A SOCIO-ECOLOGICAL APPROACH TO COMBAT DESERTIFICATION FOR SUSTAINABLE FUTURE

EcoFuture

Work Package Number 3

Deliverable 3.3 Energy Analysis of the Jordan Valley

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Table of Contents

This project is part of the PRIMA programme supported by the European Union. GA n° [2243] [EcoFuture] [Call 2022 Section 1 NEXUS WEFE IA].

This project is part of the PRIMA programme supported by the European Union. GA n° [2243] [EcoFuture] [Call 2022 Section 1 NEXUS WEFE IA].

List of figures

List of tables

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Executive Summary

Overview

This report, "Energy Analysis of the Jordan Valley (JV)," provides a comprehensive examination of the current and future energy supply and demand in the JV region, involving Israel, Jordan, and Palestine. The analysis follows three main tracks: assessing existing energy infrastructure, future energy needs, and developing strategies for secure and affordable energy systems.

Key Findings

1. **Current Energy Infrastructure**:
    - **Electricity**: The region is primarily served by national grids, with notable variations in standards and infrastructure among the three countries.
    - **Heat and Power**: Natural gas is a significant energy source, with renewable sources like solar and biofuels being explored for future needs.
    - **Water Supply and Demand**: Water-intensive activities like agriculture and desalination significantly impact energy consumption.
2. **Future Energy Needs**:
    - **Population Growth**: Substantial population increases are projected by 2050, driving up energy demand, particularly for residential, industrial, and commercial sectors.
    - **Renewable Energy**: There is a strong push towards renewable energy sources, with ambitious national targets (Israel: 30% by 2030, 80% by 2050; Jordan: various targets). The JV is expected to contribute significantly through solar and biofuel energy.
    - **Energy for Water**: Energy demand for water-related activities (pumping, treatment) is expected to remain high, with a significant portion anticipated to be met by renewable sources.
3. **Challenges and Data Gaps**:
    - **Data Inconsistency**: Incomplete and inconsistent data across the three countries hampers accurate energy planning and forecasting.
    - **Infrastructure Development**: Current grids and substations may not support the expected increase in renewable energy generation and overall energy demand without significant upgrades.
4. **Strategic Recommendations**:
    - **Microgrids**: Development of regional microgrids with connections to national grids for backup and economic trade.
    - **Renewable Energy**: Emphasis on solar energy, particularly agrivoltaics, and biofuels. Encouragement of behind-the-meter and off-grid renewable energy solutions to enhance energy security.
    - **Water-Energy Nexus**: Enhanced focus on energy-efficient water pumping and treatment technologies, integrating renewable energy for these processes.
    - **Industrial Growth**: Support for industrial growth, particularly in food industries, to provide employment and leverage local agricultural production.
    - **Cross-Border Collaboration**: Encouragement of regional collaboration among the three countries to optimize energy resources and infrastructure development.

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Long-Term Vision

The JV is envisioned as a region with substantial renewable energy integration, supported by robust microgrid systems, and capable of meeting its energy needs predominantly through local resources. This vision includes fostering regional cooperation and developing infrastructure "rings" (electricity, gas, water, wastewater, communication) to facilitate efficient resource management and peer-to-peer trade.

Conclusion

This energy analysis highlights the critical need for coordinated efforts to upgrade infrastructure, integrate renewable energy sources, and address data gaps to ensure a sustainable and secure energy future for the Jordan Valley. The recommendations aim to guide future energy policies and investments, fostering a collaborative and resilient energy ecosystem in the region.

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1. Introduction

The report describes the status and short-term futures for energy supply planning for the Jordan Valley (JV). The data requested for the preparation of this report have been collected from Israel, Jordan, and Palestine and from open publications on the Internet. The official sources of information were described in D5.1 and in D1.1, however, the data is far from completion. For example, in Jordan, the existing data relates to the whole country and not specifically to the Jordan Valley (JV). In Israel, we could not obtain the JV distribution of supply & demand according to the specific sectors (domestic, agriculture, water, industry, commerce), and the temporal supply and demand distribution, etc. The current political situation has reduced the attention of the official agencies to our requests in providing the necessary data.

Therefore, assumptions have been made to calculate the status of the energy sector in the three countries. The future scenarios were evaluated based on the estimated current situation. The future trends use assumptions that are realistic and should provide reasonable estimates of the realistic maximal demand for energy resources and an estimate of the JV potential of local supply of PER (primary energy resources) and energy production (electricity, fuels such as methane and other biofuels). The outline of this report is as follows:

- Chapter **Error! Reference source not found.** include the background Information required for our analysis, tables of relevant data that have been collected by the EcoFuture team and from the extensive masterplan of the JV performed by EcoPeace and published in 2015[1]. Their analysis covers almost the same set of countries and areas as that of EcoFuture but considered only the Water & Energy nexus (WE). The data collected in 2010 and their forecasted data do not fully comply with the current data collected in the EcoFuture project. The EcoFuture background information was updated according to the information that has been published in previous deliverables or through internal discussions. This data is used to extract the JV energy sector characteristics and estimate future requirements.
- In Chapter **Error! Reference source not found.** the energy sector information in the three countries is given. Each country is described, and the assumptions made are discussed.
- In Chapter 4, The overall understanding of the present and near-term energy situation is summarized. Since solar is considered as the main future energy source the PV potential is elaborated.
- Chapter **Error! Reference source not found.Error! Reference source not found.** provides a vision for long-term (2050 and on) development. If approved by the EcoFuture partners, this vision will be further studied in WP5 and published in the associated deliverables.

[1] Regional NGO Master Plan, *Royal Haskoning DHV (MASAR Jordan CORE Associates DHVMED), EcoPeace Middle East, European Union's Sustainable Water Integrated Management (SWIM Program), SIWI – Stockholm International Water Institute, GNF – Global Nature Fund*: www.ecopeaceme.org

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2. Background Information

The information of the energy sector in the Jordan Valley (JV) was extracted mainly from the available national data based on a few simplified assumptions regarding the area distribution for designated purposes, such as population, water consumption, waste distribution etc. Details of the collected data can be found in Deliverable 1.1 which covers the Mapping of the WEFE Nexus.

2.1 Area

The area of interest of the Jordan Valley considered in EcoFuture is shown in Figure 2.1. The Israeli sector cover the area above the dashed line to the west of the Jordan River, The Palestinian covers the area below the dashed line and the Jordanian the area east of the river.

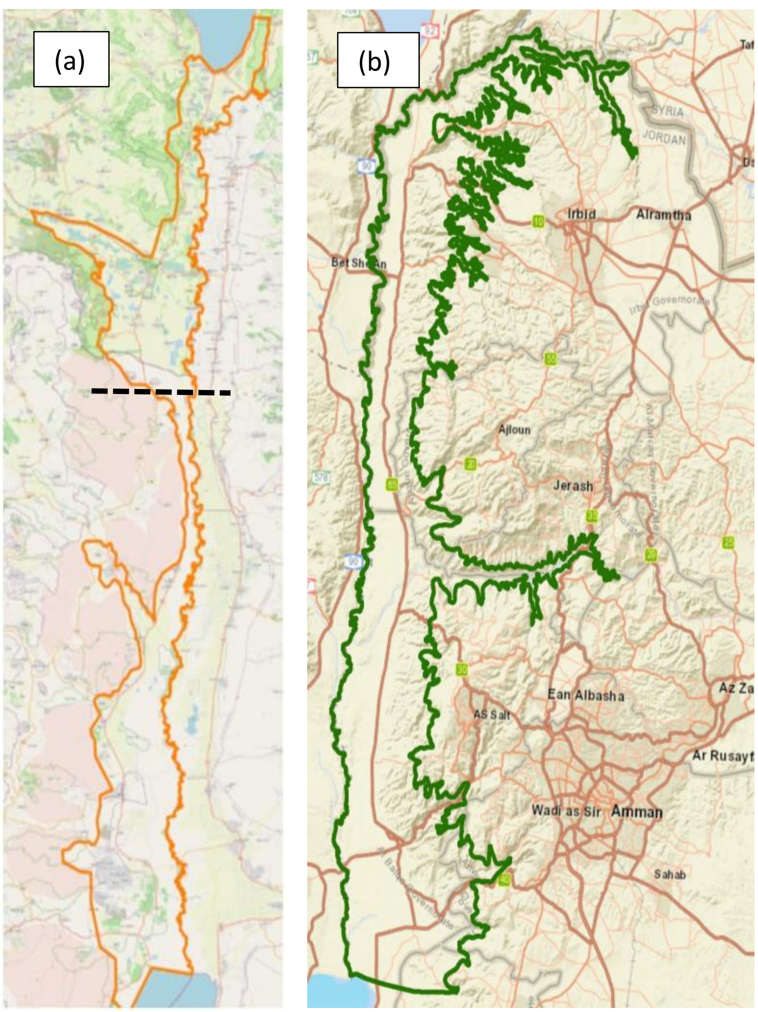

Figure 2.1 (a) The JV West (in orange) – Israel is north of the dashed line; Palestine is south of the dashed line. (b) The JV East (in green) – Jordan.

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2.2 Area and Land Designation

The total agricultural land in the JV covers 87,378 ha and accounts for 34% of the total area. In Israel & Jordan the increase of agri-land allocation estimated to be about 10%. In Palestine the agricultural land now is around only 20%. It may increase to around 30% in the coming years. Table 2.1 presents the land use area distribution of the three territories.

Table 2.1 Area of each territory within the JV – The land designation

Area (km^2)	Israel		Jordan		Palestine		Total
	2023	2050	2023	2050	2023	2050	2023
Uncultivated / nature reserves	25.9		795.3		639.2		1,454.7
Agriculture (% irrigated)	249.0 (70.7%)	273.0	451.8 (95%)	495.0	187.2 (52.6%)	225.0	888.0
Built up area	302.5		65.4		43.1		411.0
Fish Farms	16.9		0.7		0.3		17.9
Water reservoirs	0.61		5.6		0.3		6.4
Wadis	5.3		24.2		13.8		43.3
TOTAL	**600.2**		**1,343.0**		**884.0**		**2,821.4**
Total National Area [km^2]	22,145		89,213		6,220		

2.3 Population

Table 2.2 presents the current population of the three territories as well as the projections for population increase in 2030 and 2050. The increase in the expected population is remarkable. Due to the limited potential for agricultural land expansion and the tendency to reduce manpower employed in agriculture due to automatization, etc, it is possible that most of the additional population in the future will work in the industrial or commercial sectors tourism, or commute for work out of the region, which may change the profile of the energy consumers.

