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Hydropower and pumped-storage in Israel – The energy security aspect of the Med-Dead Project

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A B S T R A C T

The energy security paradigm has puzzled experts ranging from economists and politicians to military planners and historians; it is a topic which has been closely intertwined with the development of oil resources throughout modern history. Historically higher oil prices have fostered development and market penetration of alternative energy supply and demand technologies around the globe. Israel's energy security challenges, contrary to those of Persian Gulf states, derive from multiple issues. Yet, these energy security challenges are also partly a result of lack of resource diversification. From the resource diversification point of view, the impact of energy supply disruptions has multiple implications for Israel's national security. This paper focuses on reviewing the potential to establish pumped hydroelectric storage, and considers the strategic impacts of hydropower generation in Israel from the point of view of resource diversification by first building a case for a new hydropower generation. Even though the idea of introducing pumped hydroelectric storage to the Mediterranean Dead Sea project, also known as "The Seas project", is not a new concept and such technology is mature, new technological development plays an important role in determining the economic and technical feasibility of such a project. It is important to note that pumped hydroelectric storage technology is the only significant and flexible means of storing energy. There is a variety of aspects that need to be assessed in a more comprehensive analysis, and therefore the purpose of this paper is to exclusively consider the energy security aspect of hydropower generation, while assessing the Mediterranean Dead Sea project as a case study. There is plenty of leeway for future endeavors that will take Israel, the "start-up nation", to new heights in national strength and nation-building. In the past many significant infrastructure projects, such as the National Water Carrier and the coastal desalination plants, have been successfully built. At the end of the paper an open question is presented: When will Israel be ready to take such a great leap and reach towards these courageous ventures of national and economic security?

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1. Introduction

The Middle East has long been an important energy resource hub, most notably for oil and gas. With the help of significant revenue from oil exports, the Persian Gulf countries have been able to generate significant income which has led to rapid economic development. Yet, the abundance in oil has led to a rather anemic structure of local power production focusing mainly on oil and gas, which in turn reflects a low level of resource diversification in most of the Persian Gulf nations where total primary energy supply is mostly produced from oil and gas (IEA, 2014). Resource diversification, whether transportation fuels or electricity production, is a critical factor that increases energy security, and further, economic security. It is true to say that without access to modern, reliable energy sources, economic development is not possible.

The International Energy Agency (2013a), defines energy security as "the uninterrupted availability of energy sources at an affordable price" while respecting environmental concerns. When new energy resources are developed, the impact of climate change and sustainable development needs to be assessed. Economic security, in contrast, is considered to be the condition of having a stable source of financial income, which allows for the on-going maintenance of a standard of living in the present and in the foreseeable future.

Energy security is an issue of national security, which is often portrayed as an issue for the defense establishment rather than an issue driven by pure economic interests. Historically higher oil prices have fostered development and market penetration of alternative energy supply and demand technologies. Even though fossil fuels continue to dominate the future energy supply well into the 21st century, alternative fuels, such as new hydropower projects, play a growing importance. Although Israel's energy security challenges, contrary to those of Persian Gulf nations, derive from different issues, they are also partly a result of lack of resource diversification. Korin and Luft (2012, p. 56) argue that diversifying fuel sources is the most critical condition in achieving energy security. "In a well-diversified electricity system disruption in supply or price spike in one source of power can be compensated by shift to another" (ibid.).

In Israel, electricity is generated, transmitted, and distributed by the Israel Electric Corporation (IEC) – the sole integrated electric utility, which is almost completely owned by the State of Israel. Between 1999 and 2009, Israel's national cumulative electricity demand grew at an average rate of 3.6% per year. In 2011, 61.5% of the electricity produced by the IEC was generated by coal, 0.9% by fuel oil, 31.9% by natural gas and 4.8% by diesel oil (IEC, 2014). A summary of Israel's electricity generation and consumption in 2011 are presented in Figure 1. Until now most of the fuels used are imported from outside of Israel, however, in the coming years new gas-fired power stations will generate an even larger share of the electricity increasing the diversity of energy sources.

