PRELIMINARY FEASIBILITY STUDY OF SOLAR FARMING IN EASTERN JORDAN

Water/Wastewater Infrastructure Project

Prepared by CDM International for
United States Agency for International Development under
Global Architecture and Engineering IQC
USAID Contract No. EDH-I-00-08-00023-00
Task Order 02

The Hashemite Kingdom of Jordan
Ministry of Water and Irrigation
Water Authority of Jordan (WAJ)

January 2012

This Publication was produced for review by the United States Agency for International Development. It was prepared by CDM International Inc.

Preliminary Feasibility Study of Solar Farming in Eastern Jordan

Prepared by:	Stephen Blair, Luba Hamdi, Dr. Ahmed Abu Awaad, Barry Squibb	Date:	January 23, 2012
Reviewed by:	Sebouh Lebejian	Date:	January 27, 2012
Approved by:	Richard Minkwitz	Date:	January 30, 2012

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

AAD	*Al-Azraq Agricultural Directorate*
AC	*alternate current*
ACC	*Agricultural Credit Corporation*
BoS	*balance of system components*
CDM	*Camp Dresser and Mckee Inc*
C_{System}	*the sum of the cost of the system.*
C_{sub}=	*possible financial subsidy on the initial cost.*
CSP	*concentrated solar power*
DC	*direct current*
DoS	*Department of Statistics*
ECe	*Saturated past extract electrical conductivity*
ECd	*drainage water salinity*
ECw	*irrigation water salinity*
ERC	*Electricity Regulatory Commission*
E_t	*electricity generation in the year*
ET_0	*evapotranspiration*
FAO	*Food and Agriculture Organization*
GCR	*system ground coverage ratio*
GTZ	*German Technical Corporation*
I_t	*investment expenditures in the year t*
JD	*Jordanian Dinar*
Kc	*mean monthly crop coefficient*
LEC	*levelized electricity cost*
LF	*leaching factor*
MOA	*Ministry of Agriculture*
M_t	*operations and maintenance expenditures in the year t*
MWI	*Ministry of Water and Irrigation*
n	*life of the system in an economical analysis.*
NASA	*National Aeronautics and Space Administration*
NEC	*National Electric Code*
O&M	*Operation & Maintenance*
PV	*Photovoltaic*
r	*Discount rate*
TDS	*total dissolved solids*
USAID	*The United States Agency for International Development*
WAJ	*Water Authority of Jordan*
WIP	*Water/Wastewater Infrastructure Project*
W_P	*system peak rated power in Watt*

LIST OF UNITS

^oC	*degrees Celsius*
d, D	*day*
dS/m	*deciSiemens per meter*
du	*dunum (1,000 square meters)*
ha	*hectare (10,000 square meters)*
h, hr	*hour*
gWh	*gigawatt hour*
kg	*kilogram*
km	*kilometer*
kV	*kilovolt*
kVA	*kilovolt ampere*
KW	*Kilowatt*
KWh	*Kilowatt hour*
L, l	*liter*
lpcd	*liters per capita per day*
L/s, l/s	*liters per second*
m	*meter*
m^2	*square meter*
m^3	*cubic meter*
m/s	*meters per second*
MCM	*million cubic meters*
MCM/yr	*million cubic meters per year*
mg	*milligram*
mm	*millimeter*
mW	*megawatt*
mWh	*megawatt hour*
ppm	*parts per million*
W	*Watt*
Y, yr	*year*

EXECUTIVE SUMMARY

Ever-increasing demands for water in the Jordan, has resulted in large-scale pumping from groundwater reserves in eastern Jordan. The level of exploitation significantly exceeds the annual natural recharge, and the impacts of this over exploitation are becoming increasingly evident in declining groundwater levels and deterioration of water quality. Much of the Al-Azraq Oasis, once a rich habitat with its permanent fresh waters and springs has dried out, and its soil quality has drastically deteriorated as a result of over abstraction of groundwater for irrigation.

In response, as Task 6.1 of the Water/Wastewater Infrastructure Project (WIP) project, funded by the US Agency for International Development (USAID), CDM is assessing the feasibility of an alternative to the rapidly growing agriculture in the area to enhance the livelihood of local residence, reduce water consumption and at the same time begin to address the country's need for a cheap, sustainable and clean source of energy. The concept involves replacing traditional water intensive agriculture with solar energy harvesting. In particular, this preliminary assessment examined the feasibility of local farmers harvesting energy through photovoltaic (PV) arrays in place of their crop fields, thereby reducing the rate of groundwater abstraction. This analysis should not be viewed as an assessment of solar power in general as part of a national strategy toward cleaner and more sustainable energy sources. Rather, this assessment focuses on solar power for the specific purpose of reducing water consumption in the eastern highlands.

A review of Ministry of Agriculture data suggests that the dominant crops in the Al-Azraq area are: olive, grape, fruit trees, alfalfa, tomato, and barley, representing 96.3 percent of the total irrigated, cultivated area in Al-Azraq. The total irrigated, cultivated area is 114,995 du, of which 71.3 percent contain olive, 9.9 percent grape, 6.3 percent fruit trees, 4.3 percent alfalfa, 3.1 percent tomato, and 1.4 percent barley. The data suggest that the agricultural area has seen a dramatic increase in recent years with the irrigated, cultivated area increasing by 3 times for alfalfa, 2.3 times for tomato, 1.9 times for olive, 1.7 times for grape, and 1.5 for fruit trees. Irrigated barley cultivated area decreased by 10 percent. Current annual agriculture water demands are estimated to be more than 7 times the sustainable yield of the aquifer and the agricultural area continues to grow at an alarming rate.

Farmer profits are found to be highly dependent on the cost of irrigation. Based on the information obtained from the Agricultural Credit Corporation, the cost in 2005 was estimated to range between 0.08 JD/m^3 for irrigation of olive trees to 0.4 JD/m^3 for irrigation of fruit trees. Based on these irrigation costs, estimated profits range from up to about 150 JD/du for field crops to in excess of 1,600 JD/du for fruit trees (pomegranates). Olive farming was calculated to actually lose money despite accounting for more than 70 percent of the total agricultural area (and a similar percentage of the total agricultural water demand). It is suspected that farmers practice deficit farming, providing less water than is optimal to return a marginal profit despite reduced yields.

Discussions with local farmers suggest the reason for the recent increase in agriculture in the area, is in part due to the extension of the electrical grid to agricultural areas. Farmers previously struggling to turn a profit using diesel powered pumps to irrigate their crops are now able to irrigate at a much lower cost due to more efficient and cost effective electric pumps. This not only has encouraged local farmers to expand their fields but combined with cheap land has brought investors from outside the area. Ironically, solar powered irrigation systems may offer an even more cost effective means of irrigation, thus further exacerbating the problem.

Modeling of solar power generation from 3 conceptual systems of capacity 500-kW, 1,000-kW and 1,500-kW was performed using two estimates of incident energy (NASA and Solar Pathfinder) and the results were in good agreement. Rated power densities of the conceptual layout developed were on the order of 50 W/m^2. The levelized electricity cost (LEC) reflecting costs over a 25 year system life on a per mWh basis was calculated for each of the three conceptual systems. This is considered the price at which the produced electricity needs to be sold to breakeven on the investment. **Table ES-1** summarizes the results.

Table ES-1 Summary of Solar Energy Production and LEC for Conceptual Systems

System Capacity (KW)	System Area (du)	Energy Production (mWh/yr)	Levelized Electricity Cost (JD/mWh)
500	12	790	222.99
1,000	20	1,573	221.50
1,500	30	2,363	220.51

Based on per capita power consumption for Jordan and daily variations in demand presented in the 2008 Electricity Regulator Commission Annual Report, a local system would be limited to a capacity of about 2.5 mW to service a community the size of Al-Azraq with a population of about 10,000 people. For larger systems, electricity in excess of local demand would have to be transmitted to other locations for use, resulting in high costs and transmission losses. A 2.5-mW system would occupy about 50 du.

Comparison of the above LEC with electricity production, transmission and distribution costs as reported in the 2010 Electricity Regulator Commission Annual Report suggests the PV electricity would be, almost 3.8 times the conventional system generation cost under the normal conditions and 2.2 times the average domestic tarrif. Even if the low end of the range of implementation costs found in the literature were used, PV electricity is about 2.7 times as costly. Inclusion within the calculation of farmer profits, similar to what is being gained from agricultural production, has little effect on the calculation, with increases of the LEC up to about 12 percent, depending on the crop.

In 2011 the civil unrest in Egypt has resulted in disruptions to the Egyptian gas pipeline which has caused disruption of the gas supply to Jordan. As a result Jordan has relied on costlier heavy fuel oil for most of 2011 to produce electricity. This has pushed the electricity production cost to 156 JD/mWh, and has raised questions regarding the reliability of this supply. Moreover there has been a dramatic rise in the need to develop and consider alternate energy resources such as PV solar energy and its sister technology, CSP. If this geopolitical situation persists then installing PV systems to supplement the current system might become marginally economically viable. Under these conditions the estimated LEC of power generation is 137.2 JD/mWh, which is closer to the LEC values for PV as presented above.

Investment in PV is capital intensive. For purposes of this assessment an average unit capital cost of 4 JD/Wp was assumed based on a review of literature and interviews with local vendors. Calculations suggest that under 2010 conditions, the unit capital cost would need to be about 0.8 JD/Wp in order for a system to be economically viable. Under 2011 conditions with higher generation costs associated with the disruption of Egyptian gas, the unit capital cost would need to be about 2.34 JD/Wp, much closer to current market prices.

The use of subsidies may reduce the capital costs. This assessment examined the subsidies in an amount of the value of water saved over a period. The subsidized LECs vary by the type of crop replaced, however, even under the most favorable conditions, the PV LEC is still above the 2011, inflated LEC of conventional production.

Considering the solar energy as part of national strategy to meet future energy needs is beyond the scope of this study. If Al-Azraq is to play a significant role as a central PV plant to supply Jordan, then converting only the olive farms to solar farms will be more than sufficient to satisfy the current required system capacity of 3,069 mW. It should be noted that the electrical demand will double in 2030 due to the population growth, the industrial development and the need to support the major water projects such as Disi and the Red Dead connector. Further analysis would need to consider costs of expansion of the conventional electricity generation system to determine whether expansion with solar energy is viable

In summary, investment in PV with an objective of reducing water abstraction in the Eastern Highlands is not currently economically viable. If the current geopolitical conditions persist and the associated disruption of gas from Egypt, such an investment may be marginally viable in the near future with the expected continued reduction in PV panel costs. Furthermore, the area of crop cultivation to accommodate solar farms to meet local demands, and thus the amount of water saved, is minimal. To make a significant difference in the amount of water abstracted in achieving the safe yield of the basin, a system on the scale of the current production capacity of Jordan would be needed.

SECTION 1 - INTRODUCTION

Ever-increasing demands for water in Jordan, has resulted in large-scale pumping from groundwater reserves in eastern Jordan. The level of exploitation significantly exceeds the annual natural recharge, and the impacts of this overexploitation are becoming increasingly evident in declining groundwater levels and deterioration of water quality. Much of the Al-Azraq Oasis, once a rich habitat with its permanent fresh waters and springs has dried out and its soil quality has drastically deteriorated as a result of over abstraction of groundwater for irrigation.

In response, as Task 6.1 of the Water/Wastewater Infrastructure Project (WIP) project, funded by the US Agency for International Development (USAID), CDM is assessing the feasibility of an alternative to the rapidly growing agriculture in the area to enhance the livelihood of local residence, reduce water consumption and at the same time begin to address the country's need for a cheap sustainable and clean source of energy. The concept involves replacing traditional water intensive agriculture with solar energy harvesting. In particular, this preliminary assessment examines the feasibility of local farmers harvesting energy through photovoltaic (PV) arrays in place of their crop fields. This analysis should be considered a preliminary assessment of the general viability of the approach with a basic assessment of the water that could be preserved and the economic return that could be realized by local farmers. If considered viable, significant additional work will be required to examine the practical logistics of the approach as well as the farmer overall willingness to try a new technology in place of their traditional farming techniques. Furthermore, this analysis should not be viewed as an assessment of solar power in general as part of a national strategy toward cleaner and more sustainable energy sources. Rather, this assessment focuses on solar power for the specific purpose of reducing water consumption in the eastern highlands.

This analysis focused on conditions in the Al-Azraq oasis area where rapidly growing agriculture has significantly depleted groundwater. The Al-Azraq Oasis is a rich habitat with its permanent fresh waters and springs. In addition to providing the natural habitat for numerous unique indigenous aquatic and terrestrial species, the oasis is nationally and internationally acclaimed as a major station for migratory birds. Despite its significance, the area was almost destroyed by environmentally damaging activities. Most of Al-Azraq Oasis had dried out, and its soil quality had drastically deteriorated as a result of over abstraction of groundwater for irrigation. Despite the very obvious impacts of over abstraction, within the past few years, agricultural irrigation appears to be growing at an alarming rate. Furthermore, the approximate 10,000 inhabitants of the area require energy. Currently, this energy is transmitted long distances resulting in significant losses. These two factors, rapidly growing agriculture resulting in significant impacts to the environment combined with a significant demand for electric energy made Al-Azraq an ideal candidate for analysis. It is expected however that if proved viable for Al-Azraq, the approach could be considered throughout much of east Jordan including large portions of Al-Azraq and Mafraq municipalities as shown on **Figure 1-1**.

Section 2 of this report provides background information, starting with a brief overview of water resources of Jordan and the Al-Azraq area, followed by relevant information concerning climate and crop patterns as well as information concerning power generation and consumption in Jordan. Section 3 develops estimates of water irrigation consumption based on the crop patterns observed in Al-Azraq and develops estimates of crop production, value and profitability. Section 4 presents an analysis of energy production using solar PV in the Al-Azraq area, developing estimates of power of generation of a 500 kW, 1000 kW and 1,500 kW solar arrays. Section 5 presents an economic analysis of the approach. Section 6 provides a brief conclusion.

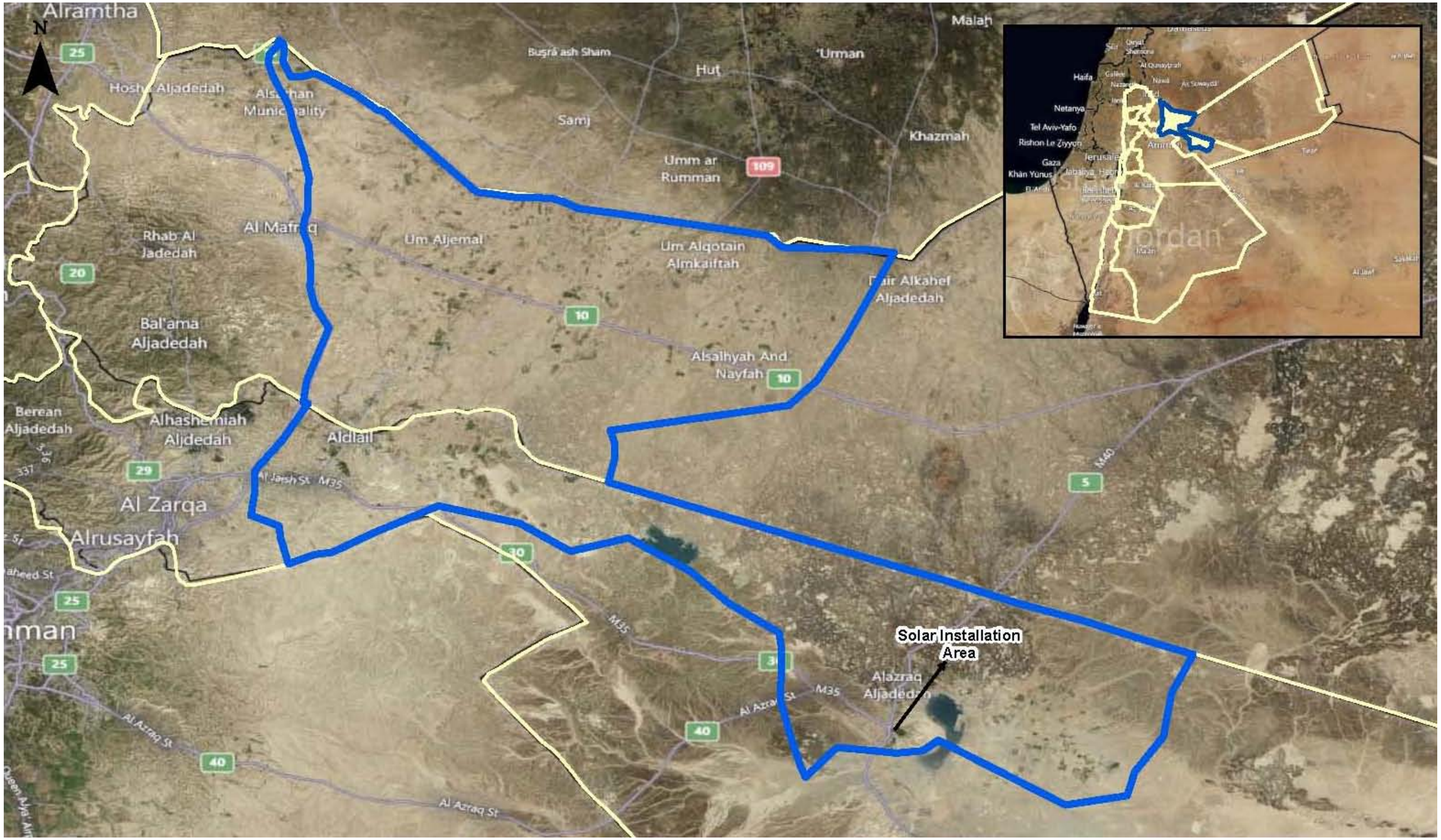


Figure 1-1 **Study Area Location**

2.1 OVERVIEW OF WATER RESOURCES

The water resources in Jordan are comprised of both surface water and groundwater. Groundwater is the main source of drinking water in Jordan and is also the main source of water for irrigation in the highlands as well as for industry throughout Jordan. Surface water is the main source of water for irrigation in the Jordan Valley.