Table 2.2 Population. Currently, short (2030) and long-term (2050) estimates

[capita]	Israel			Jordan			Palestine		
year	2024	2030	2050	2024	2030	2050	2024	2030	2050
JV population	60,000	70,000	100,000	260,000	284,000	404,000	65,000	75,000	90,000
Total national $\times 10^6$	9.3	10.1	13.0	11.4	12.0	15.0	5.5	6.3	8.9

2.4 Water Supply & Demand

Table 2.3 presents the total supply and demand of water for the three territories of the JV. The total agricultural water supply is 374.06 MCM/yr while the drinking water supply is 37.11 MCM/yr. The

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agricultural water uses accounts for 91% of the total water supply where 16% is used for aquaculture and 75% for irrigation.

Table 2.3 Summary of supply and demand of water for the three territories in the JV

Supply	Unit	Israel	Palestine	Jordan
Agricultural water	MCM/yr	134.84	32.80	206.42
Drinking water	MCM/yr	7.09	6.40	23.62
Demand		**Israel**	**Palestine**	**Jordan**
Agricultural water	MCM/yr	134.84	182.00	400.00
Drinking water	MCM/yr	7.09	10.00	26.00

Table 2.4 presents a comparison of the irrigation rate and the drinking water use per capita for the three territories in the JV. The differences in irrigation rates can be explained by the water losses/leakages in the network that is estimated to be about 40% for Jordan and 50% for Palestine. On the other hand, the drinking water use per capita has been estimated to be 324 l/d/cap for Israel, 205 for Palestine and 249 for Jordan. If we account for water losses in the distribution network in Jordan and Palestine, only half of this water is reaching the consumers.

Table 2.4 Comparison of irrigation rate and drinking water use per capita for the three territories in the JV

	Unit	Israel	Palestine*	Jordan
Agricultural Area	km^2	249	173	349
Irrigated Agriculture	km^2	176	91	332
Irrigation water	MCM/yr	67.8	32.8	206.4
Irrigation Rate	mm/dunam	385	360	623
Drinking water	MCM/yr	7.1	6.4	23.6
Population	population	60,000	70,000	260,000
Water use per capita	liters/day per capita	324	205	249

* *Around 11,000 settlers in the Palestinian JV not included*

The demand for both drinking and agricultural water use is quite significant in Jordan and Palestine arising the agricultural demand to 715 Mm^3/yr in the region and the drinking water demand to 43Mm^3/yr. This deficit in the supply and demand of water has prompted the governments of the three territories to develop plans and strategic objectives to reduce its impacts.

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3. The JV Energy Sector in the three countries

Electrical energy is supplied to customers via their national grids. Heat and power customers may use natural gas distributed by pipes or fuel supplied mainly by ground transportation and marginally by pipes. The electricity standards in Jordan are slightly different than in Israel and Palestine but the differences have no effect on the actual and future possibility of grid connection and sharing electricity. Table 3.1 presents the basic details of the National Eclectrical Grids including the transmission and distribution grids, the number of substations, voltage and the max power to the JV. Questionmarks denote uncertainty in the collected data.

Table 3.1 National Electricity Grids

Nation	Transmission Grid [KV]	# of substations	Distribution Grids [KV]	Customers 3 phase [V]	Max. Power JV / nation [GW]	Remark / Reference
Israel	400 / 161	4	33 / 22	220	~1 / 14	IEC
Palestine	400 / 161	2 (?)	33 / 22	220	0.3 (?) / ?	IEC
Jordan	400 / 132	2 (?)	33	220	0.2 (?) / 1.6	NEPCO

Overall, the current energy supply in all the three countries satisfies all the needs on the national level and for the JV.

Two extreme approaches exist for future development. The centralized one where the management of the electrical system from the suppliers to the end customers is managed on a national level by the TSO (Transmission System Operator) through the DSO (distribution system operator). This is the leading approach in the three countries today. The other direction is to create small regional energy-islands, managed by local DSO, almost autonomously, leaning on a smart microgrids topology. The energy islands are connected to each other to increase the security of supply and the resiliency of the entire system. The distributed approach is highly recommended in this report. Farther justifications are given the following Chapters.

The present centralized attitude causes the TSO (The NOGA company in Israel and NEPCO in Jordan) to regulate the grid in a way to reduce competition among suppliers and make the life of independent prosumers difficult (prosumer is an individual who both consumes and produces). It doesn't allow simple peer to peer trading; thus, the energy cost is not optimal. The centralized systems were the best choice in the past. But, when many small and medium distributed renewable energy providers, exist the local management is far more efficient.

We propose that the Jordan Valley electricity sector will consist of regional microgrids with connections to national systems for backup and by peer-to-peer trade among those systems and the national grid. This would reduce the need for transmission and distribution investment at the national level. While

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connected to the national grids, will mainly serve either as: (1) reliability backup; or (2) a conduit for economic imports and exports. A Distributed System Operator ("DSO") will be responsible for managing that regional microgrid and administering internal transactions among generators, suppliers, prosumers, and consumers. Specific functions and responsibilities of the DSO will be developed in future stages of the EcoFuture project.

Key Data Gaps:

At this juncture, the following information is missing or is inadequate:

1. Electricity, heat, and fuel requirements. There is significant variation, not only among the three countries, but also among regions within each country. For example, among Israel's 4 local authorities (Emek Hayarden, Emek Hamaayanot, Beit Shean, and Gilboa), Beit Shean urban characteristics stand in contrast to the rural characteristics of the others. Moreover, the commercial and industrial activity varies widely, with manufacturing and commercial food production predominating in some areas, while tourism and agriculture (especially in Jordan) are the leading sectors in others. The population, and the requirements for housing and employment, vary widely throughout the JV and are likely to continue to do so. We will also need to account for residential, commercial, industrial, water, and agriculture as separate classes for forecasting these requirements, and to develop reasonable forecasts by each class of class-level usage. This information is, unfortunately, unavailable.
2. Projections of energy requirements for water needs, including desalination, water treatment, and agriculture. The energy intensity and associated costs related with each service and across countries varies widely.
3. Optimal siting and technology for photovoltaic facilities to be installed through 2030. Fixed, single-track PV facilities using widely available crystalline silicon solar cells is the most representative model to consider during the short term. Single and double-track facilities may be considered as an alternative scenario, though it is unlikely that they will become more widespread prior to 2030. Moreover, while it appears reasonable to assume that about 20% of agricultural areas could be available for PV coverage without compromising agricultural operating efficiency, regional data should substitute for this assumption wherever possible.
4. Bioenergy potential. To date, there is inadequate data on bioenergy, let alone on facility type (landfill, agricultural waste, wastewater treatment facilities, etc.). Such information should be made available.
5. Levelized Cost of Energy ("LCOE") for each generation and storage technology, recognizing regional differences in financing, operations and management costs and technology-specific capacity factors. (which are also location-specific for PV and wind facilities). In particular, we are missing the relevant data on financing, operations and management costs, and technology-specific capacity factors for actual and planned facilities in the Jordan Valley.
6. Electrical infrastructure characteristics through 2030. Despite our concept of a Jordan Valley regional microgrid that is largely self-sufficient, we must assume the need for reliance on the national electric systems for backup and for opportunity trades with those systems during each hour of the year through 2030. While we have some data on the capacities (physical and contractual) of relevant substations and projected smart meter penetration among end-use

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customers,[2] the data is insufficient, thus requiring reasonable estimates. Current transmission and distribution infrastructure is insufficient to accommodate the amounts of renewable energy (especially non-dispatchable solar and wind energy) needed to achieve national targets for renewable energy in the JV microgrid, thereby requiring behind-the-meter renewables expansion.

The following sections provide greater detail on the energy sectors of each country.

3.1 Israel

3.1.1 Overview

Approximately 60000 people live in the Israeli section of the Jordan Valley, ranging from small communities (Kibbutzim and Moshavim with 300-1000 families) to the town of Bet Shean with about 20,000 inhabitants[3]. The population is expected to reach 68 thousand by 2030.

The area is rich in water resources and the local springs cover the water demand of the population. However, the national centralized water system doesn't permit the consumers to pump water, and they are procuring their water requirements by buying their needs from the centralized infrastructure at the national water authority's declared price. Historically, nearly 80% of Israeli fishery production is at this region. The large variety of agricultural products and livestock farms are intensively grown. But the area devoted to agriculture cannot and is not expected to rise significantly (~10%). Agriculture production may increase due to increased efficiency and automatisation. For example, the open fishery will be transformed to more industrial configurations, more advanced irrigation, cultivation of agricultural crops with better resistance to climate conditions, improved efficiency, improved crop protection, post-harvesting treatments, etc. In parallel the labour in the agriculture sector is not expected to increase significantly.

Therefore, it is predicted that the amount of energy demand for agriculture may not change radically by 2030, but the demand for the domestic, industrial, and commercial sectors will increase reflecting the increase in the population and the labour force.

Therefore, it is assumed that in the future the energy demand will resemble the general trends of the national demand energy spectrum.

3.1.2 Electricity

Currently, most of the electrical energy is supplied by a 600MW combined cycle natural gas power station at Alon Tabor situated on the border of the JV region. The power station is connected to the national transmission grid and the JV consumes about 100MW from this station. The electricity from the national transmission grid is distributed to distribution grids through 4 substations that can support between

[2] See the WP3 Task 3.3 presentation by Shlomo Wald at the April 2024 EcoFuture Meeting.
[3] This population figure excludes residents in the settlements located in Area C, as defined by the Oslo Accords.

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100MW to 150MW each. The implication of this situation and the plan of the grid expansion is discussed below.

The general trend, from the supply side, is toward increasing the renewable energy market to its maximum. The second trend is toward distributed energy supply systems. These two trends are expected to contribute both to climate change mitigation and to improve the security of supply. Furthermore, they are expected to have also a positive socioeconomic impact on the JV inhabitants. Since the region is primarily rural, the increased implementation of dual land use for energy production n addition to agriculture (and other purposes) is the major driver of the local renewable energy supply. Agri-photovoltaics (APV) is the leading approach considered. Moreover, since the energy production must not affect the agricultural quality and productivity, the implementation of the PV must be adapted to the specific case. As an example, the NREL report[4] describes the typical APV configurations and the various considerations that must be made when designing a dual-use APV system.

We surveyed the potential of large-scale PV stations; connected directly to the transmission and high-voltage grid. They are considered more economical compared to the dual-use, small and medium installations connected to the low-voltage grids. But they require the use of uncultivated area with acceptable geographical forms and publicly acceptable, which can hardly be found in this region. Most of the solar potential is in medium-sized installations connected to the distribution grids. This increases the importance of agrivoltaics installations over crops or floating panels on fishery and water reservoirs. Small rooftop installations are and will widely be employed.