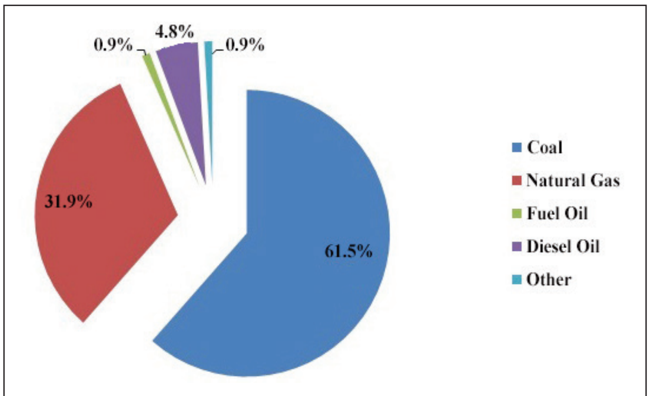

Figure 1: Electricity production in Israel

Israel's electricity is currently generated almost exclusively by thermal power plants. The current system has no hydroelectric resources, neither conventional nor pumped storage, and is not interconnected with any system outside of Israel excluding 56 MWh imported from Jordan to the Jericho area. Thus, it has been necessary for Israel Electric Corporation to maintain considerable reserve capacity in the form of oil-fired steam plants and gas turbines. (IEC, 2014)

The impact of energy supply disruptions has multiple implications on Israel's national security. Presently, most of Israel's power generation is located on the Mediterranean coast, mainly to ensure a supply of cooling water and due to transportation logistics of fossil fuels, namely, coal, natural gas, diesel and heavy oil. Further, when the power stations are located in the same geographical area, they are more vulnerable to various threats, such as sabotage and terrorism, in times of conflict and more intensive military operations. According to Koknar (2009, p. 20), electricity power grids are vulnerable to become top targets for terrorist organizations. This has been the case in countries like Peru, Pakistan and Iraq. Thus, one potential benefit of the Mediterranean Dead Sea projects and other pumped hydroelectric storage projects is increasing geographic distribution of electric power stations.

Hence, Israel's lack of control over the availability of fuels, and the dependence of operating desalination plants along the Mediterranean coast on the national grid, mean that any disruption in the supply, due to political or other reasons, would impact the state's ability to provide water for residents' domestic, agricultural and industrial use.

Yet, recent natural gas discoveries in the offshore Tamar and Leviathan fields in the Mediterranean will mitigate the potential for harm by consolidating a greater fuel supply within Israel's borders, and the government together with private corporations are working quickly to develop this resource.

This paper focuses on reviewing the potential of electricity production from pumped hydropower storage in Israel, and considers the strategic impacts of hydroelectric generation from the point of view of resource diversification. This article will first build a case for a new hydropower generation. Even though the ideas of introducing pumped storage stations and the Mediterranean Dead Sea project (known as "The Seas project"), are not new concepts, technological development plays an important role in determining the economic and technical feasibility of such a project. There are various aspects that need to be assessed in a more comprehensive analysis[1], and therefore the purpose of this paper is solely to consider the energy

1 Including environmental and socio-economic impacts assessment, engineering study and financial and political feasibility (Tahal, 1983)

security aspect of hydropower generation, while assessing the Mediterranean Dead Sea project as a case study.

The first chapter considers the energy security aspect of hydropower generation, while the second chapter introduces the pumped storage. The third chapter discusses the basics of the Med-Dead project. The last chapter concludes and draws up recommendation for further research.

2. Energy security through resource diversification: Reintroducing hydropower

"Current trends in energy supply and use are unsustainable – economically, environmentally and socially" states the International Energy Agency in its publication "Hydropower Roadmap 2012" (IEA, 2013b, p. 1). The demand for energy will increase in the emerging economies while the energy consumption in the industrialized nations will remain stable. A transformation in the energy production is desperately needed to meet the concerns for future energy supply. Sustainable and low-carbon energy technologies will play a central role in the energy revolution required to make the transformation happen. Without decisive action, energy-related greenhouse gas emissions could multifold by 2050, and increased oil demand will heighten concerns over the supply security of energy resources (ibid.).