Both surface water and groundwater resources mainly depend on the amount of annual rainfall. The average annual precipitation ranges between 25 mm in most areas of the south and southeast to over 600 mm in areas of the northern highlands and the northwestern portion of the Kingdom. More than 90 percent of Jordan receives less than 200 mm of rainfall annually. Therefore, most areas of Jordan, in terms of climatic zones, can be classified as semi-arid to arid regions. According to the Ministry of Water and Irrigation (MWI), Annual Water Budget Report, 2009, high evapotranspiration rates deplete up to 92.5 percent of the annual volume of the rain that falls in most areas, leaving scarce water for beneficial use.

The Al-Azraq Oasis, once the most significant surface water feature in Jordan, has been reduced to about 10 percent of its original size. The natural springs feeding the oasis dried up in 1992 and most migratory birds subsequently moved away from the area. Al-Azraq wetland reserve was established in 1978 and covers 12 km^2. The 10 MCM/yr provided by MWI to maintain the oasis is only sufficient to maintain about 10 percent of its original size. In just 37 years the numbers of migrant birds have reduced from 347,000 in 1967 to 1,200 birds in 2000. Al-Azraq groundwater basin is one of the most water abundant, but ecologically sensitive and heavily used, providing a major share of Amman's municipal water supply.

This section provides review of water resources in Jordan with a focus on the Al-Azraq area to provide context for this assessment.

2.1.1 Surface Water Resources

Surface water in Jordan includes the water of the base flow in the valleys, spring discharge, and flood flow. In terms of surface water, Jordan is divided into 15 catchment areas based on the characteristics of the topography and hydrology as depicted in **Figure 2-1**.

The average annual rainfall volume over the entire country from 1937 through 2009 was about 8,240 MCM as shown in **Table 2–1**. The average annual base flow was approximately 370 MCM and the annual flood flow was about 476 MCM giving a total average surface flow of approximately 846 MCM per year. Of these renewable surface water resources, an estimated 560 MCM are usable or can be economically developed. In order to make maximum use of water from rainfall, the MWI built a number of dams in suitable locations throughout Jordan to increase the surface water storage capacity to approximately 330 MCM. Work is underway to build a number of small earth dams and water harvesting projects. However, the overdrawing of groundwater aquifers has been the main factor in lowering the discharge of springs from an average total of 317 MCM prior to 1985 to less than 130 MCM after 2000 (MWI annual report, 2003).

The Al-Azraq basin has an area of 12,200 km^2 and is located in the heart of the Jordanian Badia (**Figure 2-1**). It is located in the northeastern part of the country, extending northwards into Syria and southwards into Saudi Arabia. Over 94 percent of the basin's area is located within Jordan, less than 5 percent in Syria, and about 1 percent in Saudi Arabia. Qa' Al-Azraq is the lowest point of the basin with an altitude of 500 m above sea level.

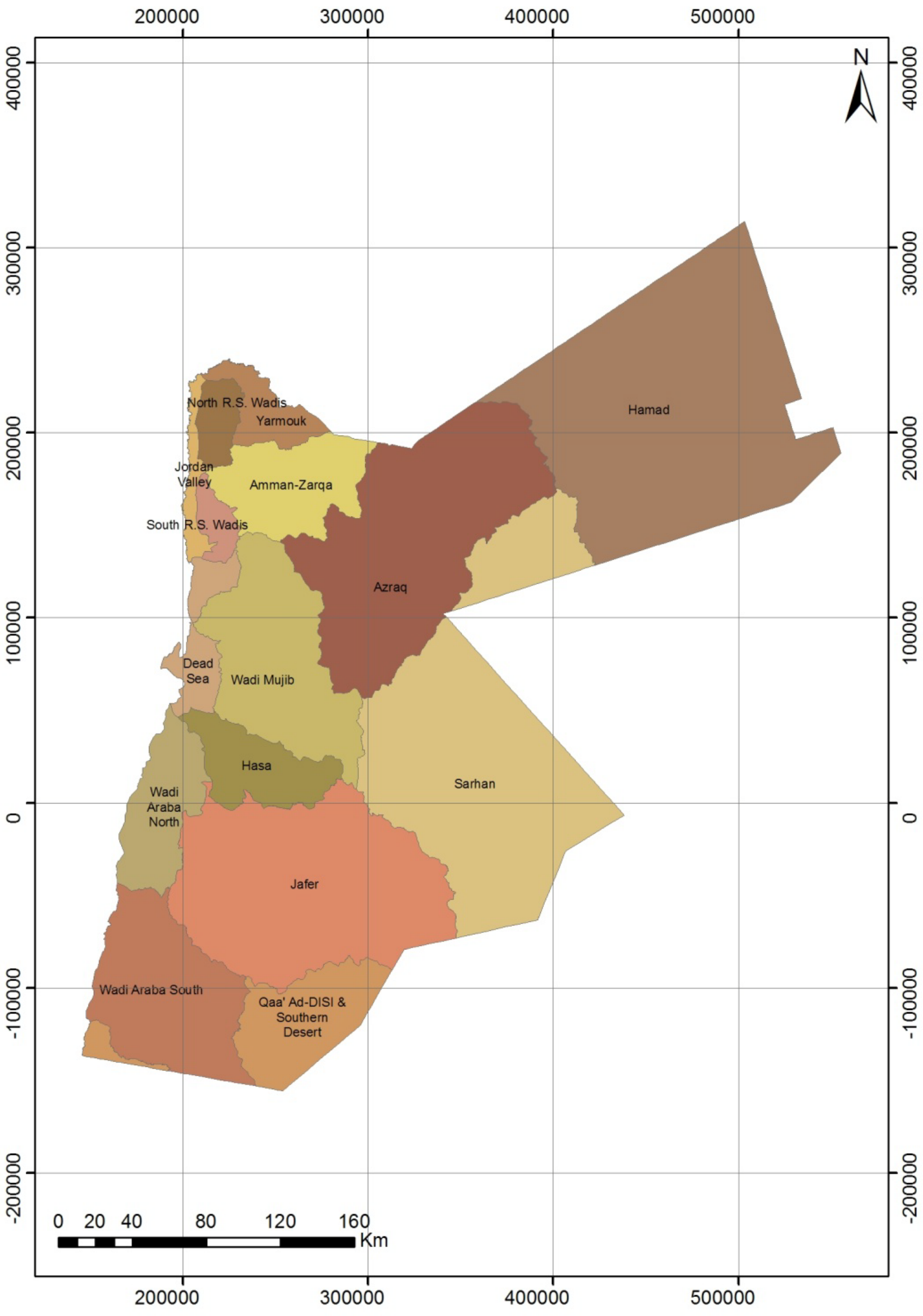


Figure 2-1 Surface Water Basins of Jordan

Table 2–1 Flow Volumes for Drainage Areas within Jordan

Basin name	Area (Km^2)	Average annual rainfall (1937 - 2009) (MCM/yr)	Flood flow (MCM/yr)	Base flow (MCM/yr)	Total flow (MCM/yr)
Yarmouk	1,500	427	133	167	300
Jordan Valley	775	226	8.3	-	8.3
North R. S. Wadis (NRSW)	975	560	18	39.5	57.5
South R. S. Wadis (SRSW)	725	281	25.1	32.9	58
Amman-Zarqa	3,725	892	47.5	36.5	84
Dead Sea	1,525	284	21.7	21.4	43.1
Wadi Mujib	6,675	875	70.9	31	101.9
Hasa	2,600	332	13.1	29.4	42.5
Wadi Araba North	2,975	384	34.2	11.6	45.8
Wadi Araba South	3,725	139	7.8	0.1	7.9
Qa' Disi & Southern Desert	6,300	101	1.0	-	1
Azraq	12,200	836	40.9	-	40.9
Sarhan	15,700	434	17.5	-	17.5
Hamad	18,150	1950	24.3	-	24.3
Jafer	12,450	519	12.5	0.6	13.1
Total	90,000	8,240	475.8	370	845.8

2.1.2 Groundwater Resources

The most important water resource in northeastern Jordan is groundwater. In general groundwater in Jordan is classified in three categories or systems whose composition can be summarized as follows:

Upper Basalt and Limestone Aquifers: This system includes the basalt aquifers located in the northeastern portion of Jordan as well as the shallow limestone aquifers. Basaltic rocks cover an area of 11,000 km² of the northeastern part of Jordan. This aquifer formation comprises the upper layer of water bearing strata, especially in the Al-Azraq Basin, where groundwater is found at shallow depths. This aquifer currently provides significant quantities of good quality water that is used for drinking and irrigation in the northeastern region of Jordan. Underlying the basalts in the northeast and outcropping in the west along the Jordan Valley escarpment is the A7/B2 aquifer, perhaps the most important aquifer in Jordan, where the majority of abstraction is taken. The outcropping of the aquifer corresponds with the areas of highest precipitation thus this aquifer receives the majority of natural recharge. In the northern and central parts of Jordan, this water bearing zone contains good quality water, however, salinity levels tend to increase to the east.

Lower Limestone Aquifers: Separated from the upper A7/ B2 aquifer by the A5/6 aquiclude are two limestone aquifers, the Hummar and the Naur. These aquifers are of local importance only and receive limited recharge but some abstraction wells are located in these aquifers.

Deep Sandstone Aquifers: The deep sandstone aquifers including the Kurnub and Disi extend over a large area. The aquifers are made up of bedded sandstone formations of varying thickness and water bearing capacity. These sandstone aquifers have stored water for many thousands of years and receive little recharge. In the east, the deep sandstone aquifer, may be found at depths of 1300–3400 m, but have not been explored in detail. In southern and western Jordan, where they are shallower, both the middle and lower aquifers form extensive aquifers of national importance, supplying large quantities of good quality water.

The general hydrogeology of Jordan is best conceptualized with the aid of **Figure 2-2** depicting a stratigraphic cross section from west to east through central Jordan.

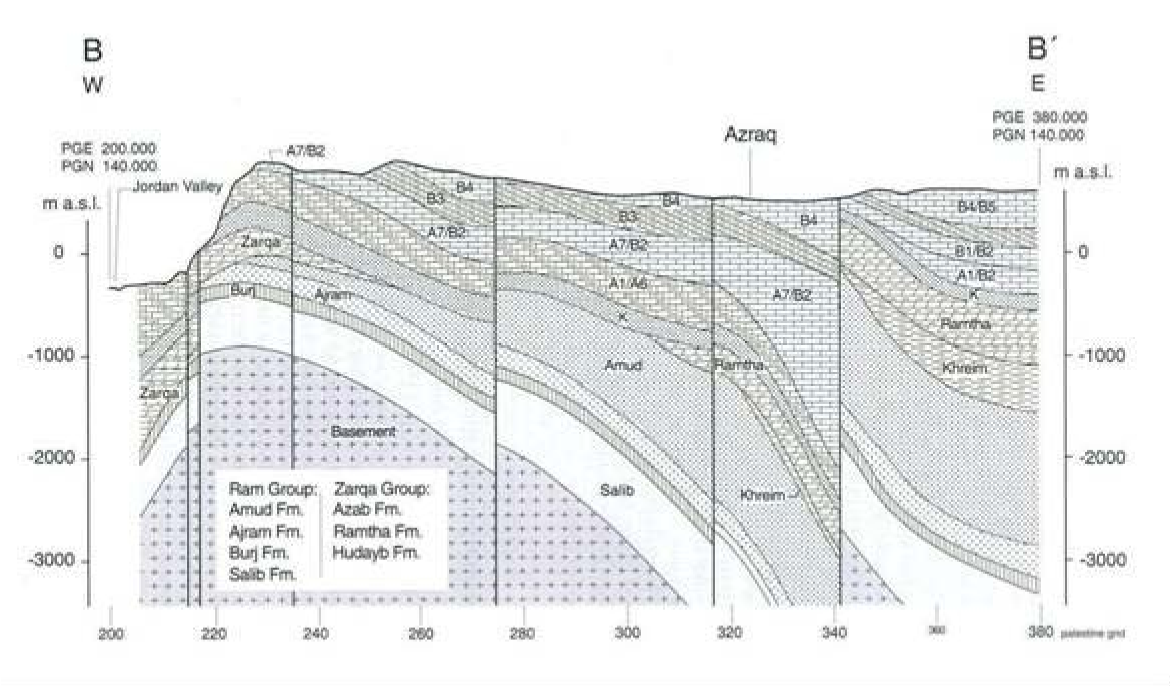


Figure 2-2 Stratigraphic Cross Section from West to East through Central Jordan

2.1.3 Groundwater Basins

Groundwater resources in Jordan are distributed among 12 distinct groundwater basins as shown in **Figure 2-3**. Each basin has a number of surface and confined aquifers. The sustainable yield of each groundwater system varies from one aquifer to another. There are eleven renewable groundwater basins in Jordan which receive significant natural recharge. The yearly amount of recharge depends mainly on the annual rainfall, surface conditions and the characteristics of the subsurface strata. The sustainable yield and 2009 abstraction for each basin are shown on **Table 2-2**; it should be noted that sustainable yield is not equivalent to recharge. Recharge needs to balance both sustainable abstractions from wells as well as acceptable flow from spring surface discharges in consideration of groundwater base flow. The details of the development of the sustainable yields have not been reviewed as part of this assessment. The actual abstraction was about 430 MCM in year 2009. This amounts to an overdraft of about 166 MCM for renewable groundwater aquifers. As of 2009 the reported annual abstraction from the Al-Azraq basin was on the order of 51.5 MCM, more than double the safe yield estimated at 24 MCM.

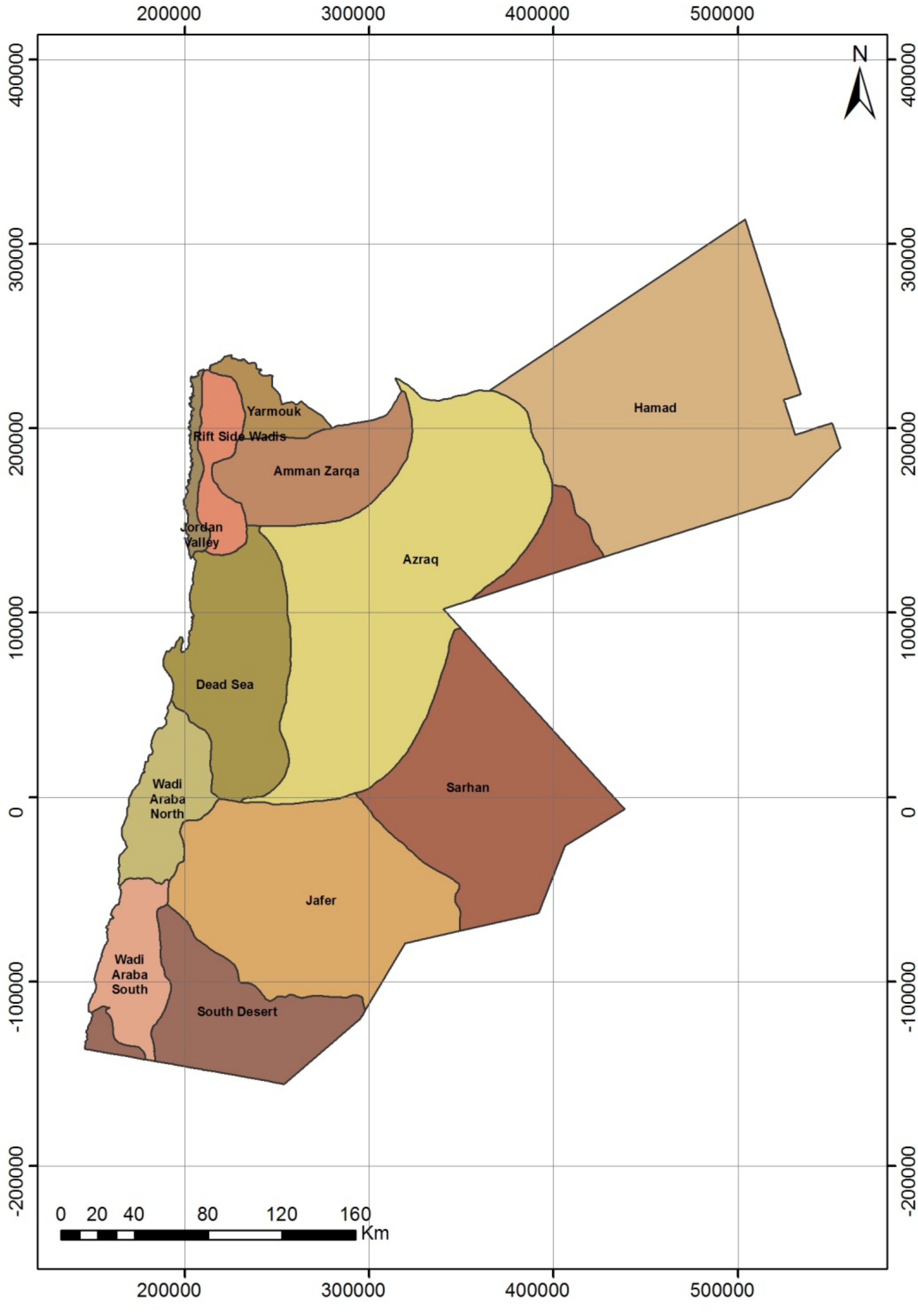


Figure 2-3 Groundwater Basins in Jordan

Table 2–2 Quantities of Abstraction and Safe Yield of Groundwater Systems for Year 2009

Basin Name	Safe Yield (MCM/yr)	Yearly Abstraction (MCM)	Yearly Budget (MCM)
Yarmouk	40	50.16	-10.16
Rift Side Wadis	15	22.7	-7.7
Jordan Valley	21	25.39	-4.39
Amman-Zarqa	87.5	154.2	-67.2
Dead Sea	57	80.74	-23.74
Wadi Araba North	3.5	5.5	-2.0
Wadi Araba South	5.5	7.34	-1.84
Jafer	9	30.6	-21.6
Azraq	24	51.5	-27.5
Sarhan	5	1.32	+3.68
Hamad	8	0.8	+7.2
Total	275.5	430.25	-166.13

Source: Annual report, Ministry of Water and Irrigation, Year 2009.