The JV area within the Green Line is served by the IEC Northern Region management. According to the current regulations, all the PV production is sold to the IEC at approved tariffs and the prosumers buy from the IEC the amount of energy they consume at the market price which is lower than the purchase feed-in tariffs. This arrangement is economically beneficial to the prosumers, but it reduces the security of the energy supply, which is the primary objective. An additional problem is that it motivates the farmers to supply energy instead of food…

On top of these disadvantages, there is a cap on the renewable energy supply to the IEC distribution network as the IEC currently limits the total consumption of electricity, including the renewables' access, to the substation access point to 60% of the interconnection capacity of these parts of the grid. Therefore, no new supplier with a total capacity exceeding 15 kW of installed capacity may currently receive a supplier license unless the grid and the transformation substation are upgraded. Since it is desired to increase renewables production as fast as possible, and to increase the security of energy supply, the following is suggested:

> It is recommended to increase the usage of produced energy "behind the meter" and/or promote the local communities to establish their own managed smart microgrids.

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[4] Macknick, Jordan, Heidi Hartmann, Greg Barron-Gafford, Brenda Beatty, Robin Burton, Chong Seok Choi, Matthew Davis, Rob Davis, Jorge Figueroa, Amy Garrett, Lexie Hain, Stephen Herbert, Jake Janski, Austin Kinzer, Alan Knapp, Michael Lehan, John Losey, Jake Marley, James MacDonald, James McCall, Lucas Nebert, Sujith Ravi, Jason Schmidt, Brittany Staie, and Leroy Walston. 2022. *The 5 Cs of Agrivoltaic Success Factors in the United States: Lessons From the InSPIRE Research Study*. Golden, CO: National Renewable Energy Laboratory. NREL/TP-6A20-83566. https://www.nrel.gov/docs/fy22osti/83566.pdf.

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Microgrid topology may serve our long-term plan as suggested in Chapter **Error! Reference source not found.** with the objective that the JV energy market will be almost self-sufficient. This will highly improve the energy security in the region. The Israeli Electricity Authority's present regulations make the installation of local smart-grid (energy island) impossible. However, there is a lot of public pressure on the Authority to adjust the regulations to public demand.

3.1.3 Heat & Power

Heat and power requirements for the present and future industries, residences, and commercial centres, can be provided by electricity or, preferably, by renewable sources like solar panels, combustion of gases (methane from waste, or green hydrogen) and biofuels produced from wastes.

NG is to be supplied from the national transmission NG system. There are sites of Pressure Regulating and Metering Stations ("PRMS") that reduce pressure to levels necessary for delivery to end-use gas customers, including power stations. The PRMS feeding distribution pipes lead to the end-customers including power stations. The gas supply flowing from Alon Tavor to Neve Or in the northern section of the Jordan Valley is about 500 thousand m^3 per hour. Consumption in the Alon Tavor power station varies around 200 thousand m^3 per hour. Similarly, the maximum capacity of Tzemach (south of the Sea of Galilee) customers is around 4 thousand m^3 per hour. PRMS in Beit Shean can feed the Jordanian JV as well. However, NG is a GHG source, and it is preferable to replace it by gases of biofuels recovered from waste and thus be considered a renewable resource. NG can be mixed or replaced by methane.

Methane is the most common product from landfills and agricultural wastes. Any solid-waste, sludge or waste-water treatment process produced this gas. Today, methane is produced in two facilities operating small electrical power plants feeding the electricity grid. The first uses the emissions of the Hagal landfill and operate about 1.5 MW electricity production. The second is based on cow manure, also in the range of 1 MW electricity production. The waste heat of these installations is not used.

NG and biofuels and waste-heat from combustion processes can be used for several purposes, including: (1) operating small electrical power plants feeding the electricity grid; (2) heat and power to industries, agriculture, and communities; and (3) local small-scale steam networks. Solar panels can easily produce low grade (160°C) steam which is quite common in the food industries.

Since the population is assumed to increase significantly and opportunities for agriculture to expand are limited, the non-agricultural sectors must be allowed to thrive to provide decent employment conditions to the newcomers. Many of those will be food industries that will take advantage of the local agricultural products. The post-harvest treatment improves the quality, the shelf life, and the profitability of the food products.

Direct production of heat and power from renewable resources is very efficient and highly recommended to be produced and consumed locally in the JV.

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3.1.4 The Israeli JV Energy Market

In a base-case scenario for 2024 through 2030, electricity consumption is forecasted to grow annually by 3.1% for the residential, commercial, and water sectors, but only by 1.8% for the agricultural sector, however, these forecasts do not reflect projections by Israel's Ministry of Energy, the independent system operator (Noga) responsible for system planning, or by any other governmental body with regional planning responsibilities for the JV. The 3.1% growth forecast is based on the average of load forecasts produced by the Bank of Israel, Noga, and BDO Consulting Israel. Table 3.2 indicates the potential for each JV substation to accommodate additional grid-connected generation, given the spare-capacity constraints mentioned above. The data suggest that there is 271 MVA available spare power in the distribution grid in the Israeli territory.

Table 3.2 Added energy available at each of the 4 existing sub-stations in the Israeli JV region

Substation	Production technologies	Added Power Production during Daytime [MVA]	Added Power Production during Nighttime [MVA]	Available spare in the distribution grid for production installations [MVA]
1	**NG** - Natural Gas	0.00	0.00	101
	PV - Photovoltaic	110.02	0.00	
	PVS = PV+battery storage	39.20	68.77	
	WT - Wind turbines	30.11	30.11	
Total		**179.33**	**98.88**	
2	**BG** - Biogas	2.37	2.37	49
	PV	4.74	0.00	
	PVS	8.74	12.83	
Total		**15.85**	**15.20**	
3	**PV**	2.69		55
	PVS	0.00	3.89	
Total		**2.69**	**3.89**	
4	**BG**	4.67	4.67	66
	PV	81.85	0.00	
	PVS	4.93	16.33	
	WT	10.39	10.39	
Total		**101.84**	**31.39**	
Total of the 4 SS		**299.71**	**149.36**	

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Table 3.3 presents the current Israeli electricity demand in the JV in the residential, commercial, water and agricultural sectors. Present day total consumption is 261.7 GWh which are expected to increase to 585.7 GWh by 2050.

Table 3.3 Current Israeli - JV electricity demand

Customer Type	Population in 2022 [capita]	Number of Customers in 2022*	Consumption 2022 [GWh]	Consumption 2030 [GWh]	Consumption 2050 [GWh]
Residential	59,953	18,794	154.5	190.9	349.3
Commercial		448	29.0	35.8	65.4
Water sector			50.7	67.2	126.5
Agriculture			27.5	31.1	44.5
Total			261.7	325.0	585.7

* Number of customers according to their classification

Table 3.4 The water sector electrical consumption by water usage type to be met by renewable and non-renewable resources.

	Renewable					
	Supply			Demand		
Consumption for water sector	Current	Short term (If available) 2030	Long-term (If available) 2050	Current	Short term (If available) 2030	Long-term (If available) 2050
Drinking	1.2	3.2	17.3	1.2	3.1	16.8
Wastewater	0.4	0.9	3.1	0.4	0.8	3.0
Irrigation	4.3	11.2	56.3	4.2	10.9	54.6
Industrial	2.1	5.6	27.9	2.1	5.4	27.1
TOTAL	8.1	20.8	104.6	7.8	20.2	101.4

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	Non-Renewable					
	Supply			Demand		
Consumption for water sector	Current	Short term (If available) 2030	Long-term (If available) 2050	Current	Short term (If available) 2030	Long-term (If available) 2050
Drinking	6.3	7.5	4.3	6.1	7.2	4.1
Wastewater	2.0	2.0	0.8	2.0	1.9	0.7
Irrigation	22.9	26.0	13.9	22.2	25.3	13.5
Industrial	11.4	12.9	6.9	11.0	12.5	6.7
TOTAL	42.6	48.4	25.9	41.3	46.9	25.1

Table 3.5 summarizes the main assumptions underlying these energy projections for the Jordan Valley. It illustrates how the energy consumption per sector was calculated given the constraints of limited data and the sources of the assumptions.

Final remarks: The current installed capacity of renewable resources status is over 350MW. Two-thirds of this capacity has come online during the last 3 years. The PV is by far the dominant technology over wind, biogas and hydropower. About 73MW are connected to the high-voltage grid. The rest are connected to the medium and low voltage grids. Most installations are dual use of mainly agricultural land. The Israeli Ministry of Energy (IMoE) envisions having 30% of the energy basket consist of renewable energy by the year 2030. The national electricity consumption in 2023 was about 72TWh. We assume 1.8% increase on demand and the demand in the JV to be in proportion to the JV population. We further assume that the energy demand per capita is about 8000kWh/capita as it is in the rest of Israel, in this case the current JV energy consumption may reach 480GWh and will grow to around 530GWh in 2030. In 2050 the JV consumption is expected to climb to 920GWh.

Please note that the forecast of JV consumption for 2030 and 2050 are 325 GWh and 586 GWh, respectively. This forecast reflects a 1.8% annual growth in the agricultural sector and a 3.1% annual growth in the other sectors, based on the average of the forecasts produced by the Bank of Israel, Noga, and BDO Consulting Israel. If we wish that the JV will comply with the IMoE vision it is enough to produce about 175GWh from renewables by 2030, so less than 100 MW of installed PV capacity will be sufficient. However, renewable capacity in 2024 has already exceeded this level by a factor of three. EcoFuture proposes a much more ambitious renewable target. Since this vision is at the core of the project Chapter 4 hereunder is devoted to that.