Dependence solely on fossil fuels, such as oil, coal and natural gas, involves economic and security risks. Most of this comes from the necessity to maintain significant fuel stocks. Inventory policies still leave countries open to economic and security risks, which new pumped hydropower storage projects can reduce. Therefore, diversifying energy sources reduces this risk.

Hydroelectric power is a developed and cost-competitive renewable energy source. Although hydropower's share of gross energy consumption is only 2.4% (International Energy Agency, 2013c, p. 7), it plays an important role in today's electricity mix in multiple countries ranging from developed and emerging to developing nations, contributing to more than 16% of electricity generation worldwide and about 85% of global renewable electricity. Hydroelectricity is the largest single renewable power source today (International Energy Agency, 2013b, p. 9).

Hydropower provides significant amounts of clean, renewable electricity. It also helps control water flows and availability. Its high flexibility is a strong asset for electric systems, and will be vital to accommodate and facilitate the growth of variable renewable energy technologies such as wind and solar power. It can foster social and economic progress, especially in developing countries. (ibid.)

Hydro electricity is a competitive energy source today, but its further exploitation still faces important regulatory, financial and public acceptance issues. Also, the environmental concerns are critical factors that determine the feasibility of such projects. In considering the success of a hydropower development project, financing is usually the most critical factor (Tahal, 1983, IEA, 2013b and Willner et.al. 2013). Yang and Jackson (2011) reached the same conclusion in their study.

Despite heavy initial investment costs, hydropower has several advantages that continue to drive its development in future. (IEA, 2013b and BW Engineers, 1984) It has long and productive generation capacity and low life-cycle costs, it has proven reliable electricity production and its operation is flexible and safe. In addition, it is equipped with large-scale energy storage for seasonal load balancing provides many non-energy services such as flood control, water supply and irrigation, and it is environmentally and socially sustainable. While fuel inventory policies leave countries open to economic and security risks, hydropower can reduce this by introducing local power generation.

Hydroelectric power generated from regulating reservoirs has special merits due to its high dependability and flexibility. It can supply a considerable proportion of the variable load in the electrical grid. Therefore, each unit of energy produced by the project will be of especially high value because it will replace expensive fuels and inefficient generation of power during peak demands and crises.

In 1985 the US Army Corps of Engineers produced a comprehensive handbook introducing various aspects of hydropower generation. According to that handbook, in order to meet varying electricity demand, power stations' operation is divided into three loads based on the time of the day and the amount of energy consumed, more specifically: base load, intermediate load and peak load. Conventional hydro varies from other types of power plants in that the quantity of fuel available at any given time is fixed. While increasing plant size may increase the percentage of the potential energy that can be utilized, it cannot increase the total supply. The size of the energy storage, that is, the reservoirs, and the amount of time the power station generates electricity determine how much it can contribute to the total load. Yet, "some potential hydro developments are constrained from peaking operation by operating limits designed to protect the environment and other project purposes", while other installations can have constraints from "the daily and weekly shaping of power discharges to fit power demand by lack of storage or pondage" (ibid. p. 17) for seasonal flow regulation.

Hydropower production has limitations due to long-time variations in precipitation and water run-off. According to the International Energy Agency (2013b, p. 11) hydropower stations are generally highly site-specific and tailor-made to local conditions. Further, IEA (ibid.) classifies hydropower plants into three categories: run-of-river, reservoir or storage and pumped-storage plants. This article concentrates on the pumped storage option since it is the only significant source of hydroelectricity in Israel as several dry riverbeds, or "wadis", draining to the Dead Sea could potentially be harnessed to produce hydropower. Most notably, the pumped hydroelectric storage technology is the only significant and flexible means of storing energy.

3. Pumped-storage systems: More flexibility to the power generation

According to Dell and Rand (2001, p. 6), fossil fuels have two chief characteristics in addition to being concentrated sources of energy. They are energy stores and in most cases they are readily transportable. This means that the fuels may be stored for future use and may be transported by sea, rail, road or pipeline to where they are to be consumed. By contrast, most of the renewable energy resources, except for biomass and hydropower, cannot be stored and cannot be transported to the place of use, except by first converting them to electricity. This is where water comes in to the picture. The pumped-storage hydroelectricity (see an illustration of the Dead Sea power station complex in Figure 2 (Tahal, 1983 and Willner et al. 2013) is a type of hydroelectric power generation that stores energy in the form of water and is the most widely used form of bulk energy storage.