Note: Jafer Groundwater Basin has a component of renewable water in the amount of 9 MCM/yr in the upper portion which has surface communication that allows recharge. The other 18 MCM/yr is below the aquiclude and is non-renewable fossil water.

In addition to the above renewable resources, Jordan utilizes some of its non renewable resources. Studies have suggested that the Disi Aquifer located in southern Jordan has sufficient capacity to yield additional 100 MCM/yr for a period of 50 years to supply Jordan. In general the Disi Aquifer water is of good quality, with low total dissolved solids ranging between 300 mg/L and 400 mg/L. However, it is reported that elevated levels of radionuclides will require blending of the water at two parts Disi water with one part water from other sources. It is understood that through the blending as described above the water will be rendered safe for human consumption.

Other non renewable groundwater resources include water from the Jafer Basin which is expected to supply Jordan with 18 MCM/yr over the next 50 years as well as other brackish groundwater reserves which require desalination. Significant brackish groundwater reserves are found within the Zarqa and Ram formations. Estimates provided by JICA in 2001 suggest as much as 75 MCM/yr in the Southern Jordan Valley escarpment and as much as 230 MCM/yr in the Dead Sea escarpment.

2.1.4 Water Demand in Jordan

Population growth, in addition to the economic and agricultural development, has led to an increased demand for water. The water supply to meet the increased demand has risen from 817 MCM for all water use within Jordan in 2000 to 938 MCM in 2009 as presented in **Table 2–3** and **Table 2-4,** respectively. This represents an increase of about 15 percent.

The demand on Jordan's resources differs depending on the type of resource. The data indicate that overexploitation of groundwater is high because of the relative ease of access to this resource, especially in the Al-Azraq, where good quality groundwater is found at shallow depths. Demand for groundwater usually diminishes during the rainy seasons when the availability of surface water increases, particularly for agricultural purposes in the Jordan Valley. For this reason the government of Jordan constructed a series of dams such as Wala, Mujib, Tannour, Wehda dams and others to assist in alleviating the water shortage in the country. **Table 2–3** shows that in 2000 the water use within Jordan for domestic purposes was about 239 MCM, representing 29 percent of the total water use in the country. Water use for domestic purposes increased to approximately 309 MCM in 2009 as can be seen in **Table 2-4** representing 33 percent of the total water use in the country. The increased demand for water is attributed to the increase in population. In contrast, the water supply to the industrial sector has risen from 36.69 MCM in 2000 to 37.52 MCM in 2009, or an increase of about 1.5 percent, a slight increase when compared to the percentage increase for the domestic sector. The table also reveals that there was an increase in the amount of water supply to the agricultural sector, however, the increase was 9.4 percent, 534 MCM in 2000 to 584 MCM in 2009, a moderate increase when compared with the increased supply for domestic purposes. The increase in agriculture supply was mainly from treated wastewater. Overall, the data suggest a general shift in the proportionate amounts of water use from agriculture and industry to domestic use requiring a higher quality, more reliable source.

Table 2–3 Sources and Water Use for Different Sectors in Jordan during 2000

Water resources	Water use (MCM)				
	Domestic	Irrigation	Industrial	Rural areas	Total
1. Surface Water	53.3	209.67	2.54	6.0	271.51
renewable water	38.46	121.18	2.53	0.0	162.18
springs	14.84	38.0	0.0	0.0	52.84
base flow and floods	0.0	50.49	0.0	6.0	56.49
2. Groundwater	185.73	252.3	34.16	1.41	473.6
renewable water	176.36	204.64	29.59	1.41	412.0
non-renewable water	9.37	47.65	4.57	0.004	61.6
desalination(Abu Az-Zaighan)	0.0	0.0	0.0	0.0	0.0
3. Treated Water	0.0	72.03	0.0	0.0	72.03
Total	239.04	534.0	36.69	7.41	817.15
Percentage	29 %	65%	5%	1%	

Table 2–4 Sources and Water Use for Different Sectors in Jordan during 2009

Water resources	Water Use (MCM)				
	Domestic	Irrigation	Industrial	Rural areas	Total
1. Surface Water	93.9	237.39	3.06	7.0	341.35
renewable water	49.65	159.88	2.09	0.0	211.6
springs	44.25	39.16	0.97	0.0	84.38
base flow and floods	0.0	38.34	0.0	7.0	38.34
2. Groundwater	214.67	245.75	32.98	0.88	494.29
renewable water	157.311	203.47	18.52	0.82	380.10
non-renewable water	14.44	51.69	18.36	0.05	84.54
desalination(Abu Az-Zaighan)	10.172	0.0	0.0	0.0	10.17
3. Treated Water	0.0	101.16	1.2	0.0	102.36
Total	308.57	584.31	37.25	7.88	938.0
Percentage	33%	62%	4%	1%	

Agricultural irrigation is one of the major consumers of water in Al-Azraq Basin, reportedly demanding over 20 MCM/yr (in 1996), nearly equivalent to the entire safe yield of the basin, which is 25 MCM/yr. Agricultural activities are a major threat to water sources in the area and require constant monitoring and enforcement, as the water balance of the oasis wetlands is very sensitive to any change in the hydrological system within the basin. Studies reviewed as part of this assessment indicate that the area of irrigated farms has increased a thousand fold since the early 1970s.

2.1.5 Impacts of Over Abstraction

The impacts of over abstraction of groundwater are obvious in groundwater level data from observation wells maintained by WAJ. Groundwater levels at observation well F1022 (**Figure 2-4**) have been dropping at a rate of about one meter per year since 1997.

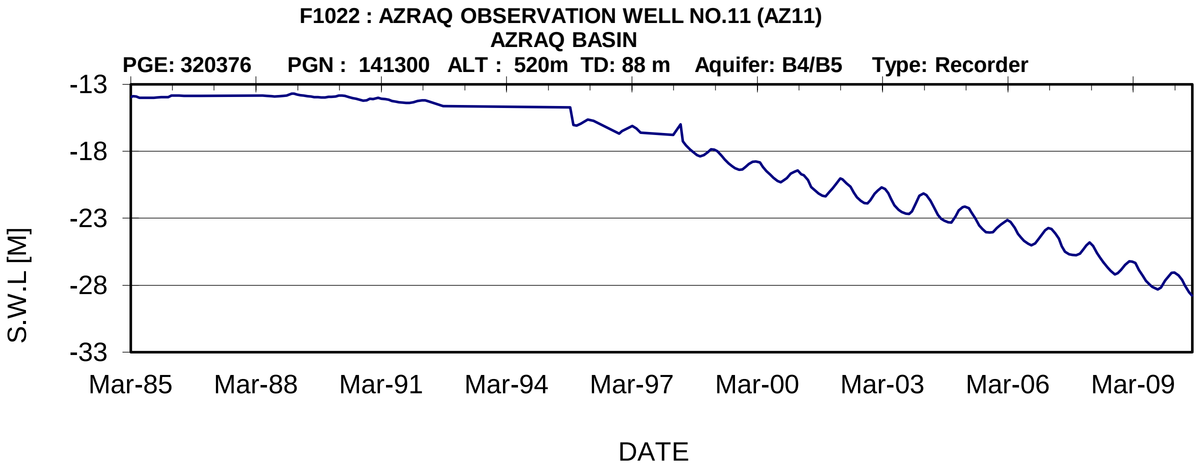


Figure 2-4 Decline in Groundwater Levels in Al-Azraq Basin

2.1.6 Irrigation Water Tariff Structure

Irrigation water tariff in the highlands of Jordan is complicated, depending both on when a license for abstraction was obtained and how much water is withdrawn. Complicating the matter further a 2010 amendment is pending approval by the Prime Minister's Cabinet which includes a special case for the Al-Azraq basin. Based on information contained with the 2010 report "Farming in the Desert, Analysis of the Agricultural Situation in Azraq Basin" (GIZ, 2010) the relevant tariff structure for private agricultural wells is summarized in **Table 2-5**.

Table 2–5 Water Tariff Structure

Quantity of Water Pumped (m^3)	2002 Bylaw w/ 2004 Amendment (JD/m^3)	2010 Draft Amendment (JD/m^3)
Wells with no abstraction license or permit		
0 - 100,000	0.025	0.05
100,000 - 150,000	0.03	0.07
150,000 - 200,000	0.035	0.1
Greater than 200,000	0.07	0.1
Wells with abstraction license or permit (special case for Al-Azraq Basin)		
0- Permitted Quantity	Free	
0 - 50,000		Free
Permitted Quantity - 100,000	0.02	
50,000 - 100,000		0.02
Greater than 100,000	0.06	0.1

2.2 CLIMATE

In general, Jordan experiences moderately cold winters and dry hot summers. Hot, dry summer from mid-May to mid-September and rainy, rather changeable winters from November to mid-March are separated by short autumn and spring seasons. The climate is characterized as arid to semi-arid climate (Mediterranean) and the potential evaporation is very high.

Al-Azraq area is characterized by desert conditions, low rainfall, and a high evaporation rate (around 3,000 mm annually). Seasonal Khamasine winds blow into the area. The highest recorded temperature is 47°C; the lowest is -5.7°C.

Average monthly climatic data were collected from South Al-Azraq weather station, from the Metrological Department. Data are summarized in **Table 2-6**, which illustrates mean, minimum and maximum temperatures, rainfall, relative humidity, wind speed, actual sunshine hours, and Class A pan evaporation for South Al-Azraq weather station (1981 - 2010).

The average daily mean temperatures measured at South Al-Azraq range from 8.9°C in the month of January to 28.7°C in the month of August, the average daily maximum temperatures range from 15°C in January to 37.2°C in August, and minimum temperatures range from 2.8°C in January to 20.3°C in August. The mean annual maximum rainfall is 12.7 mm/month falls during the month of January with a total rainfall of about 57.5 mm/year. The maximum evaporation at Al-Azraq region is about 15.3 mm/day in the month of August and the minimum of 2.9 mm/day in the month of January.

Table 2-6 Climatic Data for South Al-Azraq (1981-2010)

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Days	31	28	31	30	31	30	31	31	30	31	30	31
Mean daily, Tmean (°C)	8.9	10.6	14.3	19.3	23.8	26.9	28.6	28.7	26.7	22.3	15.2	10.4
Mean daily, Tmax (°C)	15.0	16.9	21.2	27.1	31.9	35.4	37.0	37.2	34.8	29.8	22.3	16.7
Mean daily, Tmin (°C)	2.8	4.2	7.3	11.5	15.6	18.3	20.1	20.3	18.6	14.7	8.2	4.0
Mean daily, RH (%)	70.2	63.9	56.5	48.1	43.7	44.9	48.2	51.3	52.5	54.1	60.9	68.9
Mean daily, Wind speed (m/s)	2.34	3.30	4.16	4.52	5.04	5.92	6.06	5.52	4.85	2.92	2.07	1.78
Sun shine hours, n (hr)	6.1	6.7	7.8	8.6	9.6	11.2	11.1	10.9	9.9	8.3	7.3	6.1
Class A pan Evaporation (mm)	89.8	111.3	195.3	282.6	381.0	451.4	475.4	457.8	362.2	243.5	132.9	94.9
Rainfall (mm)	12.7	9.3	9.6	4.3	1.4	0	0	0	0.3	3.0	6.5	10.4

Latitude: 31°50"16' (0.556 radians)
Longitude: 36°47"54'
Elevation: 521 m

Figure 2-5 shows the monthly average rainfall at South Al-Azraq area. The main rainfall season in the South Al-Azraq is from October to April. The average rainfall ranges from 0 mm in summer months to its maximum (12.7 mm) in January, with an annual average of 57.5 mm/yr. Winter precipitation tends to fall in short, intense events.

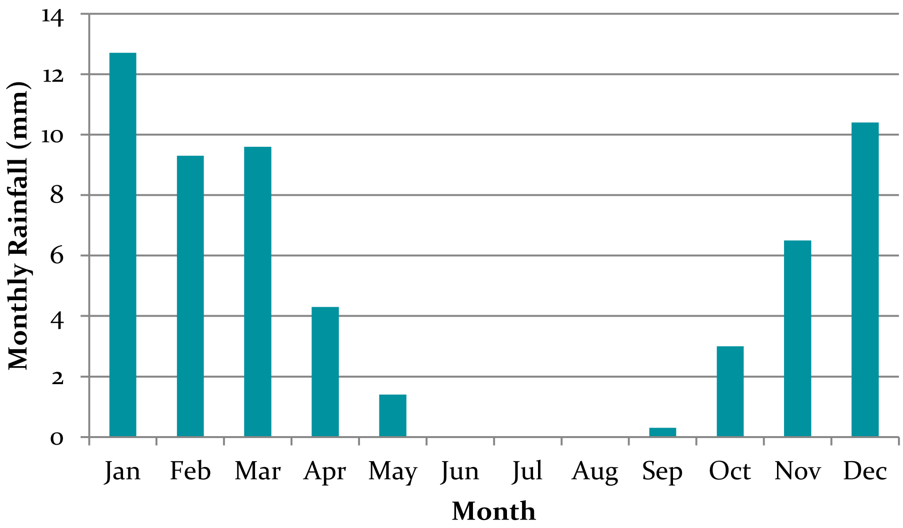


Figure 2-5 Monthly Average Rainfall in South Al-Azraq Area

2.3 AGRICULTURE

The surface area of Jordan is 88,780 km² in 2008, according to the World Bank, of this amount, 10.9 percent is agriculture land. According to the Department of Statistics (DOS), 2010, the cultivated land in Jordan in 2010 is 2,593,501 du (26.8 percent of the agriculture land), of this amount 39.5 percent is irrigated and 60.5 percent is rain-fed (**Table 2-7**).

Table 2–7 Irrigated and Rain-fed Crops in Jordan 2010

Rank	Crops	Total Cultivated Area (du)	Irrigated		Rain-fed		Percent of Total Area of Jordan (%)
			du	%	du	%	
1	Field crops	1,285,568	128,625	10.0	1,156,943	90.0	1.45
2	Fruit trees	827,128	447,246	54.1	379,882	45.9	0.93
3	Vegetables	480,806	448,851	93.4	31,956	6.6	0.54
Total		2,593,501	1,024,721	39.5	1,568,780	60.5	2.92

Comparing agriculture data in 2010 with 2009 indicates that:

- Total cultivated area increased by 16 percent.
- Irrigated area increased by 8 percent.
- Rain-fed area increased by 21 percent.
- Fruit trees area increased by 0.5 percent.
- Field crops area increased by 28 percent.
- Vegetables area increased by 17 percent.

2.3.1 Agricultural Demographics

People working mainly in agriculture comprise about 6.8 percent of the Al-Azraq labor force. However, about 47 percent of Al-Azraq residents practice some agriculture, mostly in their own backyards. Forty percent of Al-Azraq residents own property other than the house they live in, whether it is an individual possession (28 percent) or a shared one (12.7 percent). Of these people, only 23.4 percent own agricultural land. Such lands are distributed in Al-Awahaq, Dugalieh, Ain Al-Biyda, Ratami, and other areas around Al-Azraq and outside the Al-Azraq area.

Of those who own agricultural land in Al-Azraq, 7.7 percent own a second agricultural property elsewhere, and 0.18 percent owns a third one. Of the total owned agricultural land, 70.4 percent is cultivated mostly by olives, fruit trees, field crops, vegetables, and dates. Of this cultivated land 97.5 percent is managed by the owners themselves.

2.3.2 Agricultural Land Use

Al-Azraq is organized in six districts: North Al-Azraq, South Al-Azraq, Al-Emari, Ein Al-biyda, Qasser Amra, and Al-Azraq Badia. The total area of tenure is 143,979 du, of which 125,954 du is agricultural land or potentially cultivable. **Table 2-8** shows the distribution of the total area of tenure by land use in 2007.

Table 2–8 Al-Azraq Land Tenure by Land Use (du) (DOS, 2007)

Land Use		North Al-Azraq	South Al-Azraq	El-Emari	Ein Al-bida	Qasser Amra	Al-Azraq Badia	Total
Field Crops		8,589	3,103		674		6,004	18,370
Vegetables	Open	2,001			406		1,334	3,741
	Protected	812	300		485		200	1,797
Orchards		20,726	2,982		2,827		26,913	53,448
Residential and other structure areas		101	83	2	14	4	61	265
Permanent range land		300	8					308
Forests		2,175			12		15	2,202
Agriculture land	Uncultivated (rotation)	10,689	10,435		2,673		9,525	33,322
	Uncultivated (suitable)	4,093	115		1,697		9,371	15,276
Land	Non cultivable	4,609	205		658		9,302	14,774
	Non classified	152	15		118		191	476
Total Area (du)		54,247	17,246	2	9,564	4	62,916	143,979

Table 2-9 presents field crop cultivated areas by crop type and irrigation system in Al-Azraq, (DOS, 2007). In 2007 the total field crop cultivated area was 18,385 du, of which 79.4 percent was rain-fed and 20.6 percent was irrigated. Alfalfa and barley were the dominant irrigated field crops (3,407 du) and accounted for 90 percent of the total irrigated field crop land.