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Table 3.5 List of assumptions

Item	Assumption	Values	Sources
Solar PV – supply and demand	% of total energy	6% in 2022; At least 30% in 2030; At least 80% in 2050	Nurit Gal presentation[5] and Israel Environment Ministry[6]
Water sector energy consumption	Total energy consumption for each water use for 2030 and 2050. The water uses are: drinking, irrigation industrial, and wastewater treatment.	Conversion of MCM water consumption to GWh; varies per water use type. It varies between 1-3.5 kWh/m^3	Ecopeace (2015)[7] ; conversion of MCM to GWh based on prior studies. Challenges and Solutions for Global Water Scarcity[8]
Agricultural consumption	Agricultural area (in hectares) in the Jordan Valley and electricity consumption based on Israel data		Knesset report on agriculture sector [9]; R&D report on the Jordan Valley[10]
Forecast of total Jordan Valley load growth	Average of Bank of Israel, NOGA, and BDO electricity load forecasts	Average of 2.7%, 3.0%, and 3.5%	Average of Bank of Israel[11], NOGA, and BDO forecasts[12]
Biofuel	Current share of agricultural energy consumption[13]; forecasted growth rates[14]		Arava Institute[15]; Israel Central Bureau of Statistics[16] European growth forecast[17]
Natural gas	Exclusive non-renewable fuel deployed after all renewable fuels are deployed.	Calculated as residual.	Israel Energy Ministry[18]

[5] https://unece.org/sites/default/files/2021-12/6.1%20Energy%20Policy%2C%207Dec.pdf
[6] https://www.calcalistech.com/ctech/articles/0,7340,L-3781010,00.html
[7] https://ecopeaceme.org/wp-content/uploads/2022/03/Regional_NGO_Master_Plan_Final.pdf
[8] Shemer, H.; Wald, S.; Semiat, R. Challenges and Solutions for the Global Water Scarcity. *Membranes* **2023**, *13*, 612. h�ps://doi.org/10.3390/membranes13060612
[9] https://fs.knesset.gov.il/globaldocs/MMM/270ba95d-f71d-eb11-811a-00155d0af32a/2_270ba95d-f71d-eb11-811a-00155d0af32a_11_16452.pdf
[10] http://www.mop-bika.org.il/130651/haklaut_babika
[11] https://boi.org.il/media/mxufzcvv/dp202117e.pdf
[12] https://en.globes.co.il/en/article-as-power-shortage-looms-solutions-lag-1001445866#:~:text=Forecasts%20of%20demand%20for%20power,3.5%25)%20according%20to%20BDO.
[13] https://pubmed.ncbi.nlm.nih.gov/32149195/
[14] https://www.statista.com/statistics/1297018/global-biofuels-market-cagr-by-region/
[15] https://arava.org/wp-content/uploads/2022/04/2021-11_Arava-Institute_Sustainable-transformation-of-Israels-Energy-System_en-digital.pdf
[16] https://www.cbs.gov.il/he/subjects/Pages/%D7%9E%D7%A9%D7%A7%D7%99-%D7%91%D7%99%D7%AA.aspx
[17] https://www.statista.com/statistics/1297018/global-biofuels-market-cagr-by-region/
[18] Per e-mail sent by Chaim Melamed of Israel's Energy Ministry to Shlomo Wald, there are natural gas facilities capable of providing 500 thousand and 400 thousand m^3 per second

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Table 3.6 Renewable energy installations in the Israeli part of the Jordan Valley. (May 2024[19])

Region	Installed power [MW]	Wind [MW]	Biogas [MW]	Hydroelectric [MW]
Beit Shean	20			
Gilboa	119	9.4		
Jordan Valley	60			
Spring Valley	101	12.1	2.2	0.96
Total	**301**	**22**	**2**	**1**

[19] The Israeli Electricity Authority 2024 intermediate report

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3.2 Jordan

3.2.1 Overview

Jordan's overall electrical consumption is rose by 7.9% from 2021 to 2022 and is projected to grow at a more moderate annual rate of 1.6% through 2030. The most dominant source of electric energy in both regions is combined cycle, which accounts for 64.2% of the total generation in Jordan (including the Jordan Valley), followed by solar, which accounts for 15.6% of total generation. The share of solar energy will increase as two solar-powered desalination units for brackish water and solar PV projects for dams begin to operate during the upcoming years Through the year 2030 and beyond, Jordan aims to increase biofuel usage, explore waste-to-energy technologies, explore improving energy efficiencies.

The Jordanian national interconnected grid transmits electricity from the power stations to the distribution substations and transformer substations in the Jordan Valley via 400-kV and 132-kV power lines. The grid has a clearly identifiable north-south axis. The national 400-kV power line runs outside the Jordan Valley from Aqaba via Amman and up to the Syrian border. In the north, the power grid is connected to the Syrian grid through a 230-kV and a 400-kV power line. In the south, there is a 400-kV connection to the Egyptian grid. The interconnected grid feeds the local distribution systems that serve most of the Jordan's population, including that in the Jordan Valley[20].

Energy usage for water services is of primary importance, especially in the Jordan Valley, which represents the main agricultural productive area for Jordan. The Energy & Minerals Regulatory Commission noted that water pumping overall accounted for 14.6% of the country's total electricity consumption. To accommodate continued growth, Jordan is planning to integrate solar energy for water pumping.

Due to the limited availability of specific information on the Jordan Valley, we propose applying the share of Jordan's overall population residing in the Jordan Valley (2.626%) to Jordan's national energy statistics. This assumption has its shortcomings, including: (1) the almost exclusive focus on the agricultural and construction materials sector in the JV, and (2) the differences in fuel mix readily available in the JV. Regarding the latter, data is aggregated up to the "steam" technology level, with no differentiation among the relevant primary fuels (coal, oil shale, heavy fuel, etc.).

Assumption – The JV energy consumption is estimated by the ratio of the population reside in the JV to the total population in Jordan, equals 2.625%.

As mentioned above, energy-intensive water services constitute a significant share of overall energy usage. Within wastewater treatment plants (WWTPs), the complexity of the treatment process directly correlates with energy demands. Key components such as aeration, pumping, and solids processing constitute the majority of electricity needs. Additionally, factors including climate conditions, inlet and outlet parameters, system size and age, and specific design characteristics intricately influence the energy intensity in WWTPs and sewerage systems. Within the desalination process, the most common Reverse

[20] Note that this information comes from Ecopeace and may require updating.

Osmosis process requires from 0.5-2.5 kWh/m^3 for brackish water and 5-9 kWh/m^3 for seawater. As requirements for desalinated water increase, Jordan is exploring integration of renewable energy technologies, such as solar collectors, photovoltaic (PV) systems, or wind power, especially in decentralized applications in rural off-grid areas.

Solar water pumping in JV is being explored in greater depth, as Jordan's National Energy Research Centre has been involved in replacing inefficient diesel irrigation pumps with solar PV. Moreover, there is a plan for the replacement of five hundred surface water pumps, with a capacity of around 7,655 kilowatts, with energy-efficient solar pumps, generating an annual output of 7,655 megawatt-hours. The pumps will be operated by solar photovoltaic facilities. In general, solar energy's full potential in Jordan has yet to be realised. Jordan's annual daily average solar irradiance. Solar insolation allows PV resources in Jordan to produce from 4 to 7 kWh/m^2/day, placing Jordan among the countries with one of the highest solar irradiance levels globally. Solar energy is extensively harnessed for water heating, especially in the domestic sector and for remote-site lighting and telecommunications to a lesser extent but is not at a level expected for a country with such high insolation levels.

Critical challenges are:

- Improving the energy efficiencies of water pumping technologies and the maintenance of water pumping equipment.
- Integrating renewable energy sources for pumping loads.

In terms of agriculture for energy, biofuels have made some inroads. However, even in the short term, Jordan will likely increase its focus on increasing biofuel's role in meeting Jordan's agriculture-related energy needs. Future considerations should primarily focus on waste-to-energy technologies based on agro-industrial, human, and animal residues as secondary energy sources. This approach is preferred due to the water and energy consumption involved in cultivating and processing crops, as well as the essential need to cover scarce water resources. Waste-to-energy strategies not only produce energy but also reduce the quantities of waste requiring final disposal, which, in turn, also demands energy.

3.2.2 Electricity

Overall, Jordan's electricity demand is expected to rise gradually from 17672 GWh in 2020 to 19701 GWh in 2030. The average annual growth rate of primary energy demand is projected to be 1.6% over the decade. Some of the issues in Jordan are very similar to those of Israel regarding the bottlenecks in the grid substations that may limit the large-scale exploitation of solar energy and may cause high curtailment of energy. The suggested response to the problem is the same as in Israel:

- Promote "behind the meter" and off-grid utilization of solar energy.
- More sophisticate energy management: such as smart local microgrids; SCADA systems on the main grid, establishing reliable load profiles, optimizing energy procurement, and leveraging reservoir buffers.

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For the sake of energy security of supply, it is recommended for Jordan to evelope greater energy independence. Currently, Jordan relies heavily on imported energy resources, which exceeds 90% of total energy needs. At the same time, Jordan wants to enhance its electrical connections with neighbouring systems, including Israel and Egypt to increase system reliability and stability. An additional short-run energy sector issue that Jordan plans to address is: Planning and implementing **renewable energy generation plans** in the Lower Jordan River Basin, per the National Master Plan for the Jordan River Valley. Jordan expects nearly six hundred thousand people to live in that area by 2050 and is looking toward central-station and distributed renewables as a solution.

3.2.3 Heat and power

The rural agricultural nature of the region promotes the use of organic wastes, waste-water treatment sludge, etc. to produce gases such as methane, and biofuels. These energy resources together with solar heating systems can serve the heat and power demand in the JV region. As in Israel, the area allocated for agriculture is almost exhausted, and only about 10% increase is expected. But the huge, expected increase in population (around 600,000 by 2050) is expected to drive a vast expansion of industries, especially food industries, that are heavy consumers of heat. Exploring the potential for methane capture, Combined Heat and Power (CHP) production, on-site solar, and micro-hydro generation where feasible.

3.2.4 The Jordanian energy market

Tables 3.7 to 3.9 provide the electricity supply and demand for Jordan for 2021 and 2022, the calculated values for JV assuming a 2.625% population ratioand the electricity demand according to costumer category. The first two tables supply the annual peak load and energy statistics for Jordan in 2021 and 2022, and the relevant generation sources, based on information from the Jordan Department of Statistics ("DOS") and Jordan's national electric utility National Electric Power Company ("NEPCO").

Table 3.7 Electricity supply and demand in Jordan in the years 2021 and 2022.

Jordan – Supply & Demand	Jordan		
	2021	*2022	Reference
Large Industries	970	1,100	DOS
Consumed energy (GWh)	19,311	20,577	DOS
Losses %	13	13.3	DOS
Fuel consumption in electricity (1000 Toe)	3136.4	3311.9	DOS
Peak load (MW)	3,770	4,010	NEPCO
Available Capacity (MW) traditional	3,977	4,212	NEPCO

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Available Capacity (MW) Renewable	1,564	1,584	NEPCO
Purchased electricity (GWh)	19,619	20,763	NEPCO
Sold Electrical Energy (GWh)	19,281	20,446	NEPCO
Wheeling Energy (GWh)	77	119	NEPCO
Transmission Losses (%)	1.72	1.94	NEPCO

Table 3.8 Electricity supply in Jordan and in the Jordan Valley, assuming 2.625% population ratio, in the years 2021 and 2022. The energy is given in GWh.