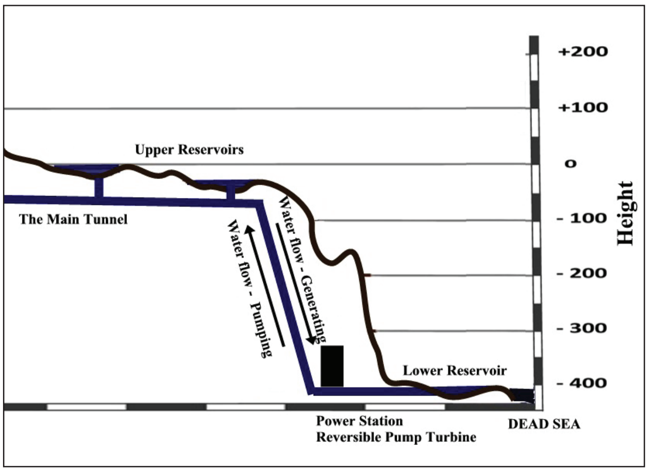

Figure 2: Pumped storage system (Tahal 1983 and Willner et al., 2013)

According to the International Energy Agency (2013b, p. 25), currently "there is no global study on the technical potential of pumped storage hydropower, but its potential is quite significant". According to the US Army Corps of Engineers (1985, pp. 5-7) the concept of pumped hydroelectric storage has existed for more than hundred years, and pumped-storage facilities were constructed in Europe as early as 1908. Still, it was "not until after reversible pump-turbines were perfected in the 1950s that pumped storage became an important source of peaking capacity in the United States" (ibid. pp. 5-7). This technological advancement led to steady developments of several medium and large-scale projects. Further, Yang and Jackson (2011, p. 840) revisit the history of pumped storage and say that the concept was considered as an important complement to nuclear and other base load power station for providing peaking power. The desire to protect the frequency, stability, and reliability of electricity supply has led many industrialized nations to make considerable investments in hydroelectric and pumped-storage projects (BW Engineers, 1984 and US Army Corps of Engineers, 1985).

Dell and Rand (2001, p. 4) debate that the increasing use of combined cycle gas turbines[2] and pumped storage for electricity generation will make an important contribution to energy security, while supporting economic development and reducing CO^2 emissions. Hydropower can be used in a power system in several ways: for peaking, for meeting intermediate loads, for base load operation, or for meeting a combination of these loads.

Creating an additional, relatively small reservoir near existing hydropower plants is often possible in mountainous areas. While pure run-of-river projects have no usable storage, pumped storage hydropower facilities typically take advantage of natural topography, and are built around two reservoirs at different heights. The water is pumped from a lower elevation reservoir to a higher elevation reservoir during low-cost off-peak periods by pumps, and during periods of high electrical demand, the stored water is released through hydroelectric turbines to produce electricity. Thus during non-peak hours, water is pumped from a low elevation to a higher elevation reservoir by exploiting the surplus capacity of efficient thermal units. Despite the losses of the pumping process, the system increases revenue by selling more electricity during periods of peak demand due to higher electricity prices. With the peak load pumped storage, facilities can generate a relative advantage over thermal stations despite the energy loss in pumping and regenerating (US Army Corps of Engineers, 1985 and BW Engineers, 1984).

2 Combined cycle power generation: Combining two or more thermodynamic cycles results in improved overall efficiency of power generation while reducing fuel costs. In stationary power plants, a widely used combination is a gas turbine burning natural gas (Wikipedia, 16.07.2014).

Taking into account evaporation losses from the exposed water surface and conversion losses, approximately 70% to 85% of the electrical energy used to pump the water into the elevated reservoir can be regained (The Economist, 2012). According to Deane et al. (2009) this technique is currently the most cost-effective means of storing large amounts of electrical energy (over 100 MW) on an operating basis, but capital costs and the presence of appropriate geography are critical decision factors. Fortunately, the construction costs of pumped-storage schemes are relatively low. For instance in the case of the Mediterranean Dead Sea project (Tahal, 1983 and BW Engineers, 1984), around 95% of the costs are expected during construction, and therefore, the economic risks to energy sector are significantly reduced.