Table 2–9 Field Crops Cultivated Area and Irrigation System in Al-Azraq (du), (DOS, 2007)

Crop	Rain-fed (du)	Irrigated (du)			Total (du)	Percentage (%)
		Surface	Drip	Sprinkler		
Barley	14,055	460		1,300	15,815	86.0
Wheat	547	190			737	4.0
Yellow Corn		70	50		120	0.7
Alfalfa		295	35	1,317	1,647	9.0
White Corn			40		40	0.2
Others			26		26	0.1
Sub Total	14,602	1,015	151	2,617	18,385	100
Total	14,602	3,783			18,385	

Table 2-10 presents irrigated and rain-fed orchards cultivated area by crop type in Al-Azraq, (DOS, 2007). The total irrigated orchard cultivated area was 48,132 du in 2007, of which 40,306 du (83.7 percent) contained olive, and 4,165 du (8.7 percent) contained grape, and 3663 du (7.6 percent) contained others (date palm, apple, stone fruit, pear, pomegranate, fig, and others).

Table 2–10 Irrigated and Rain-fed Orchards Cultivated Area by Crop Type in Al-Azraq (du), (DOS, 2007)

Crop	Irrigated (du)	Rain-fed (du)	Total (du)	Percentage (%)
Olive	40,306	2,535	42,841	77.4
Grape	4,165	2,481	6,646	12.0
Date Palm	1,372		1,372	2.5
Apple	103	1,250	1,353	2.4
Stone Fruit	205	950	1,155	2.1
Pear	1,054		1,054	1.9
Pomegranate	619		619	1.1
Others	299		299	0.5
Fig	11		11	0.0
Total	48,132	7,216	55,349	100

Table 2-11 presents irrigated vegetables total cultivated area in 2007. The total irrigated cultivated area was 6,547 du, of which 2,388 du (36.5 percent) contained melon and water melon, 1,572 du (24 percent) contained tomato, and 1,186 du (18.1 percent) contained cauliflower and cabbage.

Table 2–11 Irrigated Vegetables Cultivated Area by Crop Type in Al-Azraq (du), (DOS, 2007)

Crop	Area (du)	Percentage (%)
Tomato	1,572	24.0
Water Melon	1,498	22.9
Cauliflower	1,046	16.0
Melon	890	13.6
Onion	317	4.8
Squash	305	4.7
Eggplant	220	3.4
Lettuce	160	2.4
Cabbage	140	2.1
Green faba bean	135	2.1
Peas	100	1.5
Others	65	1.0
Carrot	50	0.8
Hot Pepper	28	0.4
Okra	20.5	0.3
Total	6,546.5	100

2.3.3 Irrigated and Cultivated Land Development (1987-2011)

Based on available data from DOS; Al-Azraq Agricultural Directorate (AAD); Ministry of Agriculture (MOA), WAJ, and other literature reviewed as part of this assessment, a significant increase in irrigated cultivated land occurred in the last three decades (**Figure 2-6**). Agriculture activities started in the Al-Azraq area with one 40-du farm in 1957. After the speech of His Majesty King Hussein for a green desert as a motivation to invest in agriculture in the 1980s and because of the national land regulation dictating that proven activity in an acquired land is sufficient to grant the alleged owner right to this land, Al-Azraq underwent the development of large farms. Consequently, cultivated land area increased dramatically from 7,566 du in 1980 to 24,686 du in 1996 (more than three times) with the motivation of land speculation, prospect of cheap land, and free water. Between 1996 and 1998, irrigated cultivated land area doubled from 24,686 to 48,230 du. Even with government prohibition of new expansion in irrigated agriculture in Al-Azraq region and water tariffs imposed by MWI, irrigated cultivation continued to grow to reach 114,995 du in 2010/2011, but shifting from vegetables to orchards, mainly olive trees. **Figure 2-7** shows that area of irrigated cultivated orchards (mainly olive trees) and field crops (mainly alfalfa) were doubled in the last three years (2007-2010/11). Irrigated vegetables cultivated area remains almost constant.

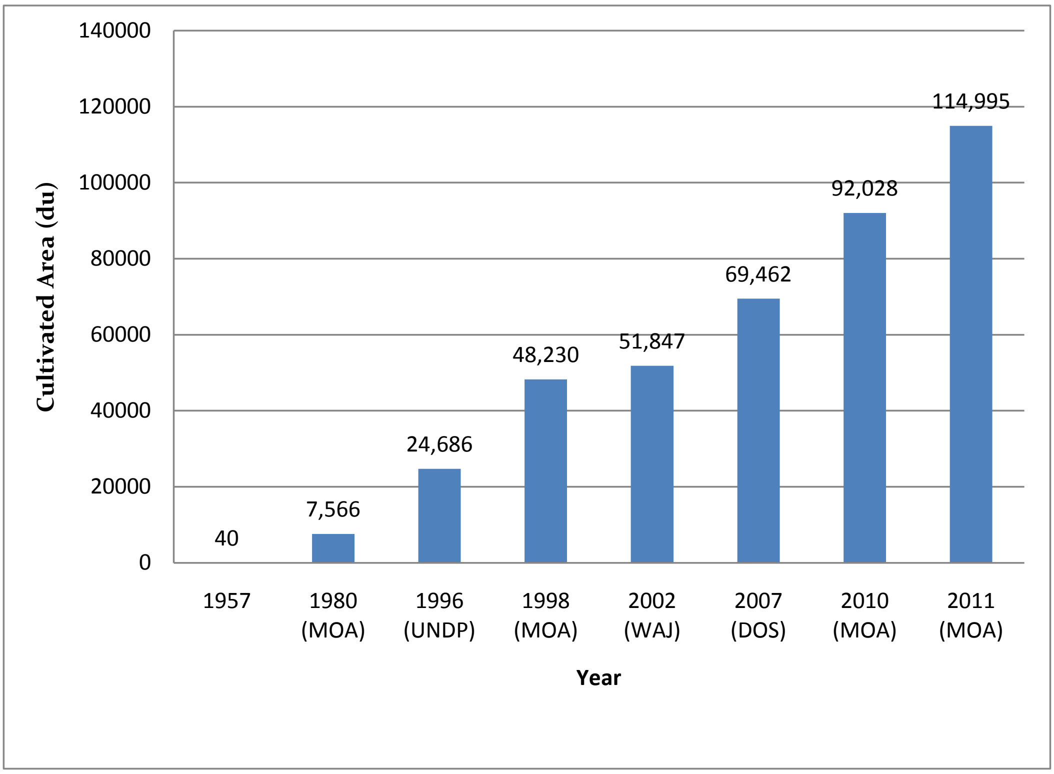


Figure 2-6 Irrigated Agricultural Development in Al-Azraq Area (1957-2011)

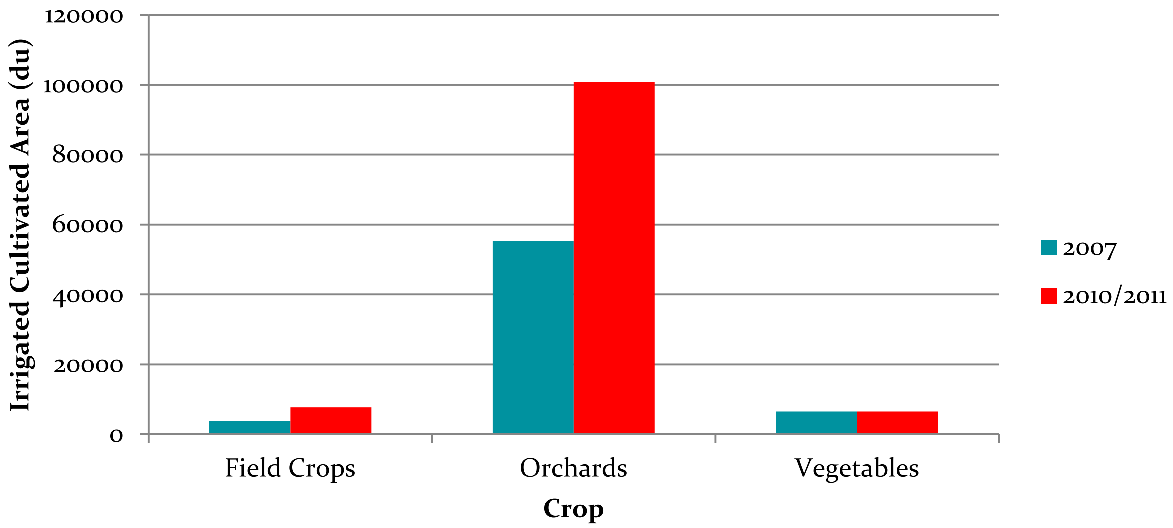


Figure 2-7 Agriculture Structure Development in Al-Azraq (2007 - 2010/11)

2.3.4 Current Agricultural Cropping Patterns and Structure

CDM conducted a review of data available from MOA, DOS, and other literature to investigate and understand the agricultural structure and cropping pattern in Al-Azraq area. **Table 2-12** presents the cropping structure in 2010/2011 according to the Ministry of Agriculture records. Notably orchards are the dominant crops occupying 100,720 du, representing 87.6 percent of the total irrigated, cultivated area. Of which 81.4 percent contain olive trees, 11.3 percent grapes, 7.1 percent fruit trees, and 0.2 percent citrus. Field crops and alfalfa accounted for 7,750 du, representing 6.7 percent of the total irrigated, cultivated area. Of which 63.2 percent was alfalfa, 29.7 percent barley and wheat, and 7.1 percent corn fodder. Vegetables accounted for 6,525 du. Of which 55.2 percent were tomatoes, 24 percent melon and water melon, 9.9 percent onion and garlic, 5.4 percent cauliflower and cabbage, 4.0 percent eggplant, 1.2 percent okra and 0.5 percent peppers.

Table 2–12 Agricultural Structure and Cropping Pattern in Al-Azraq Area, 2010/2011

Crops		Area (du)	Total
Field crops and Alfalfa	Alfalfa	4,900	7,750
	Barley	1,650	
	Wheat	650	
	Fodder Corn	350	
	Yellow Corn	200	
Orchards	Grape	11,350	100,720
	Olive	82,000	
	Fruit trees	7,200	
	Citrus	170	
Vegetables	Tomato	3,600	6,525
	Melon	1,080	
	Onion	515	
	Water Melon	480	
	Eggplant	260	
	Cabbage	200	
	Cauliflower	150	
	Garlic	130	
	Okra	80	
	Pepper	30	
Total		114,995	

Source: MOA, ADD Internal records, 2011.

In 2010/2011 the dominant crops were: olive, grape, fruit trees, alfalfa, tomato, and barley, representing 96.3 percent of the total irrigated, cultivated area in Al-Azraq. The total irrigated, cultivated area is 114,995 du, of which 71.3 percent contain olive, 9.9 percent grape, 6.3 percent fruit trees, 4.3 percent alfalfa, 3.1 percent tomato, and 1.4 percent barley (**Figure 2-8**).

Figure 2-9 presents the cultivated area development for the main dominant irrigated crops in the last three years (2007-2010/11) in Al-Azraq area. In the last three years irrigated, cultivated area increased by three times for alfalfa, 2.3 times for tomato, 1.9 times for olive, 1.7 times for grape, and 1.5 for fruit trees. Irrigated barley cultivated area decreased by 10 percent.

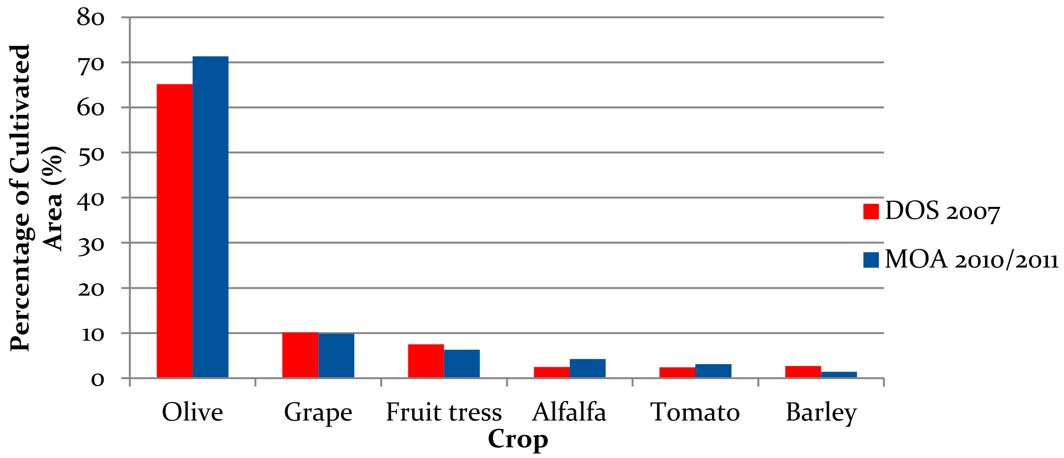


Figure 2-8 Percentage of Dominant Irrigated Crops Cultivated Area in 2007 and 2010/2011

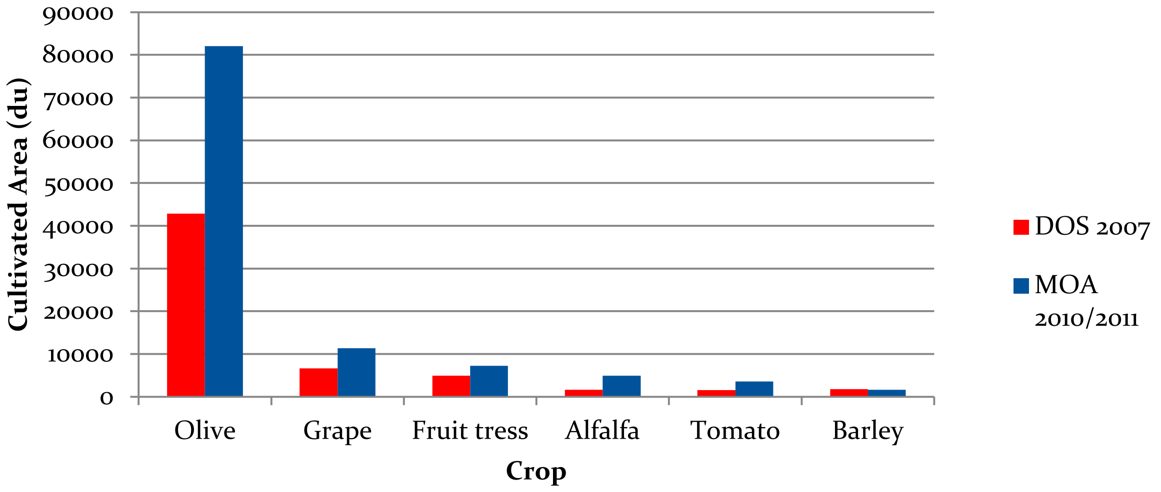
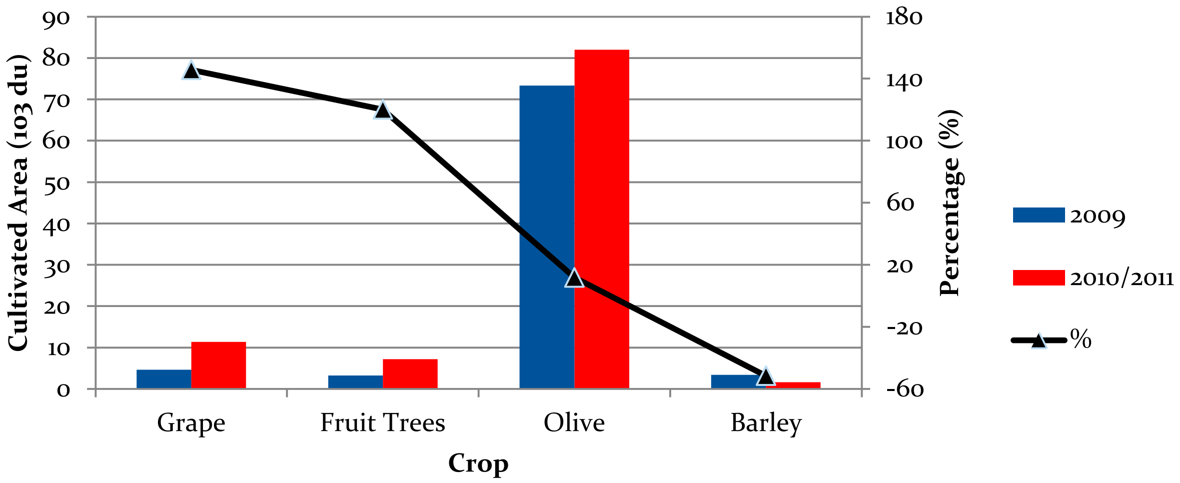


Figure 2-9 Dominant Irrigated Crops Cultivated Area Development in the Last Three Years (2007-2010/11)

Grape cultivated area increased from 4,620 du in 2009 to 11,350 du in 2010/2011, corresponding to 145.7 percent increase; fruit tree cultivated area increased from 3,270 du in 2009 to 7,200 du in 2010/2011, corresponding to 120.2 percent increase; olive trees cultivated area increased from 73,330 du in 2009 to 82,000 du in 2010/2011, corresponding to 11.8 percent increase; while the barley cultivated area decreased from 3,400 du in 2009 to 1,650 du in 2010/2011, corresponding to 51.5 percent decrease (**Figure 2-10**).

Total fruit trees, excluding grape, cultivated area is 7,200 du, in 2010/2011, about 2.2 times the cultivated area in 2009. Non fruitful orchards provide an indication of agricultural expansion. The highest non-fruitful fruit trees is date palm representing about 81.7 percent of its total cultivated area, suggesting that a significant increase in date palm cultivated area occurred at the last few years (**Figure 2-11**). Among all fruit trees, excluding grapes, pears accounted for the highest cultivated area in 2009 at about 1,220 du, of which 920 du fruitful and 300 du none fruitful. Even though combined fruit trees, excluding grapes, ranked as third in terms of cultivated area, after olives and grapes, they are analyzed separately because they include seven different types and vary in their cultivated area, production cost, water requirement, and produce value.