	Jordan			**Jordan Valley**		
	2021	*2022	Reference	2021	2022	Reference
Total Generation (GWh)	21924.2	23654.0	DOS	575.73	621.15	Estimated
Steam	327.8	1301.4	DOS	8.61	34.17	Estimated
Diesel gensets	702.0	1127.0	DOS	18.43	29.60	Estimated
Simple cycle	490.2	498.5	DOS	12.87	13.09	Estimated
Combined Cycle	14277.6	13947.7	DOS	374.93	366.27	Estimated
Wind	1628.1	1783.9	DOS	42.75	46.85	Estimated
Hydro	18.3	19.1	DOS	0.48	0.50	Estimated
Biogas	3.5	3.5	DOS	0.09	0.09	Estimated
Solar - transport network	2206.7	2267.7	DOS	57.95	59.55	Estimated
Solar - distribution network	1300.0	1605.2	DOS	34.14	42.15	Estimated
Total electricity generation (GW)	20954.2	22554.0	DOS	550.26	592.27	Estimated

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Table 3.9 Electricity demand in the Jordan Valley, in the years 2021 and 2022, according to the customer category.

Usage	2021		*2022		% of increase
	GWh	% of total	GWh	% of total	
Household	**9,296.4**	**48.1**	**9,862.6**	**47.9**	**6.09%**
Industrial	**4,048.0**	**21**	**4,370.1**	**21.2**	**7.96%**
Commercial	**2,808.9**	**14.5**	**3,019.3**	**14.7**	**7.49%**
Water Pumping	**2,769.4**	**14.3**	**2,916.9**	**14.2**	**5.33%**
Street Illumination	**388.6**	**2**	**408.2**	**2.0**	**5.04%**
Total	**19,311.3**	**100**	**20,577.1**	**100**	**6.55%**
*Primary + Appreciation					

In contrast to the rapid annual electricity demand growth in the 5-6% range in recent years, Jordan's annual electricity demand growth through 2030 is expected to be only 1.6%. Table 3.10 presents the projected growth by customer category.

Table 3.10 Projected growth by customer category

Usage	2030	
	GWh	% of total
Household	**11,021.67**	**47.9**
Industrial	**4,883.68**	**21.2**
Commercial	**3,374.13**	**14.7**
Water Pumping	**3,259.70**	**14.2**
Street Illumination	**456.17**	**2.0**
Total	**22,995.36**	**100**

Table 3.11 shows the projected fuel mix for Jordan's electricity generation in 2030. Jordan has raised its renewable capacity target to 50% from 31% and its renewable energy target from 14% to an estimated 22.5%

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Table 3.11 Projected fuel mix for Jordan's electricity generation in 2030

	Jordan		Jordan Valley	
	2030	Reference	2030	Reference
Total Generation (GWh)	26856.80	Estimated	704.99	Estimated
Steam	1471.07	Estimated	0.00	Estimated
Diesel gensets	1239.60	Estimated	0.00	Estimated
Simple cycle	566.00	Estimated	0.00	Estimated
Combined Cycle	15486.25	Estimated	0.00	Estimated
Wind	1898.24	Estimated	0.00	Estimated
Hydro	20.26	Estimated	0.00	Estimated
Biogas	3.65	Estimated	0.46	Estimated
Solar - transport network	2412.82	Estimated	412.53	Estimated
Solar - distribution network	1707.81	Estimated	291.99	Estimated
Total electricity generation (GW)	25607.86	Estimated	672.21	Estimated
Note that Jordan has a renewables target for 2030 of 50% of total capacity and 22.5% of total energy. Annual demand growth rate of 5%				

Data on the current renewable energy production in the JV is incomplete, although it is possible to assess its prospects. Regarding PV, the land that can be allocated for dual-use (agricultural land etc.) today and in the future, is higher compared to Israel, on a per-capita basis. Moreover, although current demand is much lower than that of Israel, it is reasonable to assume that demand within the overall JV ring will converge to that of Israel. Therefore, we assume that future per-capita demand will converge to Israel's current 8000 kWh/year. However, the Solar radiation in Jordan is higher than in Israel. Therefore, we can easily use the forecast made on the Israeli JV as a reasonable, perhaps slightly conservative estimate of the Jordanian JV renewable energy prospects. The energy prospect in the region is further discussed in Chapter 4.

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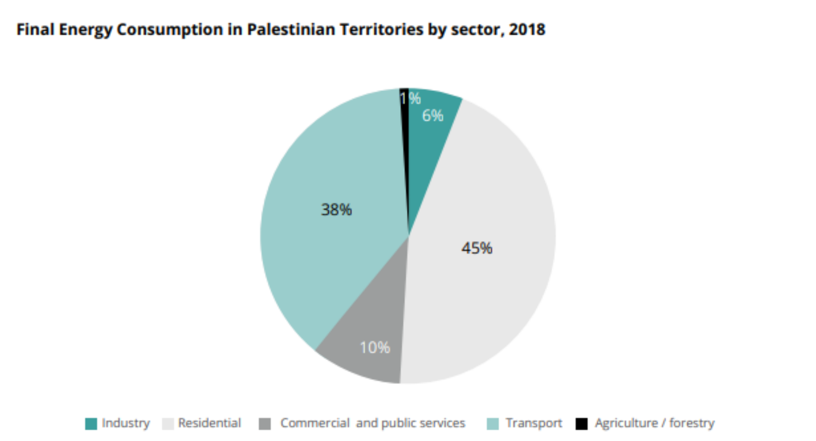
3.3 Palestine

3.3.1 Overview

The supply and demand energy data for the Palestinian part of Jordan Valley (JV) is unknown. Therefore assumptions were made for the electricity market in order to estimate the West Bank data and then the JV data from the total Palestine energy market(Figure 3.1). On top of that the Jewish settlement in area C is excluded. Palestine is heavily dependent on Israel for meeting its energy requirements. Almost all petroleum products and most of the electricity are imported from Israel and the possibility of diversifying the energy development and imports from other countries is currently limited due to political constraints as Israel control of area C (60% of the West Bank).

Population growth, increasing living standards and rapid industrial growth has led to tremendous energy demand in the Palestinian territories in recent years. The Palestinian energy market has limited options to develop local sources of electricity and Israel controls the planning and the construction of power networks in large parts of Area C.

Thus, exploitation of renewable energy resources is required at a mass-level to ensure a cheap and sustainable source of energy to the Palestinians and reduce dependency on Israel.



(Source: Palestinian Central Bureau of Statistics 2020, Energy Balance of Palestine, 2010-2019. Ramallah - Palestine.)

Figure 3.1 Energy consumption in Palestinian territories by sectors (Year 2018)

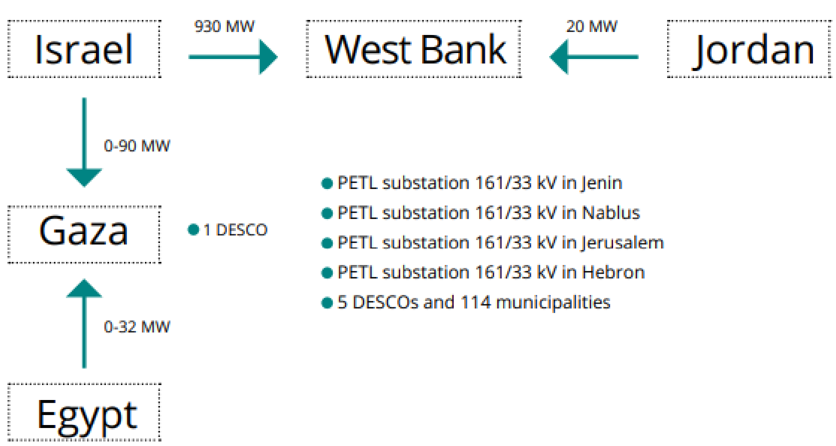
Palestine is a net importer of oil and petroleum products. Total energy consumption in the Palestinian Territories is considered the lowest in the region, while its costs are relatively high compared to its neighbors. The largest portion of the different types of imported fossil fuels consumed in the Palestinian

Territories originates from Israel, while the remainder comes from Jordan and Egypt. The energy provided by the three sources, however, does not meet the power needs of the Palestinian Territories.

The distribution of the **energy** consumption among the various demands is given in Figure 3.1. Figure 3.1 indicates that the residential sector is responsible for the largest share of energy consumption (45%). The demand of the agricultural sector is relatively small. The residential sector consumes mainly electricity while the energy for transportation and for many of the industries is based on fossil fuels. We assume that the 2018 data in Figure 3.1 reflects the present situation as well. This fact provides a hint for the estimation of the JV electricity demand. The electricity demand per capita is assumed to be the same in the whole PA. The area devoted to agriculture in the JV is limited with a great chance for expansion. We may estimate the energy for industry & commerce by the ratio of consumers (and not population) in the JV to those in the whole PA.

3.3.2 Electricity

According to the Palestinian Central Bureau of Statistics (PCBS), Palestine's total electrical energy consumption in 2019 was reported to be 5,929.5 GWh. This quantity is almost entirely imported from outside sources, mainly from the Israel Electric Corporation (IEC). While a share of 5% of the total electricity supply was imported from Jordan and Egypt, the largest electricity supplier (accounting for 86%) was the Israeli Electricity Corporation (IEC). It provided 99% of the total electricity supply in the West Bank (Milhem, o. J.). Solar PV accounted only for 3% of the electricity supply. Figure 3.2 displays the electricity interconnections between Palestine and her neighbors, and shows the total electricity supply capacity to Palestine in the year 2020.



(Source: own creation based on Khaldi and Sunikka-Blank, 2020)

Figure 3.2 Structure of the Electricity Interconnections in Palestine

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3.3.3 Estimated power supply to the JV

The West Bank's area is 5,860 km^2 while the JV's area within the PA territory is 881 km^2. or about 15% of the JV area. The framework for the electricity power supply in the Jordan Valley differs from that of the rest of Palestine. The current interconnection with the Israeli system serves Palestine well but provides insufficient capacity to serve all Palestinians adequately as well. A solution is expected from Palestinian interconnection with Jordan: PNA and Jordan have agreed on connecting the Palestinian power grid to the Jordanian with a 33kV transmission line through King Abdullah Bridge, with a capacity of 20MW. A transformer substation is built in the south of the City of Jericho and connected to the existing network. The other Palestinian communities get the electricity from JDECO (Jerusalem District Electricity Company), or from the Israeli company Qutria.