US Army Corps of Engineers (1985, p. 1) describes pumped hydroelectric storage as a "special type of hydropower development, in which pumped water rather than natural stream flow provides the source of energy". Further, the manual on hydropower (ibid.) identifies two types of pumped storage systems: off-stream, also known as pure pumped hydropower storage projects, which relies entirely on water that has been pumped into an upper reservoir as their source of energy, and pump-back pumped hydroelectric storage which uses a combination of pumped water and natural stream flow to produce electricity.

According to Deane et al. (2009, p. 1294) pumped hydroelectric storage is a resource driven facility which requires very specific site conditions to make a project feasible, that is, high hydraulic head, favorable topography, good geotechnical conditions, access to the electricity transmission networks and water availability. Yet, "the most essential of these criteria is availability of locations with a difference in elevation and access to water" (ibid).

In the history of Israel there have been few proposed hydropower projects. The Rutenberg power plant, the most significant power station while it operated, was located at Naharayim between Israel and Jordan, and represented the so called "run-by-river" hydropower station designed to harness energy for electricity production from the available flow of Jordan River. This station was established by the British Mandate in 1930s, and before the Independence of Israel it produced most of the electricity consumed by the Mandate. The power station was destroyed by the Iraqi forces in 1948 during Israel's War of Independence (Ben-Arieh, 1965 and Gelber, 1997). Later, several plans have been investigated, most notably the Mediterranean Dead Sea and Red Sea Dead Sea projects utilizing the difference in sea level between the Mediterranean Sea (and alternatively the Red Sea) and the Dead Sea, and the pumped hydroelectric storage projects in the Jordan Valley.

Currently (2014), Israel's first pumped hydropower storage facility is under construction in Ma'ale Gilboa, 50 km east of Haifa. According to Alstom (2014) and A.D.Y.R. Constructions (2014) the facility will generate electricity with two 150 MW turbines totaling 300 MW per production capacity. When commissioned, the project will increase Israel's electricity generating capacity by 2.5% increasing the reliability of electricity supply and will "provide an important tool to control the demand and distribution of electricity" (ibid.). The water will be stored in two reservoirs with the capacity of 2.5 million cubic meters each. Another similar project for a 340 MW pumped storage power station is presently in the advanced level of planning at the Kochav ha-Yarden site. Currently the Ministry of National Infrastructures, Water and Energy has a national plan for a total of 800 MW of pumped hydroelectric storage capacity by 2020.

The Ma'ale Gilboa and Kochav ha-Yarden pumped storage facilities are not the only sites that have been considered appropriate for such hydropower production. In the 1990s the Israel Electric Corporation (IEC) evaluated the feasibility of building an 800 MW pumped hydroelectric storage power station at Nahal Parsa located at the south-west of the Dead Sea. According to Slobodkin (1998) this project is categorized as a closed system utilizing the saline groundwater consisting of two 7 million cubic meter reservoirs. The reservoir size is designed to provide 6,400 MWh of energy storage consisting of four units of 200 MW Francine turbines.

Unlike the Parsa project, which is an off-stream pumped storage system, the Mediterranean Dead Sea project would use conveyed Mediterranean Sea water and generate electricity at its Dead Sea power station (See Figure 2).

4. Mediterranean Dead Sea Project: A realistic option for diversifying electric power generation?

Due to freshwater diversions of natural runoff over the last century in Israel, Jordan and Syria, the level of the Dead Sea has dropped 38m, from a steady state of around -390m below sea-level up until the 1930s to -428m in January 2014 [see Figure 3 (World Bank, 2012 and The Samuel Neaman Institute, 2007)]. This development has threatened both tourism and industry at the Dead Sea. To solve this issue, many studies have suggested conveying seawater into the Dead Sea to produce hydropower and restore the sea to its historic steady state levels. Due to the negative differential between the elevation of ocean water and that of the Dead Sea, such a conveyance could provide major benefits by increasing resource diversification in electricity production. Several potential conveyance routes have been extensively studied, and many proposals have come and gone.