Source: Ministry of Agriculture 2009 and 2010/2011

Figure 2-10 Olive, Grape, Fruit Trees, and Barley Cultivated Areas in Al-Azraq in 2009 and 2010/2011

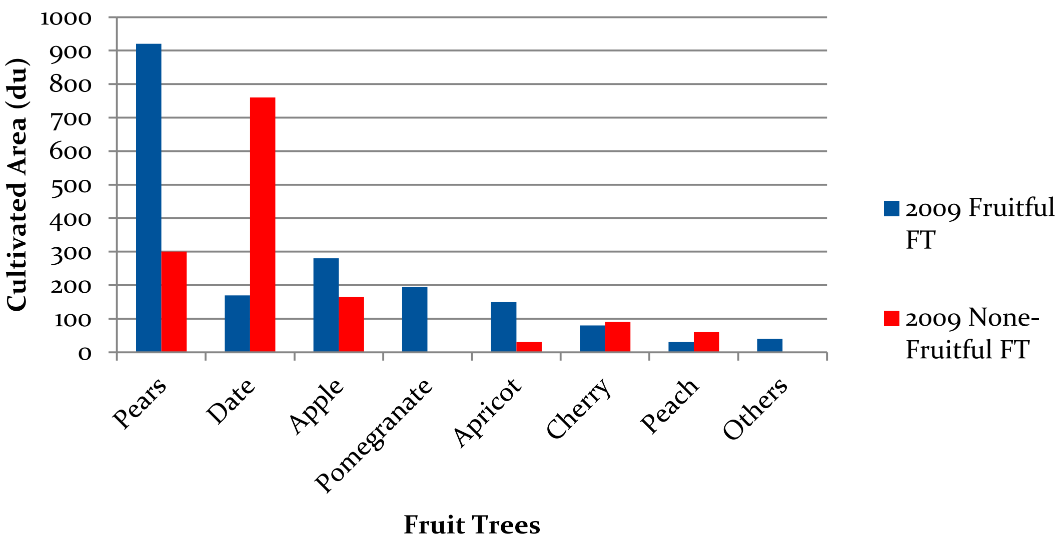


Figure 2-11 Fruit Trees Cultivated Area in 2009, (MOA 2010)

During the CDM team field reconnaissance on 30 October 2011, a significant increase in the date palm cultivated area (approximately 2,500 du) was noted. One possible reason behind the significant increase, according to Al-Azraq Agricultural Directorate, is that the Hashemite Fund distributed date palm seedlings to the farmers to enhance date palm cultivation in Al-Azraq. Also, significant increase in alfalfa, grape, and pomegranate cultivated areas was evident. Based on discussions with local farmers, one of the contributing factors is the expansion of electrical service to agricultural areas. Farmers, now with access to a cheaper power source are able to pump water at a greater rate resulting in higher profits.

Ironically, the introduction of solar power in areas as yet un-serviced by electrical power will likely further exasperate groundwater over abstraction, providing a cheap alternative to traditional diesel pumps. The photo to the right (**Figure 2-12**) is a 16-kWh PV array used to pump groundwater and drive center pivot irrigation of a 167 du alfalfa field in Al-Azraq.

Figure 2-12 Solar Power Driven Irrigation in Al-Azraq

2.4 ENERGY GENERATION AND CONSUMPTION

Provision of electricity system in Jordan may be divided into three activities:

- Generation
- Transmission
- Distribution

The electricity sector is regulated by the Electricity Regulatory Commission (ERC) which determines the tariff, subscription, service and connection fees, as well as monitors the quality of electricity. The structure of electricity sector in Jordan is shown in **Figure 2-13**.

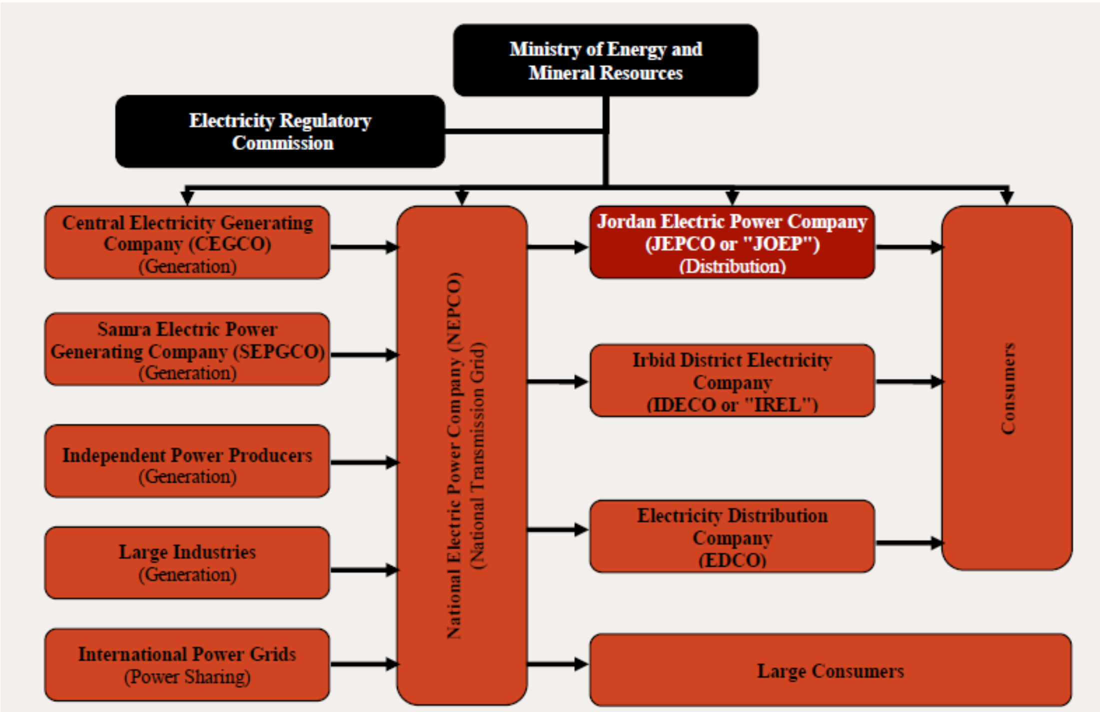
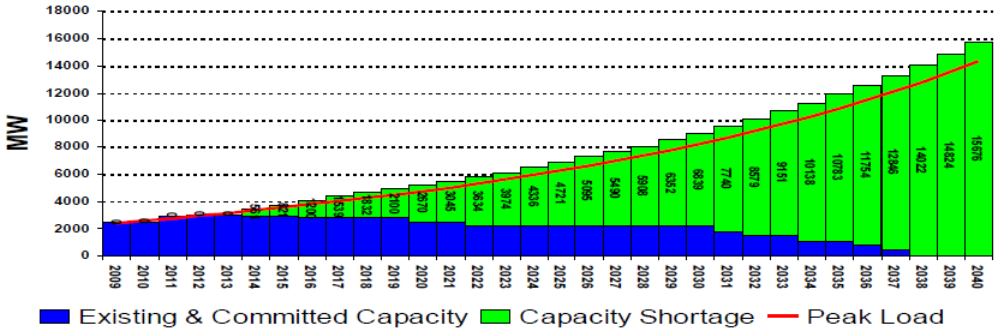


Figure 2-13 Electricity Sector Hierarchy

Based on the 2010 Annual Report of the ERC, the total amount of electricity consumed in the Kingdom in 2010 was 12,920 gWh, an increase of 7.7 percent from 2009. This results in a per capita power consumption of 2,114 kWh per person. The number of customers reached 1.498 million, an increase of 5 percent over the 2009 customers. The total generation capacity in 2010 was 3,069 mW. Distribution losses were estimated at 1631 gWh in 2010 compared to 1655 gWh in 2009, with a growth rate reduction of 1.45%. Losses in 2010 represent 12.1% of the total electrical power. Total combined system losses were estimated at 15.5 percent.

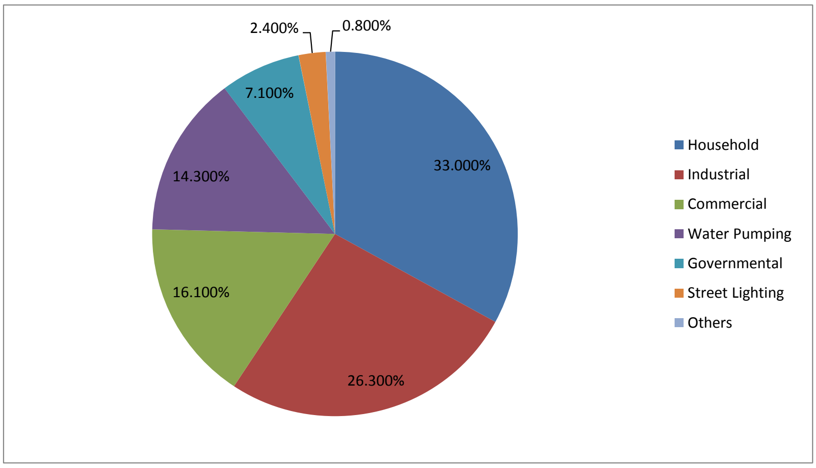
Electricity consumption is expected to double by 2030, and is expected to reach almost 15 gW in 2040. This substantial increase is partially attributed to the population growth, the expected industrial development, and the need to support the major water projects such as the Disi and the Red Dead connector. This substantial increase will widen the gap between the available capacity and the electricity demand in the absence of alternative energy resources. The Disi water conveyance system is expected to come on line in 2013 and it requires 590 mWh/year for water pumping, while phase I of the Red Dead connector project is expected to consume power at a rate of 2,213 mWh/year. Planners envision Phase I of the project to come on line in 2018. The expected gap between the current capacity and the projected required capacity by year 2040 is shown in **Figure 2-14** below.



(Source: White Paper on Nuclear Energy in Jordan Final Report)

Figure 2-14 Electricity Projected Capacity

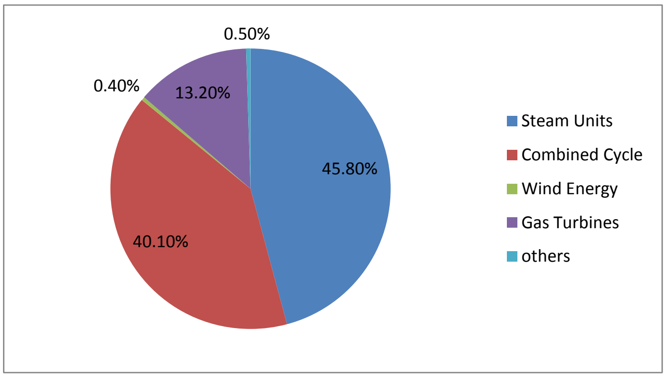
Residential use is the primary consumer of electricity in Jordan at a rate of 33 percent of the total consumption. The industrial sector is the second highest consumer at 26.3 percent, **Figure 2-15** shows the distributed percentage of consumed energy by sector.



(Source: Electricity Regulatory Commission Annual Report 2010)

Figure 2-15 Distributed Consumption of Electricity by Sector in 2010

The majority of electricity is produced from the steam units and combined cycle plants as shown in the chart below.



(Source: JPEP Equity Report 2011)

Figure 2-16 Electrical Energy Generated According to Type of Generation

Energy production, transmission and distribution cost information presented in the 2008 and 2010 annual reports issued by the ERC are summarized in **Table 2-13**.

Table 2–13 2007, 2008, and 2010 Average Costs of Electricity Generation, Transmission and Distribution per kWh

Sector	Item	JD/mWh 2007	JD/mWh 2008	JD/mWh 2010
Generation	Fuel	23.6	35.4	43.39
	Administrative, maintenance, funding and miscellaneous	7.6	8.1	22.61
Transmission	Cost of the national network, for each sold unit	4.8	4.4	
Distribution	Distribution costs per unit sold	7.3	8.8	12
Total costs of sold units from distribution networks		43.6	56.6	78

*Note that The electricity regulatory commission 2010 report combines the distribution cost with the Administrative, maintenance, funding and miscellaneous under the generation cost.

About 96% of Jordan's electricity generation is fuelled by imports, of which 80% is from Egyptian imported natural gas. Local natural gas is produced at Al Risha field, at a daily production of about 0.5 MCM, is only enough to operate generation capacity of 60 mWh. In 2001, the Governments of Egypt, Jordan, Syria and Lebanon signed a Memorandum of Understanding (MOU) to establish the Arab Gas Pipeline network, which would use natural gas from Egypt. On June 5, 2001, Jordan and Egypt signed a Framework Agreement under which Egypt will sell to Jordan a defined quantity of Egyptian gas and will implement the first and second stages of the Arab Gas Pipeline project.

A shortage in the supply of the imported Egyptian natural gas was witnessed in 2010 due to in- field technical problems, causing the system to rely more heavily on heavy oil. Even though this shortage raised the cost of production, the tariff was not raised accordingly and the system operator (NEPCO) tolerated this additional cost. In 2011,due to the civilian unrest after what is called the Arabic Spring the Egyptian pipeline was attacked several times. This has resulted in a complete suspension of the flow of $3.5m a day of natural gas from Egypt, forcing Jordan to revert to heavy fuel reserves such as diesel. As a result the cost of producing electricity has increased substantially to about 156 JD/mWh. Under this situation, which might be temporary,residential consumers have seen an increase of 10.5 fills/kWh, or of 16.7%. Since August 2011, these rates have superseded the government subsidized rates that have been in effect since the beginning of 2010 as shown in the **Table 12-4**.

Table 2–14 Domestic Electricity Tariff Structure

Monthly Consumption	Fils/kWh From 14/3/2008 to 16/1/2010	Fils/kWh From 16/1/2010
1-160 kWh/month	32	33
161-300 kWh/month	71	72
301-500 kWh/month	85	86
More than 500 kWh/month	113	114

Figure 2-14 depicts the electric power system in Jordan.

Figure 2-17 Jordan Electric Power System (Source Al Soud et al. 2008)

SECTION 3 - AGRICULTURAL PRODUCTION

Given the severe scarcity of water in Jordan, and in light of: (1) the decrease in groundwater resources from both a quantity (aquifer depletion) and quality (increase in the salinity of the groundwater) standpoint; (2) limited surface water resources; and, (3) the increasing demand for potable water due to population growth, it has become a priority to dedicate considerable efforts to manage water resources, prioritize use and maximize its return. Irrigated agriculture has been the highest water consuming sector, in the range of 65-70 percent of the total demand, for the last two decades. Starting from the background information provided in Section 2, this section provides more detailed data and preliminary analysis of Al-Azraq groundwater use for irrigated agriculture. This section presents two methodologies for developing estimates of crop production costs. The first was adopted from the Agricultural Credit Corporation (ACC), 2005, that is intended for application throughout Jordan. In reviewing this methodology, it was noted that the crop water requirements appeared low for the Al-Azraq area, likely because the document was developed for application throughout Jordan. Therefore, independent estimates of crop water requirements were developed, specifically for Al-Azraq and incorporated into the calculations.

3.1 AGRICULTURAL PRODUCTION AND COSTS

In 2010/2011 the dominant crops were: olive, grape, alfalfa, tomato, and barley, representing 90 percent of the total irrigated, cultivated area in Al-Azraq. These are discussed below:

- **Olives**

  The olive tree is a long-living evergreen tree native to the Mediterranean basin. Olive is considered drought-resistant because it thrives in areas where water stress is frequent such as Mediterranean climates. It has been postulated that the minimum water requirement for olives is 2,000 m^3/ha/yr. Water is needed mainly during flowering and fruit setting in late spring, and again in the summer as the fruit increases in size.

  Olive is the most dominant crop in Al-Azraq area. The irrigated area of planted olive trees (82,000 du) represents about 71.3 percent of the total irrigated, cultivated area (114,995 du) for the year 2011 (ADD, 2011). Olive fruit production varies from one place to another depending on climate, variety, irrigation, fertility, agricultural practices, and other factors.

  Based on the MOA records the total irrigated, cultivated area in Al-Azraq was 73,330 du in 2009, of which only 29,520 du (40 percent) was fruitful and 43,810 du was still not fruitful. The total olive fruit production of the fruitful olive trees was 11,218 ton, representing an average olive fruit production of 0.38 ton/du.

  Production costs per one dunum of olive trees was estimated by the ACC in 2005 for three time intervals (3 stages) from planting date, as follows: JD 82.2/du for the first 3 years from planting date (assuming 200 m^3 crop water requirement, and JD 0.08/m^3 irrigation cost); JD 134.7/du for the next 4 years (assuming 250 m^3 crop water requirement, and JD 0.08/m^3 irrigation cost); and JD 236.1 for year 8 and thereafter (assuming 300 m^3 crop water requirement, and JD 0.08/m^3 irrigation cost).

- **Grape**

  Grape is one of the most important fruit crops in the world. The crop has wide adaptability and grapes can be grown under temperate, sub-tropical and tropical climatic conditions and varied agro-ecological settings. Grapes in Jordan are mainly intended for fresh consumption. The climate in Jordan is well suited to grape quality production. Grape is the second most extensively cultivated fruit crop in Al-Azraq (and in the world) after olive. The water requirement of a mature vineyard varies from 483 to 660 mm/yr, depending on the leaf canopy.

The irrigated, cultivated area of planted grapes (11,350 du) represents about 9.9 percent of the total irrigated, cultivated area (114,995 du) for the year 2011 (ADD, 2011) in Al-Azraq area, which is the second largest cultivated area after olive. Similar to olive, grape fruit production varies from one place to another depending on climate, variety, irrigation, fertility, agricultural practices, and other factors.

Based on DOS records the total irrigated, cultivated area in Al-Azraq was 4,620 du in 2009 which produced 78,000 ton, with an average grape production of 1.69 ton/du.