The Israeli Electric Corporation (IEC) operates 2 substations (SS) on the Israeli transmission grid that are supplying power to the West Bank. The first SS is in Maale Efraim, near Nablus, with the capacity of 150MW. It supplies energy to Area C which includes most of the JV. The second SS is in Jericho (Area A) and can provide 50MW. The total capacity is available for the JV consumption. That provides an estimate of more than 150MW capacity that is available at the JV. One should consider the IEC rule that this capacity reflects an estimate of at least 40% reserved capacity over the measured past average power consumption. We estimate electricity demand based on population ratio as stated above. The total consumption is about 6,000 GWh. We estimate the population in the JV to be ~5% of the total population. Therefore, the total current electricity demand in the JV is assumed to be about 300 GWh.

3.3.4 Renewable energy

The Palestinian Energy Authority issued a renewable energy strategy in 2012 that aims to gradually achieve 10 percent of electricity production from renewable sources by the end of 2020. According to the strategy, 130 MW would be installed from renewable resources projects by the end of 2020, and the major portion of green power would be generated by solar energy. The strategy comprises of two phases. The first phase involves conducting feasibility studies and preparing bids for the Palestinian market, as well as deploying small-scale projects and implementing the Palestinian Solar Initiative. The first phase was implemented between 2012 and 2015 and aimed to attain 25 MW from predetermined sources of renewable projects. As of 2022, total installed generation is about 1100 MW, Renewables comprise only about 3% of that total, indicating that this renewables strategy had not been implemented at that time[21].

The NREAP proposes the following new RE targets:

- December 2020 target: 100 MW, mostly PV
- 2030 target – scenario A: 300 MW, including only areas A and B

[21] Current West Bank installed generation is about 1100 MW, see: https://www.trade.gov/country-commercial-guides/west-bank-and-gaza-energy. It appears that the 2020 plans were not executed, since the renewables share as of 2022 was still only 3%, or about 40 MW. See https://library.fes.de/pdf-files/bueros/fespal/19430-20230313.pdf

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- 2030 target – scenario B: 500 MW, including areas A, B, and C

Eighty percent of the 2030 targets will be achieved with solar PV, 10 percent with wind energy, and 10 percent with biogas/biomass.

- Solar radiation is best in the central and southern parts of the JV.
- Land availability and financial concerns constitute the main challenges to investment in large solar energy projects.

This situation affects the potential to install renewable energy capacities. In the West Bank, Area A comprises 18% of the total land area, with Area B accounting for 22% and Area C for 60% (Hamed and Peric, 2020). Accordingly, Israel's partial/complete control of Areas B and C severely hinders the potential development of renewable and traditional energy infrastructure, as well as impeding.

In Areas A and B, the potential for large-scale solar amounts to 103 MW, while the most promising potential is for Area C, which could generate 3,374 MW. The JV potential is included in the areas A, B and C potential. Area C, which covers over 60% of the Palestinian Territories, has some promising mountainous zones not densely populated where wind energy could be harvested. However, these areas remain beyond the control of the Palestinian Authority, which is a major barrier. In contrast, Areas A and B are too densely populated, making them widely unsuitable for wind energy development (Juaidi et al., 2016).

We estimate the **RE** potential **in the JV area** by ratio of the JV area to the whole West Bank area, i.e. ~15%. ➔ about **520 MW** (by year 2030)

Ecofuture suggests that the above-mentioned plans can be much more ambitious. There are large uncultivated areas in Palestine that can be assigned for large PV farms, connected to the transmission grid. We consider the possibility of building even a 1 GW PV plant! Other areas can hold many dual-use PV installations. Energy can be a source of income to the JV inhabitants and serve as a tool for reaching energy independence of the Palestinian Authority, Large pumped storage can be designed to support the power regulation on the grid.

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4. Synthesis of the JV energy sector of the three territories

The three territories hold the same strategy and face the same obstacles on the way to accomplishing their national energy plans. Most of the land in the JV is rural, the primary energy consumer is the residential sector and the second is the water sector which is the main resource for agriculture. The current situation is that, in the JV, the three territories can provide satisfactory energy supply and demand services by mainly non-renewable sources. Most of the non-renewable energy resources are located outside the JV, but it is not an issue since currently, the JV is not a focal point for the 3 nations' energy policies. Likewise, the future climate change treatment in the JV is not at the center of their policy agendas.

But the JV can be a great source of renewable energy, far more than the local JV demand. The surplus can be sold to the national grid and supports to reach the national renewable target. This is clear for Israel and Palestine. In Jordan, renewables, as a source of income to the JV inhabitants, is not so evident since there are much larger areas on the upper Jordanian plans that are better suited for solar energy production. Nonetheless, the local JV consumption can easily be achieved in the Jordanian JV.

There is a major concern in the evaluation of the energy sector's needs in the short -term and the long-term. Many unknown parameters must be evaluated to plan and propose the design of energy infrastructures for the future of the JV. The following insights, which are similar for the three territories, are the following:

- <u>Population growth</u> - The main factor that influences the planning is the forecasted huge increase in population by a factor of 2 to 4 by 2050 in the region. The energy demand per capita is not expected to decline. Climate change may impose more energy for the residential, commercial, and industrial sectors. The expected increase of electrical mobility may drive the increase in electricity demand. The per-customer energy demand in Jordan and Palestine is substantially lower than the Israeli per-customer average of 8,000kWhyear. We assume that, over time, the Israeli demand will stay almost the same due to energy efficiency improvements. However, the demand per capita in Jordan and Palestine will reach the Israeli level by 2050.
- <u>Quest for renewable energy</u> - The desire of all nations is to increase substantially the reliance on renewable energy is evident. The Israeli <u>national</u> target of 30% in 2030 and 80% in 2050 and Jordan's plans are even more ambitious.
- It is expected that the JV will significantly exceed the national targets. The energy security of the JV may strengthen the desire for energy dependence of the area as much as possible on local supply, and mainly on renewable energy.
- Biofuels and biogas production can be meaningful and can contribute a lot to dispatchable electricity supply and for heat & power supply.
- <u>Land allocation for solar installations</u> – besides Area C in Palestine there is very limited open space in Jordan and Israel for large installations that can be connected to the transmission grids. Most of the future solar facilities are expected to be connected to the distribution grids and dual use of land will be the dominant form: Agri photovoltaic, roofs covering public areas, floating systems on water reservoirs and ponds, etc.

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The current situation in Israel as described in Chapter 3.1 demonstrates that the claims above are valid.

Energy for water - The water supply in agricultural areas like the Jordanian and Israeli JV areas, is a major electricity consumer. The energy is needed for pumping wastewater treatment and desalination. The amount of water used in the region may not grow much since the designated agricultural areas in the region are nearly exhausted. However, if we wish to use treated wastewater and to preserve all the region's environmental services, the quality of the treated water must be improved. For water-treatment energy demand we may take a high reference figure such as 3kWh/m^3 and the pumping cost may be estimated at less than 0.5kWh/m^3. With enough water storage ponds, most of the energy for the waste-water treatment plants can be supplied by solar systems.

Energy shift between sectors – The large forecasted vast increase in population on one hand, and the limited expansion of agricultural areas combined with increasing automatization in agriculture and declining enthusiasm of the young generation for agricultural work on the other, may cause substantial changes in the labor market. Specifically, we may expect a large increase of the industrial and commercial sectors. Those are currently less presented in the JV, but their future contribution needs to be studied and estimated. Maybe, advanced food industries have to be promoted. This last statement is based on the importance of post-harvesting to food security and environmental preservation.

Grid vs. off-grid and behind-the-meter energy usage – In the three territories, the current transmission grid and even distribution grids may not be developed enough to absorb a significant growth in energy demand. The plans to add and/or increase the capacity of the existing and future substations feeding the JV are not mature and the future ability of the national grids to absorb a lot of renewables cannot be trusted. Selling and buying energy from the national providers may be economically justified. But such agreements may be at odds with the quest for maximal energy security. Therefore, self-usage of the energy produced by consumers behind the grid, is advocated. Total off-grid installation is less favorable since the grid connection provides flexibility and better security of supply.

Heat and Power resources – In view of the expected growth in the industrial and commercial sectors, more attention should be given to the needs of industries, especially food industries, to the needs of heat and power resources. This market was almost ignored in the national reports. For example, many food industries make use of low-temperature steam that can easily be achieved by thermo-solar panels, by biogas heaters, waste-heat recovery from CHP facilities, and so on. The efficiency of thermal energy production is much higher than that of PV electricity production, and waste heat is also very important. Diverse type biofuels produced from waste can contribute to the CHP (Combined Heat&Power) resources and act as a primary energy resource (PER) for dispatchable electricity production.

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Natural gas and biogas – To overcome the intermittency and the non-dispatchability of renewable energy biofuels mainly biogas, can serve as PER for electricity and H&P. Lack of biogas can be compensated by natural gas supply. The easiest way to employ this option is to feed regional distribution lines, at low pressure (6-8 bar) from the Israeli PRMS near Beit Shean. Biogas and NG can be mixed and used by the customers.

In the short term, each territory can follow the recommendations given above separately. However, they should keep in mind that the segregation of three national plans is not optimal. In particular, they do not consider the great advantage of common tri-national regional collaborations sharing the JV WEFE resources.

4.1 Assessment of renewable energy potential in the JV

To assess the potential for renewable energy we use the System Advisor Model developed by the National Renewable Energy Laboratories ("NREL-SAM")[22]. NREL-SAM enables modelling of a variety of renewable energy systems, including PV, storage (both battery and thermal storage), Concentrating Solar Power, wind, solar water heating, fuel cells, and biomass combustion. NREL-SAM allows operational and financial comparisons among the technologies most likely to be components of a JV microgrid, including: (1) Power purchase agreements internal and external to the microgrid,(2) differences in ownership structures, and (3) Combinations of front-of-meter and behind-the-meter technologies. In addition, we e consider 6 reference positions of solar systems, three points on the West JV (JVWN, JVWC, JVWS – following the northern, centre, and southern locations) and three points on the East JV (JVEN, JVEC, and JVES).

Four types of PV configurations are under consideration: fixed or floating, with or without tracking. To calculate the APV potential we have to make the following assumption. We assume that APV will be implemented over 20% of the agricultural area. The reference installation will be mono-crystalline panels in the four modes of architecture listed above. his assumption, will provide a reasonable estimate to the installed PV power. However, a good estimation of the actual land allocation is needed for the energy production and its time distribution calculations.

4.1.1 A practical scenario's calculation

The PV technologies including crystalline silicon modules (SunPower SPR-E19-310-COM), capacity is 310.15 DC Watts. Each site includes 1620 modules in 4 configurations listed below, so total capacity is 502.44 DC kW.