Using a combination of early land surveys and biblical beliefs, British naval officers proposed building a navigable canal from the Mediterranean Sea to the Galilee or Dead Sea as early as the 1850s. This was done in order to explore naval routes to India.

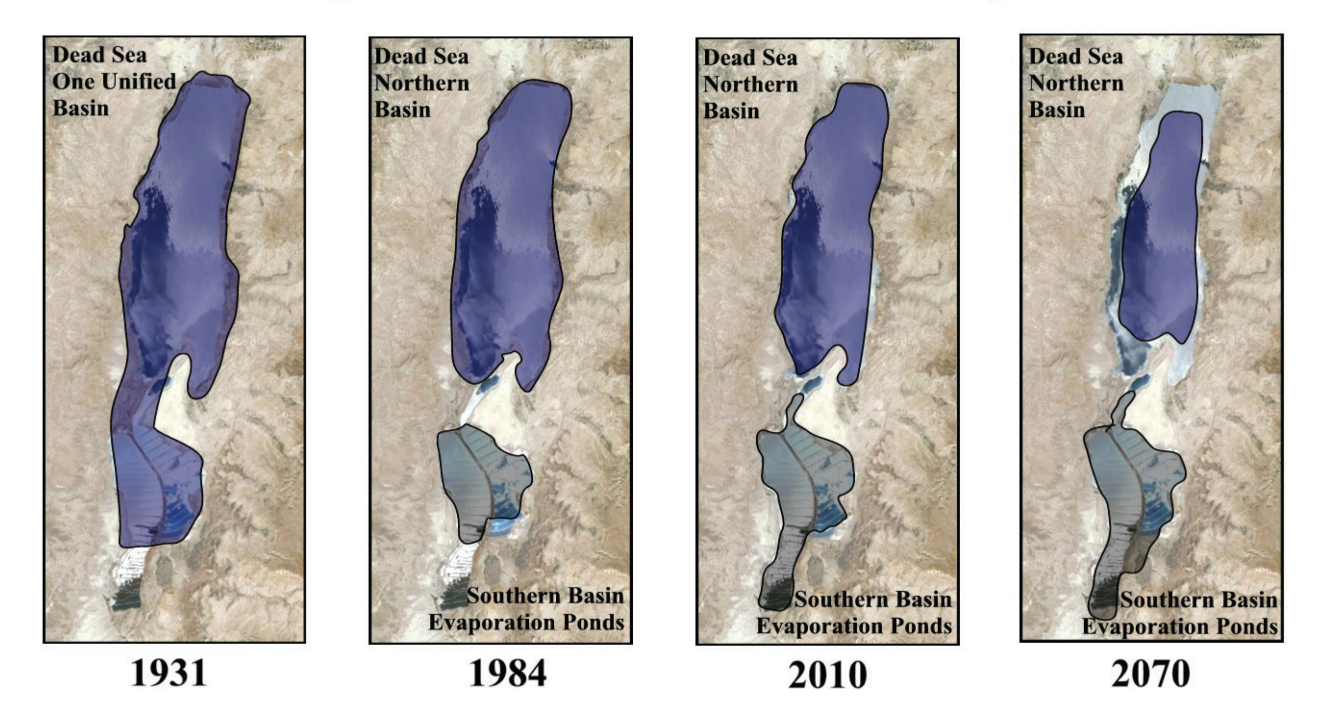

Figure 3: The shrinkage of the Dead Sea in the no-project scenario

The British continued to weigh similar plans for a while, but the construction of the Suez Canal for the purpose navigation eventually led to the abandonment of the Mediterranean Dead Sea canal (Vardi, 1990).The Zionist movement in the late 19th century led to further interest in a canal, but for hydroelectricity rather than navigation. This culminated in Theodore Herzl's work "Old-New Land-Altneuland" (1902) when he proposed building a canal to power a various manufacturing industry in the Jordan Valley. After Israel gained independence, the prospect of implementing a conveyance seemed to become a real possibility, and several detailed proposals were drafted in the decades after 1948.

