Water Rights
Jordan	++	++	*0*	–	++	+	+	*0*
Palestine	++	++	++	++	++	++	+	++
Israel	*0*	+	++	*0*	++	++	++	*0*

++	Major benefits
+	Benefits
0	Neutral/no impact
–	Minor disadvantage
– –	Major disadvantage

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