Module inverters (Sungrow Power Supply Co – Ltd. : SG250HX-US) have unit capacity of 226.997 AC kW. There are 2 inverters, so the total AC capacity is 453.99 AC kW.

The 4 site installation modes are:

[22] https://sam.nrel.gov/

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1. 1X ➔ 1 Axis, horizontal at 0° tilt.
2. 1XT ➔ 1 Axis track, Tilted at optimal angle.
3. Fix ➔ Fixed angle at 20°.
4. FixT ➔ Fixed angle at optimal angle.

The 1X mode is our reference for floating devices.1XT is the preferred mode for large, stand-alone sites. The Fix mode is used to estimate urban installations. The reason is that existing roofs were not designed for PV and therefore, either the orientation is not optimal, shadowing can limit production, and soiling due to poor maintenance reduces efficiency. Therefore, we choose the non-optimal 20° tilt. For the APV dual-use installations, we use the FixT mode.

In each test scenario, we assumed the land use, the location, and the installation mode. The land ratio dictates the installed power. We calculated the supplied energy spectrum in 30-minute resolution steps over one year. SAM has the solar radiation data for the last 25 years. For our scenarios, we used the 2023 atmospheric data. The production is compared with a reference demand curve. The curve used is the Israeli demand energy spectrum from 2019, normalized to the population ratio. Such comparison, although somewhat qualitative, can provide good enough quantitative clues for the amount of curtailment, the need of storage capacity, and the like. In the following, we present the results of a single scenario used to estimate PV potential in the Israeli JV. However, the result provides a general view to the future PV potential in Jordan and Palestine as well.

As can be seen in Table 4.1 the PV potential in Jordan and Palestine is higher than in Israel due to the higher radiation. The amount of area in those countries is higher as well but, at least currently, the energy demand per capita is much lower compared to Israel. Regarding the demand in Jordan and Palestine our vision is that all the population in the region will be provided with about 8000kWh/year/capita as it is currently in Israel. Therefore, the reference demand curve used is relevant to the whole area.

Table 4.1 PV energy output, using NREL/SAM for the following locations on the Western and Eastern sides of the Jordan Valley Locations selected

Location	Latitude (N)	Longitude (E)	kWh/kW (Fixed SI)	kWh/kW (Fixed Tilted SI)
Jordan Valley Regional Authority - West	32.63	35.29	1806	1811
Gilboa – West	32.47	35.42	1728	1804
Maale Efraim - West	32.43	35.25	1798	1799
North Goul (North Jordan) JV - East	32.55	35.58	1927	1958
Central JV – Jordan - East	31.95	34.90	1868	1880
Southern JV – Jordan - East	30.83	35.03	1951	1970

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The Short-term (Year 2030) potential for renewable energy is roughly estimated based on the limited data available. Detailed studies have been conducted within WP5 and shall be published on due time.

Table 4.2 Estimated renewables opportunities by 2030

Renewable type	Estimated supply in 2030 (MW)	Estimated JV peak demand in 2030 (MW)	Notes
Israel			
PV	252.2	62.3	Assumptions from Section 3.1 of D3.3 Report for PV and **100% saturation** for residential and commercial PV; Arava Institute et al for biofuel
PV + Storage	97.7		
Biofuel	7.0		
Wind	40.0		
Jordan			
PV	101.7	117.3	Estimated
Biofuel	0.1		Estimated
Wind	46.9		Estimated
Hydro	0.5		Estimated
Palestine			
PV	520.0	68.2	Estimated in Section 3.3 of D3.3
Biofuel	30.0		2030 target in Section 3.3 of D3.3
Wind	30.0		2030 target Section 3.3 of D3.3

Note that the **339.7 MW RE potential in Israel**, following the assumptions in Table 3.5, is based on the following inputs:

1. 100% saturation of residential and commercial rooftops. That is 19,242 residential customers with 40 sq.m. of PV panel coverage and 448 commercial customers with 52 sq.m. of PV panel coverage. Assuming 200 W/sq.m., we get a potential of about 157.3MW.
2. The agricultural area is conservatively assumed of 273 square kilometers for Israel JV, only 20% of it is assumed to be covered, and only 1% will be APV. This still produces about 109.2MW of PV potential.
3. Of the 610 thousand square meters of reservoir (Ecopeace 2015 report) for the Israel JV, 60% could be covered. This produces another 73.2 MW of PV potential.

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The main conclusion is that, for Israel, roof-top installation has enough potential to reach the official target of about 90 MW installed power by 2030. The peak demand in the Israel JV for 2030 is projected to be 63.2 MW. Moreover, if we assume capacity factors in the 20% range and electricity demand were to be supplied entirely by PV and storage, the Israel portion of the Jordan Valley would only require about 192 MW of PV much lower than the approximately 300 MW already installed, let alone the potential for PV if current regulatory, infrastructure, taxation, and regulatory constraints are removed. This excess capacity creates opportunities not only to supply the rest of the Jordan Valley microgrid, but also to “export” power to the 3 national electricity grids. This result holds true for Jordan and Palestine, making the rapid development of renewables in a Jordan Valley microgridand upgrading the national transmission and distribution systems bordering that microgrid a priority for Israel, Jordan, and Palestine.

4.1.2 The Israel north JV Scenario results

The assumptions used in this scenario are the following. The total area covered by PV panels is about 16km^2 . The total installed power is about 2GW (DC). The land allocated (in m^2) is available and feasible. As shown in Chapter 3.1 we already have about 300MW installed PV in this region. 7% PV increase per year, which has occurred in the last 3 years, will lead to the desired figure in 2050 and to about 430 MW installed in 2030. The reference data in the first 3 lines of Table 4.3 provide the data of a reference installation of about 500kW. The spectra calculated by SAM for the reference installations were multiplied by the power ratio and summed up to calculate the scenario outcome.

Table 4.3 Scenario parameters. In gray the reference installation is presented, and the scenario parameters are marked in light brown.

Scenario - Israel north JV		Uncultivated	Water	Agriculture	Residence
		JVWN 1XT	JVWN 1X	JVWN FIXT	JVWN FIX
Panel area	[m^2]	2,642	2,642	2,642	2,642
Land area	[m^2]	4,756	3,170	4,756	3,170
Installed Power	MW	0.45399	0.45399	0.45399	0.45399
Israel north JV					
Land use	15,894,100	259,300	8,450,000	5,974,800	1,210,000
Installed Power	1978.4116	25	1,210	570	173
Land Ratio		55	2,665	1,256	382
Power Ratio		55	2,665	1,256	382

The location chosen is Jordan Valley Regional Authority – North - West (See Table 4.1).

Figure 4.1 presents the average power supply in each month over the 2023 reference year. The maximal production is in August and reaches about 1.5GW and the minimum is in December when the maximum power is about 800 MW.

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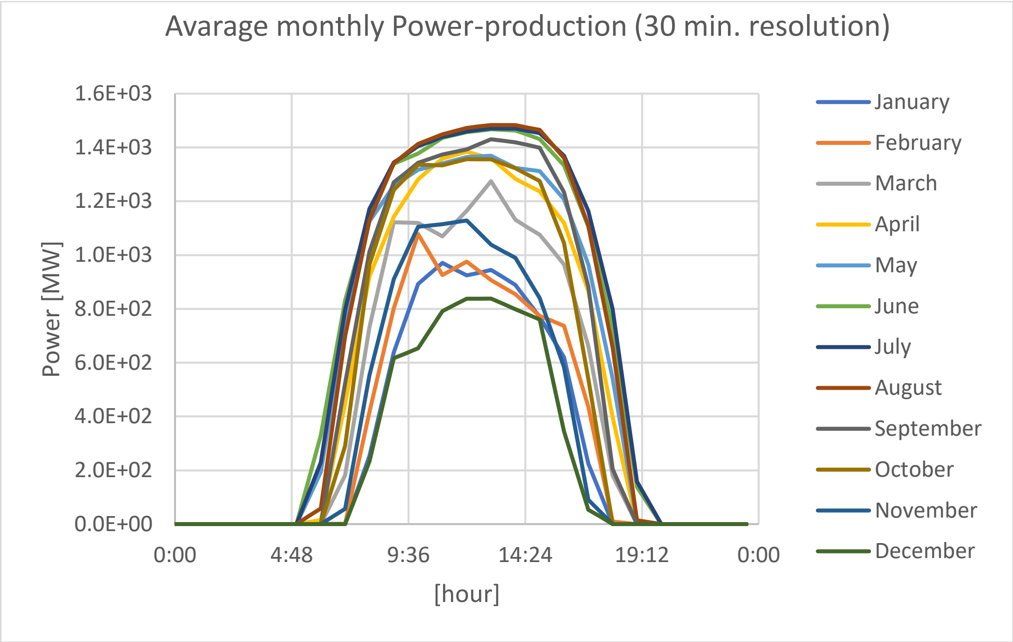

Figure 4.1 Average power provided in each month

Figure 4.2 shows that the maximum power is steadily around noon time and the standard deviation is about 3 hours.

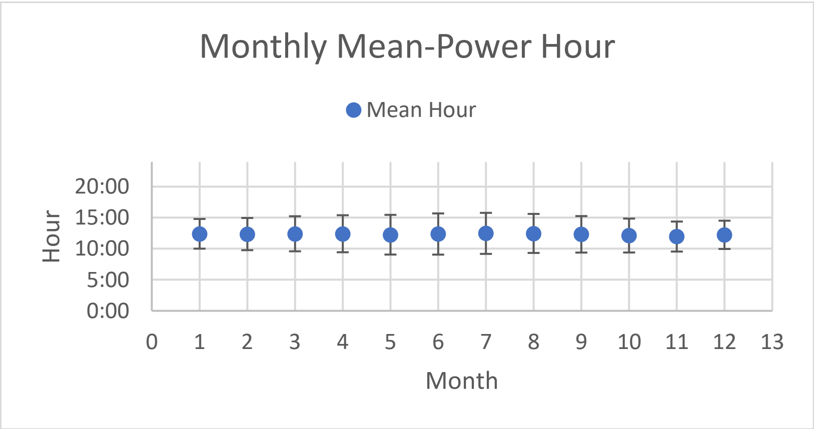

Figure 4.2 Monthly Mean-Power Hour

Figure 4.3 presents the energy production per season. The standard deviations (the error bars) are displayed on the summer and winter graphs. The large standard deviations, especially during the winter, suggest that energy storage facilities must be installed to reduce the daily variations. The vertical axis shows the ratio of the produced power to the installed power. The ratio is always less than 80%.