Major investigations and assessments were conducted in the decades following 1960 until the 1980s. However, Israel has changed significantly since the early 1980s; the nation has seen the Palestinian uprisings (1987 and 2000) and terrorism, the Jewish Russian immigration (early 1990s), and peace agreements with Egypt (1978) and Jordan (1993) were signed. Changes in demographics have led to new needs and potentially different benefits of a Mediterranean Dead Sea conveyance. As the population of the entire region has greatly increased, strains on energy and water resources have become more widespread. Israel's energy challenges in the past have lied largely in a lack of energy security and diversification. As there is currently no hydropower generation in Israel, a Mediterranean Dead Sea conveyance could tap into a new energy resource and introduce pumped hydroelectric storage to create an energy reserve for peak usage while increasing Israel's renewable energy generation to the government target of 10% of total electricity by 2020 (Ministry of National Infrastructures, Energy and Water Resources, 2014). The Government of Israel has an active policy to reach this goal, where hydroelectric resources play a small but important role supplying energy storage.

The main economic goal of the Mediterranean Dead Sea conveyance is to produce hydroelectric energy. There are several economic parameters that significantly affect the Mediterranean Dead Sea project's net benefits in comparison to thermal energy generation alternatives. The ‘Steering Committee of the Mediterranean Dead Sea Project' initially emphasized the economic and security value of the project in 1981. Tahal (1983) and BW Engineers' (1984) feasibility studies identify six factors that would determine the economic feasibility for such a hydroelectric plant; these factors are as follows: Dead Sea annual evaporation rate and stream inflow; future fuel prices; discount rate; exchange rates; electricity demand forecasts;

and alternative generating resource investment costs. Water resources and costs would also need to be examined. One important technological development has been the advance in desalination processes. According to Becker et al. (2010), in the 1970s, desalinated water cost about $2.50 per cubic meter, and in 2003, the cost had dropped to $0.50. The combination of seawater conveyance and hydroelectric power generation would make a reverse osmosis plant possible in locations beyond the coast. As water resources are so scarce in the entire region, this could be of use for domestic, agricultural, and industrial purposes.

According to Tahal (1983), the main potential economic benefits from electric power generation from the hydropower project are savings in the cost of generation by the Israel Electric Corporation (IEC) system. These savings, consisting of fuel, capital, operation and maintenance, loss of energy benefits (dynamic benefits), also accrue to the project due to the value of the unique dynamic characteristics of the hydroelectric resource in a thermal system.

In addition to the benefits to the Israeli energy system, such a major hydropower project could also contribute to regional cooperation between Israel, Jordan and the Palestinian Authority in terms of increasing reliable energy supply. In this respect, the selected route has a significant impact on the feasibility of such a project.

The engineering and financial resources required for each hydroelectric project heavily depend on the route chosen (see Figure 4), and over the last 150 years, multiple routes have been proposed for the conveyance project to connect the Mediterranean Sea to the Dead Sea. Four Med Dead routes have been promoted in the past. These plans differ considerably in terms of financial cost of construction and operation, engineering feasibility, environmental and socio-economic impact, and political possibility[3]. Each has its own benefits and consequences in terms of economic and technical feasibility, environmental impact, and political possibility (Willner et al., 2013).

3 The feasibility of each route option has varied in the past years, and there have been many proposals for the project. To see more financial, political, environmental and engineering feasibility assessments of the alternative routes, see: Willner (2013), Tahal (1983) and World Bank (2012).

Figure 4: The conveyance routes (Tahal 1978 & 1983, World Bank 2012 and Willner et al., 2013)

The first proposed route is the "Valley Route", which would require little pumping to bring Mediterranean water though the Zevulon and Jezreel valleys and into the upper reaches of the Jordan River. Haifa Bay houses several industrial plants, so the addition of this salt water to the river could potentially have far-reaching impacts on the ecology of the valley. The alternative "Mountain Routes" avoid the valley by using a tunnel to convey the seawater over the Judean Mountains and into the Dead Sea. The Northern Alignment intakes seawater north of Ashdod, tunnels water south of Jerusalem and under the West Bank and into the Jordan Valley just north of the Dead Sea (ibid.). The Central Alignment avoids both the West Bank and Gaza by beginning in Ziqim, jutting southeast, and outfalling near Masada, therefore making it the most politically feasible route. The Southern Alignment, which was once the preferred route, now seems less likely to materialize, as it would begin in Gaza, at Qatif. The tunnels involved in the Mountain Routes prevent considerable ecological damage, but a leak (if the risks are minimized in the planning phase of the system) could pollute groundwater and would be difficult to fix. For any route, Valley or Mountain, the environmental effect of mixing seawater with Dead Sea water constitutes a major unknown (Tahal, 1978 and Willner et al., 2013).