Similar to olive, production costs per one dunum of grape was estimated by the ACC in 2005 for three time intervals (3 stages) from planting date, as follows: estimated cost for the first 3 years (1-3 years) from planting date was JD 224.2/du (assuming 300 m^3 crop water requirement, and JD 0.4/m^3 irrigation cost); JD 415.7/du for the next 4 years (assuming 500 m^3 crop water requirement, and JD 0.4/m^3 irrigation cost)); and JD 635.9/du for year 8 and thereafter (assuming 800 m^3 crop water requirement, and JD 0.4/m^3 irrigation cost).

- **Alfalfa**

Planting alfalfa is a common practice in Jordan. It is considered an important crop in Al-Azraq area as it is a fodder crop to feed livestock (cattle, goats and sheep). Alfalfa is considered the third most cultivated crop in Al-Azraq area after olive and grape. A notably dramatic increase in alfalfa cultivated area occurred in the last three years (2007-2010/11), as it almost tripled.

The irrigated area of planted alfalfa (4,900 du, ADD 2010/11) represents about 6.3 percent of the total irrigated, cultivated area (114,995 du) for the year 2011 (ADD, 2011) in the Al-Azraq area.

Based on DOS records the total irrigated, cultivated area in the uplands was 62,036 du in 2010 producing 210,517 tons, with an average alfalfa production of 3.4 ton/du.

Based on the reconnaissance visit to Al-Azraq area in October 2011, production costs per one dunum of alfalfa was estimated based on interviews with farmers, literatures, and CDM/RIAL project team's experience at JD 411.3/du (assuming 1,600 m^3 crop water requirement at JD 0.12/m^3 irrigation cost).

- **Tomato**

Tomatoes are among the most important vegetables grown in Jordan whether grown inside plastic houses or in open field. There are two areas where tomatoes are grown. They are grown in the Jordan Valley from September till May, and in the highlands from April till August. In Jordan, the total area planted with tomatoes was 141,887 du in 2010, which produced 737,261 ton of tomato fruit (DOS, 2010). Usually tomato produced in surplus to the local market is exported to the neighboring countries.

The irrigated area of planted tomato (3,600 du) represents about 3.1 percent of the total irrigated, cultivated area (114,995 du) for the year 2011 (ADD, 2011) in the Al-Azraq area, which is the fourth largest cultivated area after olive, grape, and alfalfa. In the highlands, the total irrigated, cultivated area accounts 66,550 du, which produced 295,468 tons, with an average tomato production of 4.44 ton/du.

Production costs per one dunum of open tomato fields was estimated by ACC in 2005 being JD 423.7/du (assuming 500 m^3 crop water requirements at JD 0.12/m^3 water price). Despite nearly constant production costs and average yield per one dunum, produce value varies significantly from one month to another and from one year to the other. In 2009 produce value was JD 113.6/ton at the farm gate, which nearly doubled in 2010 being about JD 197/du. This significant variation in tomato produce value makes economic analysis very difficult.

- **Barley**

Barley and wheat are widely spread in Jordan, representing the main rain-fed crops in the highland areas. Both crops are winter crops. In Jordan, supplementary irrigation using groundwater resulted in increased yield of more than 3,000 kg grain/ha for these crops.

The irrigated area of planted barley (1,650 du) represents about 1.4 percent of the total irrigated, cultivated area (114,995 du) for the year 2011 (ADD, 2011) in Al-Azraq area, which is the fifth largest cultivated area after olive, grape, alfalfa, and tomato. A slight decrease in the barley cultivated area by about 10 percent occurred in the last three years (2007-2010/11).

Based on the MOA, Plant Production Annual Report 2009 the total irrigated, cultivated area in Al-Azraq was 3,400 du, which produced 952 ton, with an average barley production of 0.28 ton/du.

Production costs per one dunum of rain-fed barley was estimated by ACC in 2005 at JD 24.75/du. Adding the cost of about 250 m^3 water, (at JD 0.12/m^3 irrigation cost), for supplemental irrigation based on interviews with local farmers, brings the production costs to JD 53.8/du.

Crop production and economic data from the DOS, MOA, and ACC (2005), for 2009, 2010, and 2011, were compiled for crops of interest and are summarized in **Table 3-1.**

Table 3–1 Production and Produce Value Statistics in Al-Azraq (for Olive, Grape, Alfalfa, Tomato, and Barley)

Crop	Production	Produce Value		Production Cost	Profit (Return)	
	(ton/du)	(JD/ton)	(JD/du)	(JD/du)	(JD/du)	(%)
Orchards						
Olives	0.38	750	285	236.1(*)	48.9	20.7
Grape	1.69	520.7	880	635.9	244.1	38.4
Alfalfa and Barley						
Alfalfa	3.4	180	612	411.3	200.7	48.8
Barley	0.28	315	88.2	53.8	34.4	63.9
Vegetables						
Tomato	4.44	113.6(**) to 197(***)	504(**) to 875(***)	423.7	81(**) to 451(***)	19 to 106.4

Source: Ministry of Agriculture. 2009, 2010, and 2011. Department of Statistics. 2010. Agricultural Credit Corporation. 2005.

(*) Even though production costs estimated by Agricultural Credit Corporation (2005) based on JD 0.4/m^3, end results for olive water consumption cost indicates that it is calculated based on JD 0.08/m^3.

(**) Produce value in 2009

(***) Produce value in 2010

Based on the available data, of the crops considered, grapes produce the highest return value per dunum at JD 244.1, followed by alfalfa being JD 200.7 (**Figure 3-1**). The return for olive was JD 48.9/du. The lowest crop return value was barley at JD 34.4/du, however it has the highest return per production costs per unit area being about 63.9 percent.

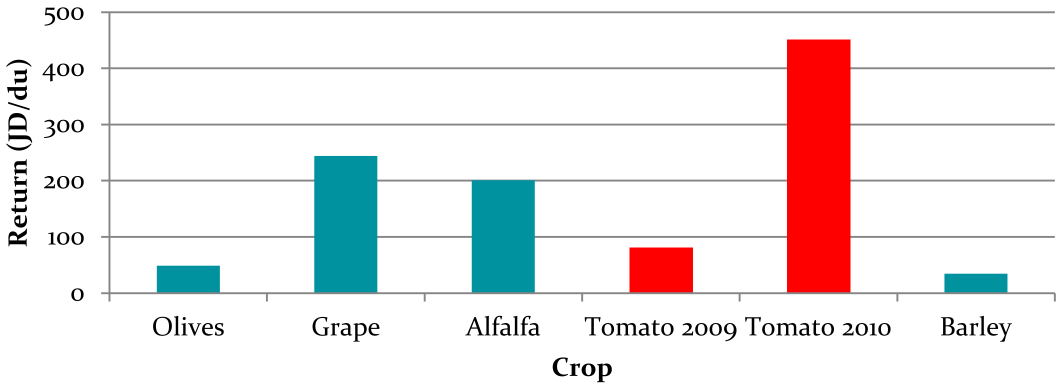


Figure 3-1 Crops Return Based on Agricultural Credit Corporation (JD/du)

The return value for tomatoes varies from one year to another, mainly depending on area cultivated, export, and diseases. In 2009, the tomato produce value was the lowest of the last five years, at JD 113.6/ton, resulting in a return value of JD 81/du. This was due to exports to Saudi Arabia being blocked accompanied by high production, and a disease free growing season. The opposite occurred in 2010, when the produce value was at a five year high, at JD 197/ton, resulting returns per dunum at JD 451/du. This was because of a disease problem growing season and resumed exports to Saudi Arabia.

Even though the return on barley per dunum (JD 34.4/du) was the lowest among crops considered, the return per unit production cost was the highest at 63.9 percent, followed by alfalfa at 48.8 percent (**Figure 3-2**). The return on olive was JD 48.9/du the second lowest after barley. Among the crops of interest, olives have the lowest return value per unit production cost at 20.7 percent.

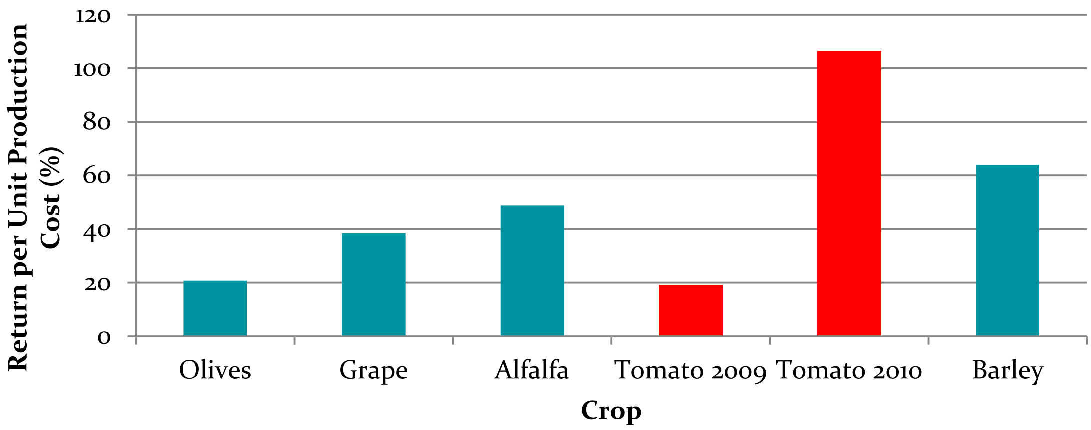


Figure 3-2 Percentage of Return Value per Unit Production Cost

Fruit trees; including apple, pear, peach, cherry, apricot, pomegranate; and date palm in Al-Azraq area account for only 7,200 du of irrigated area, representing only 6.3 percent of the total 114,995 du. These are discussed below:

- **Date Palms**

  Date palms need a long hot growing season. Low humidity and the absence of summer rain help in the production of high quality fruit. Jordan has successful experience with date irrigated with low quality irrigation water. An abundant water supply is important to the quality of the date crop. However, the date can tolerate long periods of drought, although for heavy bearing, it has a high water requirement. Dates require up to 27,000 m^3/ha/yr (with 123 palms/ha) for mature palms at ten years of age.

In 2009, the total irrigated, cultivated area of planted date palm was 930 du, of which only 170 du fruitful and 760 du none fruitful. Among fruit trees cultivated area in Al-Azraq region, date palm is the third largest cultivated area after grapes and pears. The large non fruitful cultivated area may suggest significant increase in date palm cultivated area occurred in the last few years.

- **Fruit Trees (Pears, Apples, Cherries, Peach, Apricots, and Pomegranates)**

Fruit trees include pear, apple, cherry, peach, apricot, and pomegranate. Most of the orchards are planted in the rain-fed conditions, in the highlands, but some commercial orchards in arid and semi-arid areas are also irrigated. In general, farmers tend to enlarge the area devoted to fruit trees at the expense of vegetables and field crops. Fruit prices are always higher and more stable than those of vegetables; and the risk of changing agricultural policies, especially in drought seasons, is less with fruit trees.

Based on the DOS and MOA records in 2009, fruit trees production varied from 1.0 ton/du for peach to 2.89 ton/du for pear, in Al-Azraq .

Similar to other orchards, production costs per one dunum of fruit trees was estimated by ACC in 2005 for three time intervals (3 stages) from planting date, as follows: for the first 3 years (1-3 years) from planting date was in the range of JD 71.5 and 80.4/du (assuming 200 m^3 crop water requirement, and JD 0.4/m^3 irrigation cost); JD 177.5 and 192.9/du for the next 4 years (assuming 250 m^3 crop water requirement, and JD 0.4/m^3 irrigation cost)); and JD 241.6 and 290.5/ du for year 8 and thereafter (assuming 300 m^3 crop water requirement, and JD 0.4/m^3 irrigation cost).

Table 3-2 presents fruit trees' production; produce value; production costs; and return for apple, pear, peach, cherry, apricot, pomegranate, and date palm.

Table 3–2 Production and Produce Value Statistics in Al-Azraq for Fruit Trees (Apple, Pear, Peach, Apricot, Cherry, Pomegranate, and Date Palm)

Crop	Production	Produce Value		Production Cost(*)	Profit (Return)	
	(ton/du)	(JD/ton)	(JD/du)	(JD/du)	(JD/du)	(%)
Apple	2.5	544.8	1,362	361.6	1,000	277
Pear	2.89	633.8	1,832	361.6	1,470	407
Peach	1	633.8	634	410.5	223	54
Apricot	1.33	919.4	1,223	410.5	812	198
Cherry	1.5	919.4	1,379	410.5	969	236
Pomegranate	2	1,250	2,500	361.6	2,138	591
Date Palm	1	1,000	1,000	410.5	590	144

(*) Production costs assumes 300 m^3/du crop water requirement at 0.4/m^3 irrigation cost, for $\geq$ 8 year old trees (ACC, 2005)

3.2 REVISED AGRICULTURAL PRODUCTION AND COSTS

In reviewing the details of the ACC calculations, it was noted that the crop water requirements used were low. Other costs for labor equipment and manpower appeared reasonable. The following sections present an independent evaluation of crop water requirements and crop production costs for use in this Study.

The main factors that determine crop production are:

- Irrigation water availability and quality
- Land availability and suitability
- The physiology of the crop cultivated
- Climate
- Fertility and the effectiveness of the agricultural practices

There are vast areas of cultivable agriculture land in the Al-Azraq basin. In general, the topography of the study area is flat with a gentle slope. Soil is deep and suitable for most crops. The study area is characterized by high evaporative demand being about 3,278 mm/yr (Class A pan evaporation, mean value for the last 20 years). Consequently, crop water demand is high. As reviewed in the previous section, the existing crop pattern in the area is comprised of olives (71.3 percent), grapes (9.9 percent), alfalfa (4.3 percent), tomato (3.1 percent), and barley (1.4 percent).

3.2.1 Irrigation Water Demands and Crop Water Requirements

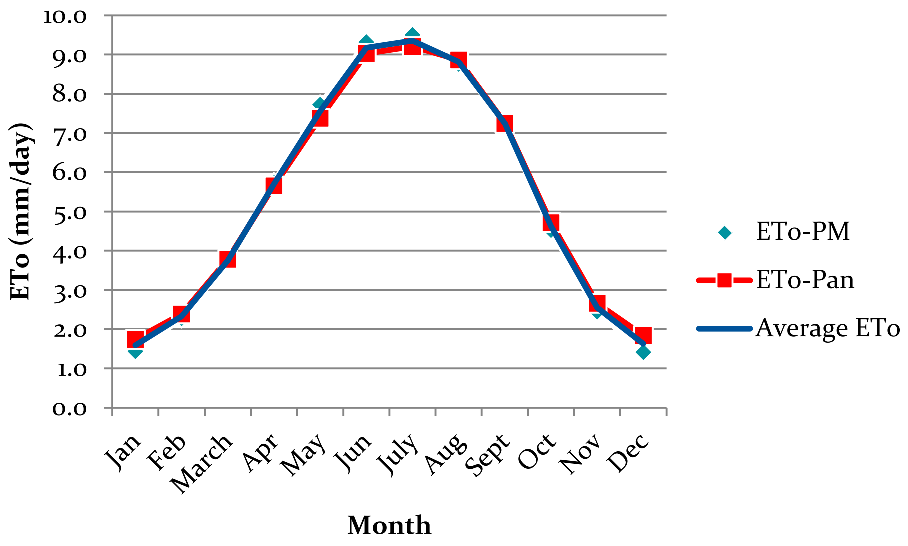
Dependable Precipitation

The study area lies within a semi-arid region. Most of the rainfall occurs between the months of November and April. Mean annual rainfall for the period 1981-2010 was very low, only 57.6 mm. Precipitation is not always a dependable quantity and may vary significantly from year to year and from one month to another.

Forty percent of the annual rainfall occurs in December and January. The term dependable precipitation, refers to that quantity of precipitation (monthly) which is received a certain percentage of the time (e.g. 8 out of every 10 years). Given the high evaporative demand, and the very low total precipitation, dependable rainfall is negligible and will not significantly contribute in satisfying part of the crop water requirement.

Reference Evapotranspiration

A review of the existing data and local information related to crop water requirement, water demand, agricultural irrigation practices, and cropping pattern was performed. Potential and/or reference evapotranspiration was estimated on a monthly basis based on historical weather data using the, Penman Monteith method and Class A pan evaporation method (Allen et al., 1998). Winters are moderately cold, while summers are moderately dry-hot (Mediterranean climate). Effective rainfall is expressed as that portion of total rainfall that becomes available for use by crops. As described above dependable precipitation is considered negligible and is not considered in crop water requirement calculations. Using South Al-Azraq Station weather data (1981-2010, Table 2-1), grass reference evapotranspiration (ETo) was calculated using the Penman Montieth and Class A pan evaporation methods. The results are shown in **Figure 3-3**. The values of calculated ETo are highly comparable and in excellent agreement. For the purposes of establishing an estimate for crop water demands, the average of the two values was used for crop actual transpiration.



ETo-PM and ETo-Pan represent ETo calculated using Penman Montieth 1998 and Class A pan evaporation, respectively.

Figure 3-3 Grass Reference Evapotranspiration (ETo), (mm/day)

Crop water requirements were estimated for the dominant crops in Al-Azraq, including olives, grapes, alfalfa, tomatoes, and barley. In general, the components of the irrigation demands include: crop evapotranspiration, leaching requirement, and irrigation losses in the irrigation system. With good management, typical irrigation efficiency is about 75 percent on average for sprinkler irrigation, and around 85 percent for drip irrigation. In calculating the crop water requirements, irrigation efficiency of 80 percent was adopted for the estimate.

Leaching Requirements

Despite concerns about salination in the upper aquifer groundwater, water quality is generally good, except in the shallow sediments of Qa' Al-Azraq, which contain hypersaline brines formed by evaporation. Elsewhere in Al-Azraq basin, the salinity is low. Total dissolved solids (TDS) increases in the direction of groundwater flow from 200 ppm to 1,000 ppm.