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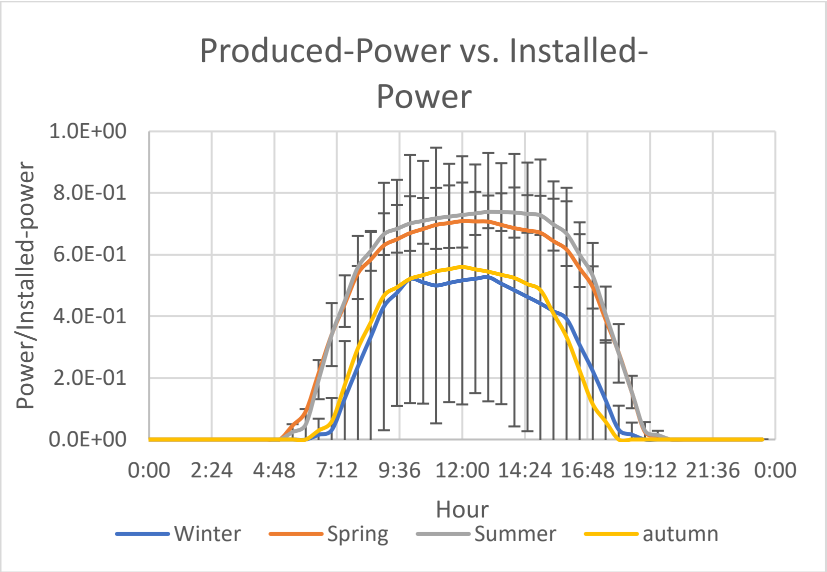

Figure 4.3 Produced-Power vs. Installed-Power

Finally, Figure 4.4 presents the daily demand curve expected in 2030 and 2050. For the supplied PV energy we estimated much lower increase rate of PV installations, therefore the supply curve is based on 495MW installed power only (1/4 of the calculated installed power taken in the scenario).

The results are striking. It seems that in 2030, PV can supply ALL the energy demand in the Israeli JV, with daily storage being sufficient to compensate for expected fluctuations). On 2050, even in this assumed poor installations performance (1/4 of the possible one) PV can supply 100% of the demand but not throughout the entire year unless a weekly storage (not existing today) will be available.

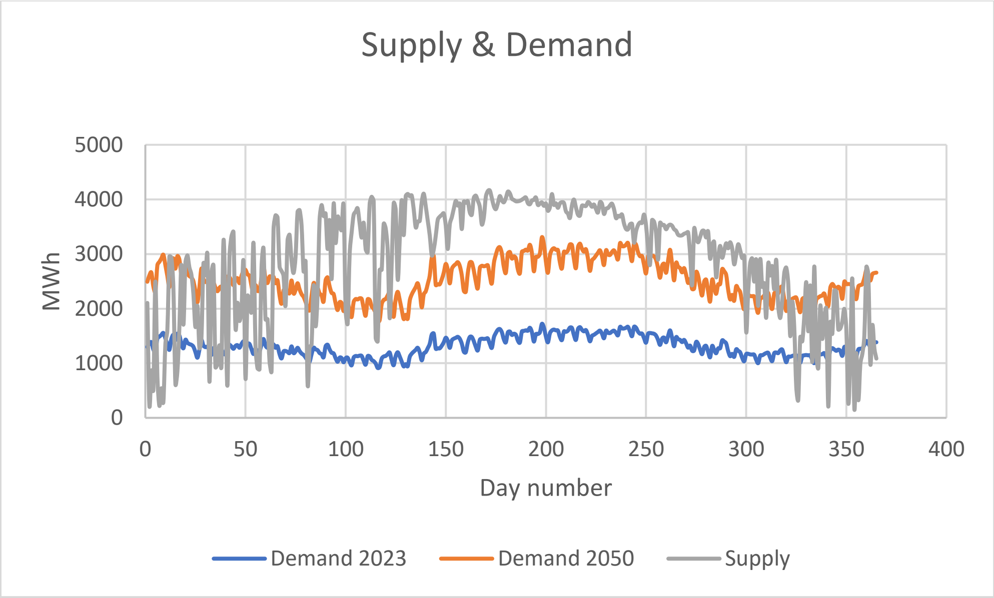

Figure 4.4 PV supplied energy versus the estimated demand in 2030 and 2050

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4.1.3 Levelized Cost of Entry ("LCOE")

LCOE represents the average revenue per unit of electricity generated that would be required to recover the costs of building and operating a generating plant during an assumed financial life and duty cycle", and is calculated as the ratio between all the discounted costs over the lifetime of an electricity generating plant divided by a discounted sum of the actual energy amounts delivered[23]. LCOE is a metric to compare different electricity generation and storage technologies on a consistent basis. LCOE is best suited to investments in conventional fossil generation, with relatively predictable annual energy production over the investment's lifetime and standard project financing but can be less reliable for intermittent renewables with high capital costs relative to operating and fuel costs, LCOE is especially sensitive to the financing terms associated with each technology type. The year-on-year output and various taxation and subsidy mechanisms. In applying LCOE to the resources likely to be included in a JV microgrid, primarily intermittent renewables and storage, these limitations must be considered. Table 4.4 provides representative LCOEs for these technologies, based on the default financing assumptions and results of the NREL/SAM model:

Table 4.4 LCOEs of technologies

Technology	LCOE ($/MWh)
PV – Fixed	$90-95/MWh ($93.30 average)
PV – Fixed Tilting	$90-95/MWh ($91.20 average)
PV – Single-Axis Fixed	$70-75/MWh ($74.31 average)
PV – Single-Axis Tilting	$70-75/MWh ($72.70 average)
PV + Battery	$100-115/MWh (fixed $110-115; 1-axis ($105-110/MWh)
Biofuel - methane	$99-$115/MWh ($112.82 average)

4.2 Conclusions

Since the Israeli PV expansion scenario is lower than that of the Jordanian and Palestinian scenarios, the conclusions below apply to the 3 countries.

The JV can easily reach energy independence relying of PV energy supply. Power fluctuation in 2030 can be overcome by daily energy storage and/or by dispatchable energy (for example from biofuels) and/or by supply from the national grid. Installations can be clustered and managed in local microgrids. Neighbouring microgrids can communicate and compensate local fluctuations and perform peer- to- peer trade of energy (can be done based on blockchain technology).

Energy storage can overcome short fluctuations, but storage cannot solve the expected huge curtailment rate. The answer could be provided by non-regrate energy-consuming solutions (NRES). NRES can be less favorable from economic point of view on the short term, but they can be beneficial on the long run.

[23] Lai, Chun Sing; McCulloch, Malcolm D. (March 2017). "Levelized cost of electricity for solar photovoltaic and electrical energy storage". *Applied Energy*. **190**: 191–203. doi:10.1016/j.apenergy.2016.12.153. S2CID 113623853.

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NRES are essential in areas with an excess of solar energy. An example is waste-water (WW) treatment. Let us say that about 100m^3 /day of WW must be treated. The energy cost is the most crucial expanse in the process. One can build a treatment facility of 400m^3/day that functions only during daytime on cheap PV energy. The installation price is not linearly proportional to the quantity; the increase in population justifies the long-term planning of a larger facility. Another example is the use of water close pond as cooling storage. In Emek Hamaayanot they intend to grow Solomon fish in a cooled-water pond, at a permanently cold temperature. By building an extra pool with water or other high heat capacity material, this extra pool can be over-chilled during daytime using a heat-pump working on cheap PV power and compensating the Solomon pool temperature by the flow between the two pools.

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5. Long term vision

The JV is a unique region. It is the cradle of humanity with a huge historical and cultural value. It holds the world's greatest variety of plant life, due to the sessional migration of 1.5 billion birds over the JV. In addition, the JV is considered a hotspot regarding climate change, and early signs of which can be seen right now. The steep descent from -120 m to more than -400 m below sea level along about 100km manifests the dramatic changes within the JV region itself. The main objective of EcoFuture is to propose a plan for future development that will maximize the socioeconomic status of the JV inhabitants in the three countries. It is not enough to consider only WEFE nexus arguments for each country , so we wish to demonstrate the benefits of regional collaboration between countries. The last scenario is extremely problematic due to the century-old political conflict between the nations. Since we wish to recommend practical solutions, we ought to be sensitive to the political gaps.

In this paper we advocated the shift to renewable energy, relying on local supply of most of the energy demand, in electricity and heat. We advocated for smart microgrids with smart management for the electricity systems, the use of CHP and solar heating to the extent, etc. However, employing interlinks between the different microgrids facilitating local trading in methane, biofuels can significantly improve all partners' energy security and the economics of all the partners. So, if the JV area in the 3 countries acts as a "free trade zone" and allows free trade among the three countries, it can be a major step forward in the relationship between the nations without garnering excessive political attention. Trade in commodities, energy included, between small customers in the region directly, in "Peer to Peer" transactions, can be achieved automatically and securely. This would pave the way to future national network bridges of electricity, water, etc.

This will be one of the scenarios that will be examined in the next phase of the project and it is neccessary to demonstrate its benefit to all partners by performing a SWOT analysis. We will examine the idea of "Infrastructure Rings" around the JV to which the local systems will be connected. We will assess 5 rings: Electricity, Gas (Methane and NG mixture and possibly hydrogen in the future), drinking water, and treated wastewater. The fifth ring is a fiberoptics communication ring that will enable the online, secure, peer-to-peer trade of the commodities (possibly managed by blockchain protocol). This scenarios and others will be examined as part of the devevelopment of the Strategic Plan for the area in the second phase of EcoFuture.

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Abbreviations list

APV	Agri photovoltaic, dual-use of land for agriculture and photo-voltaic panels.
CCNG	Combined cycle NG power plan
CHP	Combine Heat & Power system
DSO	District System Operator
IEC	Israel Electrical Company
JDECO	Jerusalem District Electricity Company
JV	The Jordan Valley
kV, MV	Kilo Volts, Mega Volts, 10^3, 10^6V
kW, MW, GW	Kilo, mega & giga watts, 10^3, 10^6, 10^9W
kWh, MWh, GWh, TWh	Kilo, mega, giga and tera watt-hour, 10^3, 10^6, 10^9, 10^{12}Wh
MCM	Million Cubic Meters, 10^6m^3
NEPCO	National Electric Power Company of Jordan
NG	Natural gas
PA	Palestinian Authority
PCBS	Palestinian Central Bureau of Statistics
PV	Solar Photo Voltaic installation
SAM	System Advisor Model developed by the National Renewable Energy Laboratories.
SS	Sub-Station (transformation station)
TSO	Transmission System Operator
WE	Water & Energy nexus
WEFE	Water, Energy, Food & Ecosystem nexus
WW	Waste-water

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Project Coordinator

Project Partners

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