Regardless of which route would eventually be chosen for the conveyance, the Mediterranean Dead Sea project will have multidimensional benefits ranging from increased energy, water and economic security.

5. Conclusions: Sustainable solutions with energy security

Hydroelectric power stations combined with pumped storage facilities continue to play an important role in the world electricity mix. As such systems help to stabilize fluctuations between demand and supply, they also provide a source of green renewable energy. Since early developments of hydropower it has "developed as a safe, reliable and inexpensive source of power and energy services" (IEA, 2013b, p. 9).

Israel is often portrayed as an ‘electricity island', because it is not interconnected to any other electricity grid. Future might bring changes to the current situation, either connecting to Europe, to Jordan or even Egypt. This would help the nation to diversify its electricity sources and increase dual-dependency. However, before this several national energy security challenges need to be addressed.

Alternative energy sources such as biomass, wind and solar power are the electricity sources of the future, and will help Israel to achieve its target in renewable energy generation. However, the relatively high prices of alternative power sources in respect to conventional power sources such as coal and natural gas slows down the adaptation process of these sources. In the recent years, Israel explored massive offshore natural gas deposits, which when fully utilized will provide Israel with an independent fuel source. The abundance of natural gas has also slowed down alternative energy source projects. Another issue that has limited solar and wind power is the lack of energy storage. At the moment, hydropower combined with pumped storage systems are the only significant source of energy storage.

Diversifying fuel sources and storing energy are the most critical conditions to achieve energy security. As stated in the beginning of the paper, the energy thirsty consumers are mainly quenched by fossil fuels. The Persian Gulf states are vulnerable as their sources are not as diversified as most of the industrialized nations. Israel's challenges are similar, although it has already taken steps to diversify and utilize its vast offshore natural gas reserves. Despite the seemingly abundant natural gas reserves, electricity generation from natural gas has several setbacks, such as the issue of affordable energy storage. In this respect, hydropower can be a great contribution to Israel's energy economy as several dry riverbeds, ‘wadis', draining to the Dead Sea could potentially be harnessed to produce hydropower through pumped-storage. As stated earlier, pumped hydroelectric storage is the most significant and flexible means of storing energy, and can significantly contribute to Israel's long-term energy independency.

The Mediterranean Dead Sea project was a dream of the early Zionist movement, most notably Theodor Herzl. Although the idea of building a canal or a tunnel to the Dead Sea arose from a visionary idea it eventually materialized into a feasibility project nearly three decades long. In the past, several energy projects have faced opposition due to political issues, environmental impacts or due to lack of evidence in their financial feasibility. A number of feasibility projects have been conducted in the past comparing the available options. Nevertheless, more detailed analysis on the strategic feasibility of these projects should be conducted along with an updated financial analysis. This would provide a wider basis for the political acceptability of such a project.

However, at the end of the day most of the hydropower projects in Israel provide a deep strategic dimension where long-term national interests and needs have to be carefully evaluated --- providing new evidence to the decision makers --- resource diversification and heightened energy security. The Mediterranean Dead Sea project goes side by side with the other pumped storage facilities: the Ma'ale Gilboa, Kochav ha-Yarden and the Nahal Parsa, which, if proven successful, can pave a path for more impressive and ambitious projects, such as the Mediterranean Dead Sea conveyance and pumped hydropower storage project. There is plenty of leeway for future endeavors that will take Israel, the ‘start-up nation' to new heights in nation-building and national strength. The main question is: When will Israel be ready for such great leaps to reach these courageous ventures in national and economic security?

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