Table 3-3 shows relative salt tolerance of the dominant crops in Al-Azraq. Barley is classified as tolerant; olive moderately tolerant; and alfalfa, grapes, and tomato are moderately sensitive to salinity.

Table 3–3 Relative Salt Tolerance of the Dominant Existing Crops in Al-Azraq Area, 2010/2011

Tolerant (ECw=3,840 to 6,400 ppm)	Moderately Tolerant (ECw=1,920 to 3,840 ppm)	Moderately Sensitive (ECw=832 to 1,920 ppm)	Sensitive (ECw≤832 ppm)
Barley Date Palm	Olive Pomegranate	Alfalfa Grapes Tomato	Apricot Peach Pear Apple

ECw represents irrigation water salinity (1.0 dS/m ≡ 640 ppm or mg/L or mg/kg).

The leaching fraction (LF) is the ratio of the net depth of leaching water to the net depth of water which must be applied for consumptive use. Calculating the leaching fraction for drip irrigation is greatly simplified as:

$$LF = \frac{ECw}{ECd}$$

Where:

ECw = Irrigation water salinity, dS/m
ECd = Drainage water salinity, dS/m

ECd is approximately equal to 2 x (max **ECe**), where max **ECe** is the electrical conductivity, in dS/m, of the saturated soil extract that will reduce crop yield to zero. This substitution results in:

$$LF = \frac{ECw}{2 \max ECe}$$

While, for sprinkler and surface irrigation systems, leaching fraction is calculated using the following equation:

$$LF = \frac{ECw}{5ECe - ECw}$$

Where ECe is defined as the electrical conductivity, in dS/m, of the average saturation extract of the soil root zone profile for an estimated yield reduction.

For a 10 percent leaching fraction, leaching is not necessary and will be compensated by irrigation's unavoidable loss. As presented in the Food and Agriculture Organization's (FAO) Irrigation and Drainage Paper No. 29 for Agriculture by R.S. Ayers and D.W. Cot (1976), the ECe values which will give 10 percent yield reduction were used to calculate irrigation water salinity threshold values that will cause the leaching fraction to exceed 10 percent, and consequently leaching is needed. **Table 3-4** shows that, for the crops considered, there is no need for leaching until the irrigation water salinity exceeds 1,000 ppm (1.56 dS/m). Since groundwater salinity, in the upper aquifer of Al-Azraq basin, is in the range of 200 to 1,000 ppm, in this study, leaching is not considered necessary in the water requirements.

Table 3-4 Irrigation Water Salinity Threshold Values for 10 Percent Leaching Fraction for the Selected Crops and Irrigation Systems (*)

Crop	Olive	Grape	Alfalfa	Tomato	Barley	Pomegranate	Date Palm	Apricot, Pear, Peach, Apple, Cherry
ECe (dS/m)	3.8	2.3	3.4	2.3	7.4	3.8	6.8	2.2
max ECe (dS/m)	14	12	16	12	20	14	32	8
Irrigation Water Salinity Threshold Values (ppm)								
Sprinkler	1,105	669	989	669	2,153	1,105	1,978	640
Surface	1,105	669	989	669	2,153	1,105	1,978	640
Drip	1,792	1,536	2,048	1,536	2,560	1,792	4,096	1,024

(*) Shaded cells represent irrigation water salinity threshold values for suitable irrigation system

Crop Water Requirements

The actual crop evapotranspiration was estimated as:

ETc = Kc x ETo

Where **ETc** represents actual crop evapotranspiration (mm/month); **Kc** represents mean monthly crop coefficient (derived according to the guideline for computing crop water requirements-FAO, Paper 56, 1998); and **ETo** (mm/month) represents the average grass reference evapotranspiration calculated using Penman Montieth approach and Class A pan evaporation method.

Table 3-5 illustrates the expected mean monthly actual crop evapotranspiration for olives, grapes, alfalfa, tomatoes, and barley. These crops are the most dominant as of 2010/2011.

Table 3–5 Mean Monthly Actual Evapotranspiration (ETc), (mm) for Selected Crops (Olive, Grape, Alfalfa, Tomato, and Barley)

Month	Olive	Grape	Alfalfa	Tomato	Barley
January	19.6		43.9		28.3
February	26.2		58.6		43.7
March	55.6		116		104
April	103	51.3	171	51.3	197
May	163	121	280	190	180
June	193	229	330	311	
July	203	246	348	331	
August	192	232	327	255	
September	153	185	261		
October	89.3	113	148		43
November	39.2	43.6	70		30.2
December	24.4		45.7		24.6
Total	1,260	1,220	2,199	1,138	651

The specific volume of water required for each month varies from crop to crop. Olive and Alfalfa, have a continuous demand pattern with a summer peak being 203 and 348 mm, respectively, in July, and a minimum demand at 19.6 and 43.9 mm, respectively, in January. Barley is an exception, showing increased demand in winter with a peak demand of 197 mm in April, and no irrigation demand in the summer months (June to September). Also, grape and tomato water demand extends from April to November/December, with their maximum demand occurring in July, at 246 mm and 331 mm, respectively, and no water demand from November/December to March. Thus, the determinate critical month is July.

Figure 3-4 presents net daily crop irrigation requirements for olives, grapes, alfalfa, tomatoes, and Barley by month.

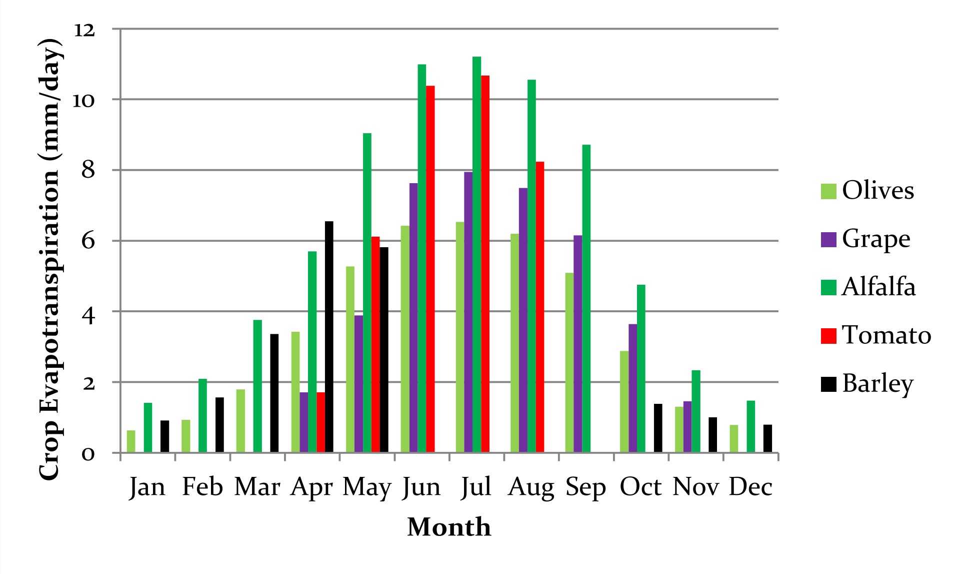


Figure 3-4 Actual Evapotranspiration (Etc) for Dominant Existing Crops

Table 3-6 illustrates mean monthly actual crop evapotranspiration for the different types of fruit trees (date palm, apple, pear, cherry, peach, apricot, and pomegranate).

Table 3–6 Mean Monthly Actual Evapotranspiration (mm) for Fruit Trees

Crop	Date Palm	Apple, Pear, Cherry, Pomegranate	Peach, Apricot
January	44		
February	59		
March	110		
April	162	68	94
May	222	140	147
June	261	234	217
July	275	290	252
August	259	273	246
September	206	206	196
October	136	100	111
November	69		
December	45		
Total	1,851	1,312	1,263

Date palm has a continuous demand pattern with a summer peak being 275 mm in July, and minimum demand being 44 mm in January. All other fruit tree water demands extend from April to October, with their maximum demand occurring in July, being 252-290 mm, and no water demand from November to March.

Figure 3-5 presents net daily crop irrigation requirements for fruit trees including date palm, apple, cherry, pomegranate, peach, and apricot by month.

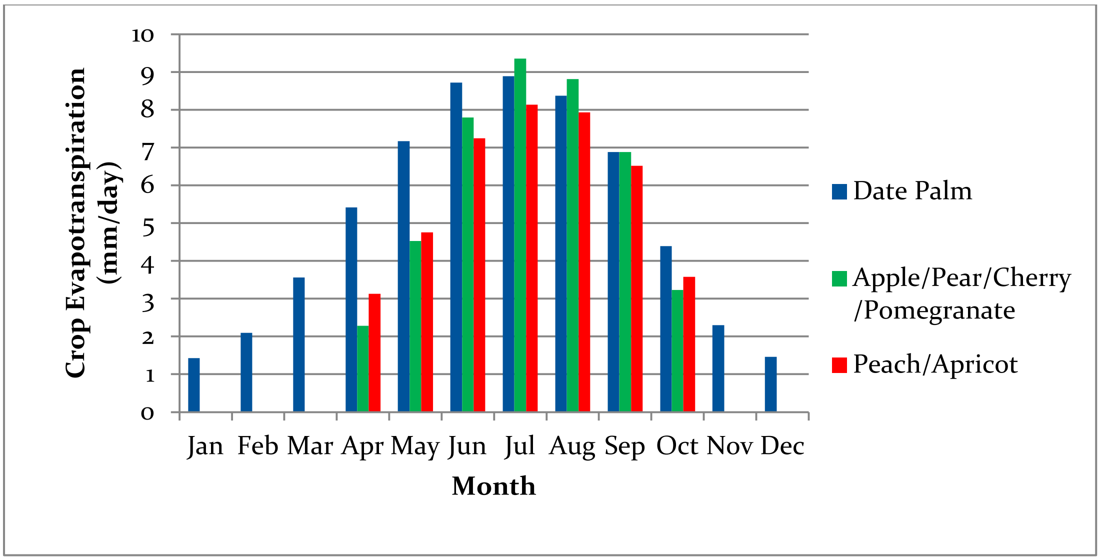


Figure 3-5 Actual Evapotranspiration (Etc) for Existing Fruit Trees in Al-Azraq

Based on the total crop areas obtained from MOA and AAD, presented in Section 2.3.4, the above calculated crop water requirements for the dominant crops in the area, and assuming 80 percent irrigation efficiency, the current total agricultural demand is in excess of 178 MCM/yr (see **Table 3-7**), i.e. more than 7 times the sustainable yield of 24 MCM/yr of the Al-Azraq Basin. Clearly the amount of agriculture in Al-Azraq is not sustainable and it is only a matter time before the livelihood of local inhabitants are severely impacted.

Table 3–7 Annual Azraq Agricultural Demand for Selected Crops

Crop	Area (du)	Annual Crop Water Requirement	
		per dunum (m^3/du/yr)	Total (m^3/yr)
Alfalfa	4,900	2,749	13,470,100
Barley	1,650	814	1,343,100
Grape	11,350	1,525	17,308,750
Olive	82,000	1,575	129,150,000
Fruit trees	7,200	1,640	11,808,000
Tomato	3,600	1,423	5,122,800
Total			178,202,750

3.2.2 Revised Crop Production and Production Costs

Revised estimates of crop production costs and profitability were made to separate fixed costs associated with agricultural activities and water consumption, so that both costs and water usage could be used in assessing the viability of replacing crop farming with solar farming. Furthermore, as described above, the crop water requirements included in the ACC report in 2005 were much lower than the above estimates. The analysis performed assumed:

1. Crop production and produce value as published by MOA and DOS.
2. Calculated crop water requirement based on prevailing climate and South Al-Azraq Station historical weather data, as described above and assuming 80 percent efficiency in the irrigation system.
3. Base costs for all other inputs excluding irrigation water, as estimated by the ACC.
4. Costs for pumping and distribution of irrigation water as per ACC.
5. Water tariffs are calculated separately as described below.

The results of the analysis are presented in **Table 3-8** and **Table 3-9** for crop production and fruit trees, respectively. Due to the complexity of the water tariff structure, results are presented as a maximum and minimum, bounding the cases where water fee is not paid and at a water fee of JD 0.1/m^3, based on the 2010 draft amendment pending approval. Also calculated is the total cost associated with irrigation (pumping, distribution and tariffs) necessary for the farmer to break even (zero profit) or the break even water cost. The base cost of the crop includes all the costs needed to produce the crop such as fertilizers, seeds, pesticides, harvesting, packaging and transportation, distribution, and labor cost. It is important to note that the analysis is performed for the optimum irrigation conditions which will result in maximum yield from the crops and the fruit trees, actual conditions might be different and is related to individual farm conditions.

The results suggest that of the considered crops, grapes provide the highest profit per dunum of JD 149/du at zero water fees. Grapes represent the second largest cultivated area, in 2011, and has increased by 1.5 times the cultivated area in 2007. The calculations suggest that growing olives, which represent the most dominant crop in the Al-Azraq area and account for 71.3 percent of the total irrigated cultivated area (2010/2011), is not profitable. Farm owners may not be fully aware of this issue. Sometimes a farmer will confuse irrigation practices for rain fed crops and irrigated crops resulting in not providing the olive trees with as much water as they need. Such deficit farming techniques provide crops with less water than is optimal in order to achieve a marginal profit, however such a practice results in a lower yield and hence affects the profitability of the investment. Supporting the conclusion that such practices are being implemented in Al-Azraq, a recent study in the highlands has found that olive trees are much smaller than would be expected for their age. This is attributed to the fact that the trees are not being provided with their actual demand needs. Similar observations are made with respect to other crops in Al-Azraq such as alfalfa and barely.

Fruit trees including apple, pear, peach, cherry, apricot, pomegranate, and date palm account for only 7,200 du of irrigated area, representing only 6.3 percent of the total. For fruit trees, profit ranges are higher than other crops with maximum profits for farmers at JD 1,602/du, if water tariffs are not paid as the case with Pomegranate.

Irrigation water availability and cost are the most determinative factors in agricultural production and expansion. Even though groundwater of good quality in Al-Azraq basin is shallow, easily reachable and pumped from depths ranging from 20 to 50 m, the source of energy used in water abstraction is the determinant factor for water unit cost and produce return. The German-Jordan Program “Management of Water Resources” (2010) estimated olive seasonal water consumption in the range of 900 to 1,300 m^3/du. The report shows that 1/3 of visited farms use diesel pumps and 2/3 use electricity. Energy costs represent an average of 19 percent of the production costs for farms connected to electricity, and 52 percent for farms using diesel. Even though the olive cultivated area, in 2011 is 1.9 times that in 2007, some of the olive farms using diesel were abandoned because of the high water abstraction costs (see **Figure 3-6** and **Figure 3-7**). Olive cultivated area expansion occurred in farms connected to electricity. It is reported that, farmers using diesel for water abstraction are hardly sustaining their olive farms, if not losing money. The German-Jordan Program in their draft report (2010) stated that "most of the farmers are just sustaining or even losing money (on average profit is JD 9/du).

The calculations suggest that barley provides a negative return on investment, accordingly the area of cultivated barley is decreasing. For date palm, the return on investment is also negative, despite expansion in Al-Azraq. Possible reasons for this as noted previously could be the date palm seedlings distributed by the Hashemite Fund, the extension of electrical service into these areas reducing irrigation costs or the practice deficit irrigation as described above for olives. Peach also returns a negative profit. Consequently, peach is the least cultivated in terms of area and has not undergone expansion in recent years.

Table 3–8 Return on Crop Production in Al-Azraq

	Crop Production (ton/du)	Crop Value		Base Production Cost (JD/du)	Water Requirement (m^3/du)	Irrigation Cost		Base Production Cost with Irrigation (JD/du)	Water Fee (JD/du)		Profit		Break Even Total Water Cost (JD/m^3)
		(JD/ton)	(JD/du)			(JD/m^3)	(JD/du)		Max (Free)	Min (0.1 JD/m^3)	Max (JD/du)	Min (JD/du)	
Olive	0.38	750	285	212	1,575	0.08	126	338	0	158	-53	-211	0.05
Grape	1.69	636	1,075	316	1,525	0.4	610	926	0	153	149	-4	0.50
Alfalfa	3.4	180	612	211	2,749	0.12	330	541	0	275	71	-204	0.15
Tomato	4.44	155	690	364	1,423	0.12	171	534	0	142	155	13	0.23
Barley	0.28	315	88	25	814	0.12	98	122	0	81	-34	-116	0.08

Table 3–9 Return on Fruit Trees in Al-Azraq

	Crop Production (ton/du)	Crop Value		Base Production Cost (JD/du)	Water Requirement (m^3/du)	Irrigation Cost		Base Production Cost with Irrigation (JD/du)	Water Fee (JD/du)		Profit		Break Even Total Water Cost (JD/m^3)
		(JD/ton)	(JD/du)			(JD/m^3)	(JD/du)		Max (Free)	Min (0.1 JD/m^3)	Max (JD/du)	Min (JD/du)	
Apple	2.5	545	1,362	242	1,640	0.4	656	898	0	164	464	300	0.68
Peach	1	634	634	291	1,579	0.4	632	922	0	158	-288	-446	0.22
Apricot	1.33	919	1,223	291	1,579	0.4	632	922	0	158	301	143	0.59
Pear	2.89	634	1,831	242	1,640	0.4	656	898	0	164	933	769	0.97
Cherry	1.5	919	1,379	291	1,640	0.4	656	947	0	164	433	269	0.66
Pomegranate	2	1,250	2,500	242	1,640	0.4	656	898	0	164	1602	1438	1.38
Date Palm	1	1,000	1,000	291	2,314	0.4	926	1216	0	231	-216	-448	0.31

Figure 3-6 Newly Planted Olive Farm

Figure 3-7 Abandoned Olive Farm

SECTION 4 - **SOLAR POWER**

Solar energy farming may be accomplished either directly using photovoltaics (PV), or indirectly using concentrated solar power (CSP). Concentrated solar power systems use lenses or mirrors and tracking systems to focus a large area of sunlight into a small beam to generate thermal energy, usually steam, and drive a heat engine generator. Photovoltaics convert light directly into electric current. There are several types of photovoltaic cells, such as thin film, monocrystalline silicon, polycrystalline silicon, and amorphous cells, as well as multiple types of concentrating solar power. To minimize the water needed, photovoltaics (PV) was selected for evaluation. This technology has a wide range of application from single home domestic systems to multi megawatt (mW) power plants.

Solar PV technology has been around for many years, though recent spikes in energy costs have renewed public interest in this and other renewable energy sources. A number of manufacturers and companies are now available to supply PV panels and associated equipment.

There are two general categories of PV power systems currently on the market. The first is a stand-alone system in which the PV panels are the primary source of power and a battery provides the energy storage for use when the PV power is not available. Stand-alone systems are generally used in remote and inaccessible locations such as water storage tanks, weather stations and communication stations. Stand-alone system output can be DC or single-phase AC.

The second type of PV power system, and the type recommended for use in Al-Azraq is the utility interactive, also known as grid-connected system, in which the utility is the primary source of power and the PV panels act as a secondary source. In this case, the PV power source operates in parallel with the utility offsetting the power drawn from the utility during daylight hours. The utility interactive system output is usually 3-phase AC, with voltage matched to the utility system, either directly or through a step-up transformer. The photovoltaic system at Al-Azraq site would be 3-phase and connected into the utility grid. Evaluation of the utility infrastructure and local utility interconnect standards for connecting a renewable energy source onto the grid is not in the scope of this preliminary analysis.

Advantages of a solar PV system include:

- Reduced risk of power disruption resulting from fossil fuel supply and associated price instability. Recently the fossil fuel has witnessed significant price fluctuations.
- Maximum hourly power production from this technology generally matches with peak hourly demand, thus making it suitable as a supplementary source. Use as a local supplementary source provides two savings: first it reduces the losses of electricity during the transmission and distribution process, and second it reduces the capital investment required for larger sized distribution and transmission lines.
- Reduction of greenhouse gas emissions; solar power plants play an important role in decreasing the environmental pollution caused by conventional fossil fuel power plants.
- PV technology and systems continue to evolve rapidly.
- Ease of extension and high flexibility.

Disadvantages of solar PV include:

- The system is considered unreliable in terms of advanced planning, as it is difficult to tell how much power will be produced from the PV in a given period of time, as the performance is dependent on the weather conditions which is highly variable.
- The current direct cost of solar PV power is widely acknowledged to be much greater than fossil fuel generation which is the conventional system in Jordan.

4.1 SOURCE OF PV POWER

The energy available from the sun is not the same at all locations on Earth. The equatorial and the tropical regions get more solar energy than other areas. The energy depends upon the latitude of the location, which determines the angle of inclination of the sun. Unlike energy from fossil fuel sources, solar energy is highly variable. During the day it varies from zero at sunrise to maximum at noon time and then to zero at sunset and during the night. During the year, it varies every day because of the ever changing inclination of the sun. The weather (clouds, rain and snow) constitutes a third variable.

Solar radiation, a value used to consider the variability of the available solar energy, is typically measured as an average kWh/m^2/d. NASA has published average solar radiation values for various locations around the world. For purposes of this analysis, NASA's solar radiation for Al-Azraq, with the latitude and longitude location of 31.5, 36.5,was compared with solar radiation data available through the Solar Pathfinder modeling program used in this analysis, to obtain the average solar radiation is estimated to be 5.34 kWh/m^2 /d on the incident surface. Backup data including a NASA data sheet, Solar Pathfinder results, and record high and low temperature data is included in **Appendix A**.

4.2 PV POWER SYSTEM DESIGN OBJECTIVE

In order to size the PV panel arrays and the associated equipment a design objective must be established first. The objective for this system is to find an affordable option for energy in the area to offset the cost of electricity and generate revenue. For purposes of this assessment, three separate systems for the area were evaluated to assess the output production and land area requirements for each.

4.3 SELECTION OF PV PANELS

In order to perform a conceptual level design, PV system components representative of the types to be used for a full scale design are selected and used in the calculations and system layouts. For purposes of this evaluation, the SunTech 275W panel (STP275-24/Vd) was chosen. This panel has one of the higher output wattage ratings in the industry, and is commercially available. This will maximize the PV system power produced on a per dunum footprint.

Each Suntech panel has Polycrystalline Silicon Cell technology and is nominally rated for 275 W. The panel dimensions are 1,956 mm x 992 mm (total panel area is 1.94 m²). See **Appendix B** for PV panel typical utility interactive inverter component data sheets.

4.4 SYSTEM CONFIGURATION

For the PV system to comply with the U.S. National Electric Code (NEC) it must be wired with 11 (minimum) to 12 (maximum) panels connected in series to keep from exceeding the 600 V rating of the wiring. Based on the Inverter selection and NEC requirements, the panels open circuit voltage and NEC temperature derating multiplier was used to determine the maximum voltage produced for the series string size. The open circuit voltage of each 275-W Sharp PV panel is 44.7 V. The 12 panels in series will produce 590 volts, which is less than the 600 volt rating of the inverter and the wire. Each series string of panels will have a maximum current of 8.26 A based on the short circuit current of the panel.

To connect the panels to the inverter, combiner boxes must be used to combine the series strings of PV panels. The recommended inverter has a combiner box within it, and is limited to six inputs with a maximum of 150 A each. Consequently, additional separate field mounted combiner boxes are necessary to reduce the total number of strings to a maximum of six prior to being wired into the inverter.

For example, a typical 500-kW layout would take up approximately 12,000 m² of land and would require 152 strings to combine 1,824 panels. Each of the strings should be wired to a disconnecting combiner box. By combining the strings in this manner the amperage and number of strings from the combiner box outputs will comply with the inverter input requirements. Once wired to the inverter the PV system output will be converted from DC to AC, and then wired to a circuit breaker within the main electrical distribution panel. See **Appendix C** for a typical electrical connection diagram.

Figure 4-1 is a representation of a large scale ground mounted PV array.

Figure 4-1 Conceptual Representation of Large Scale PV Array

4.5 PRELIMINARY DESIGN CALCULATIONS/ENERGY PRODUCTION

For purposes of this study, data was accumulated from several sources to compile the following conceptual designs. The number of panels for each design was determined by taking the size of each system and dividing it by wattage of each panel (275 W) shown in **Appendix B**. The average power produced was determined by a PV calculator program (Solar Pathfinder). The Solar Pathfinder program used a location approximately 136.8 km west of the installation location. The solar radiation data from NASA for the installation location was compared with the solar radiation data for the location used in the Solar Pathfinder program. The data was extrapolated to estimate production for the selected installation area, but it should be noted that the Solar Pathfinder data included in Appendix C is a good approximation of the performance of the installation without extrapolation, as the solar radiation data is very similar. After gathering this information, conceptual design layouts were prepared for the three systems at 500-kW, 1,000-kW and 1,500-kW capacity were developed. These are included in **Appendix D**.

Conceptual design data is summarized in **Table 4-1** through **Table 4-3.**

Table 4–1 Solar Module Data

Record Low Temperature(Degrees C)	-5
Record High Temperature(Degrees C)	43
Panel Model	Suntech 275W - STP275-24/Vd
Wattage	275
Voc	44.7
Voc Coefficient	0.33
Vmp	35.1
Pmax Coefficient	0.44

Table 4–2 Inverter Data

Inverter Model	Satcon Power Gate Plus 500kW
Minimum Inverter Operating Voltage	330 V
Maximum Inverter Operating Voltage	600 V

Table 4–3 String Calculation

Maximum Number of Panels/String	12.21	=	12 Panels/String
Minimum Number of Panels/String	10.21	=	11 Panels/String

The approximate land area required for each of the three different sized arrays is included in **Table 4.4**.

Table 4–4 Array Sizing

Number of Panels for Array Size	500-kW	1824 Panels	12,000 m^2
	1000-kW	3636 Panels	20,000 m^2
	1500-kW	5460 Panels	30,000 m^2

The system efficiency can be related to the total area of the array. The packing density is defined as the ratio of cell area to array area and it is related to the configuration of the module and to the shape of the cells. Circular silicon cells have a lower packing density when compared to square or rectangular cells. Modern photovoltaic systems have a packing density of 80 to 90 percent of the total area which has led to compact systems producing high power and occupying relatively small areas. Power density is defined as the system output power divided by the array area. **Table 4-5** present the power density of the three conceptual systems examined as part of this assessment.

Table 4–5 Power Density of the Conceptual Layouts

	Rated Power (Watt)	System Area (m^2)	Rated Power Density (W/m^2)
System 1	500,000	12,000	41.7
System 2	1000,000	20,000	50
System 3	1500,000	30,000	50

Table 4-6 through **Table 4-8** present the electricity generated by the three conceptual systems based on model results in kWh.

Table 4–6 500-kW Solar Installation

Month	Solar Pathfinder Incident Energy ($kWh/m^2/d$)	NASA Data Incident Energy ($kWh/m^2/d$)	Factor	Solar Pathfinder (kWh)	NASA Data Extrapolated (kWh)
January	2.67	2.91	1.09	45,150	49,208
February	3.57	3.68	1.03	50,957	52,527
March	4.81	4.92	1.02	65,216	66,707
April	6.11	6.26	1.02	70,774	72,511
May	7.17	7.22	1.01	75,776	76,304
June	8.07	8.01	0.99	78,788	78,202
July	8.00	7.86	0.98	81,869	80,436
August	7.28	7.05	0.97	81,475	78,901
September	6.25	6.02	0.96	76,893	74,063
October	4.69	4.41	0.94	67,739	63,695
November	3.32	3.15	0.95	53,348	50,616
December	2.45	2.61	1.07	42,295	45,057
Totals/ Averages	5.37	5.34	1	790,280	788,230

Table 4–7 1-mW Solar Installation

Month	Solar Pathfinder Incident Energy (kWh/m²/d)	NASA Data Incident Energy (kWh/m²/d)	Factor	Solar Pathfinder (kWh)	NASA Data Extrapolated (kWh)
January	2.67	2.91	1.09	90,004	98,094
February	3.57	3.68	1.03	101,577	104,707
March	4.81	4.92	1.02	130,001	132,974
April	6.11	6.26	1.02	141,083	144,547
May	7.17	7.22	1.01	151,051	152,104
June	8.07	8.01	0.99	157,058	155,890
July	8.00	7.86	0.98	163,202	160,346
August	7.28	7.05	0.97	162,415	157,284
September	6.25	6.02	0.96	153,281	147,640
October	4.69	4.41	0.94	135,033	126,971
November	3.32	3.15	0.95	106,346	100,901
December	2.45	2.61	1.07	84,315	89,821
Totals/ Averages	5.37	5.34	1	1,575,366	1,571,279

Table 4–8 1.5-mW Solar Installation

Month	Solar Pathfinder Incident Energy (kWh/m²/d)	NASA Data Incident Energy (kWh/m²/d)	Factor	Solar Pathfinder (kWh)	NASA Data Extrapolated (kWh)
January	2.67	2.91	1.09	135,152	147,300
February	3.57	3.68	1.03	152,532	157,232
March	4.81	4.92	1.02	195,216	199,680
April	6.11	6.26	1.02	211,857	217,058
May	7.17	7.22	1.01	226,825	228,407
June	8.07	8.01	0.99	235,847	234,093
July	8.00	7.86	0.98	245,070	240,781
August	7.28	7.05	0.97	243,890	236,185
September	6.25	6.02	0.96	230,174	221,704
October	4.69	4.41	0.94	202,771	190,665
November	3.32	3.15	0.95	159,693	151,516
December	2.45	2.61	1.07	126,610	134,878
Totals/ Averages	5.37	5.34	1.00	2,365,637	2,359,500

4.6 SCALE CONSIDERATIONS

One of the benefits of PV technology is its ability to produce a disproportionate amount of its output at times when system demand is high (daylight hours). In this sense, it is most efficiently used as a supplementary system, working in parallel with a conventional power source, offsetting demand during peak hours. In addition, in the case being considered, the energy is used most efficiently if used locally to avoid costs and losses associated with transmission long distances

However, using the system as a supplemental systems locally imposes constraints on the amount of energy that can be utilized in this manner and thus the size of the system. The amount of power that can be produced has to be limited to that which is consumed by the local population. Aspects relevant to the demand that could be offset by the system include:

- Nature of load
- Likely load profile and daily/seasonal variation
- Required reliability
- Likelihood of increase in demand

Figure 4-2 below shows the hourly electricity consumption pattern ordinates compared to the average consumption in Jordan.

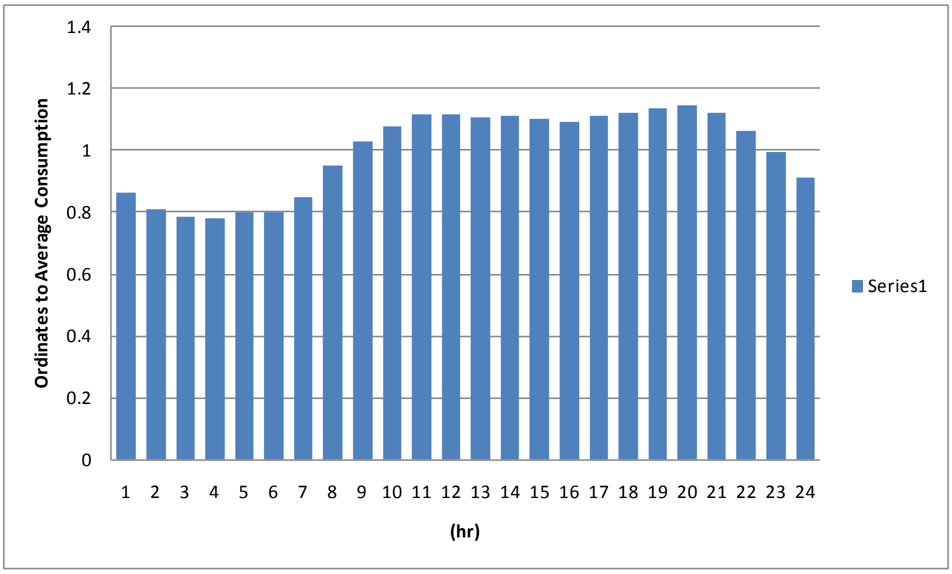


Figure 4-2 Daily Variations in Electricity Demand

As depicted in **Figure 4-2**, the daily demand varies from about 80 percent to 115 percent of average. Maximum consumptions occur between 10:00 and 22:00 which is in general agreement with the hours of maximum performance of the PV system.

The average per capita energy consumption in Jordan is 1,967 kWh. This may be related to a load per person by dividing by the number of hours in a year resulting in 0.225 kW/person. The current population of Al-Azraq is almost 10,000 which indicates an average load of about 2,250 kW would be expected, peaking to about 2,580 kW daily. Therefore the maximum size PV system that could be used locally by the inhabitants of Al-Azraq would be about 2.5 mW. Based on the power densities of about 50 W/m^2, this would be PV system on the order of 50 du in size. This is less than 0.05 percent of the total agricultural area in Al-Azraq.

SECTION 5 - ECONOMIC ANALYSIS

5.1 PV SYSTEM COST ANALYSIS

The economic viability and profitability of solar photovoltaic system in comparison with the conventional electricity generation system and other investments such as growing crops was assessed through calculating the photovoltaic system levelized electricity cost (LEC). The LEC is the price at which electricity must be generated from a specific source to breakeven. It is an economic assessment of the cost of the energy-generating system including all the costs over its lifetime: initial investment, operations and maintenance and cost of capital.

LEC can be defined as:

$$LEC = \frac{\sum_{t=1}^{n} \frac{I_t + M_t}{(1+r)^t}}{\sum_{t=1}^{n} \frac{E_t}{(1+r)^t}}$$

Where:

I_t = *Investment expenditures in the year t*

M_t = *Operations and maintenance expenditures in the year t*

E_t = *Electricity generation in the year*

r = *Discount rate*

n = *life of the system*

The LEC is highly dependent on the initial cost or installation cost, which has witnessed a drop of 20 percent through the last thirty years, and is related to the capacity and features of the system. With higher system capacity, a lower system capital cost in JD/Wp is expected. Moreover the recent technologies have led to the production of highly flexible systems that can be installed within fewer hours and do not require extensive land preparation prior to installation.

In this analysis it is necessary to set the system parameters. In this case the LEC for a photovoltaic crystalline silicon connected to grid system is considered. The system operates in parallel with the conventional electricity distribution system. Under these conditions the costs of a storage facility or a diesel generator are not taken into consideration. Moreover the cost for upgrading the current grid for the connection of the supplementary system or installing new power supply lines are not taken into consideration. Furthermore the cost model does not take into account the land use expenses, as it is assumed that the farmer already owns the land but it is a matter of whether to convert to solar harvesting or to continue growing up certain profitable crops.

The investment needed for such a system can be expressed as:

$I_o = C_{System} - C_{sub}$

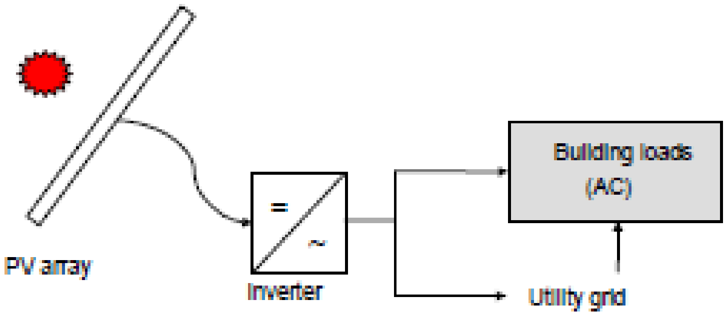
Where:

C_{System} = *the sum of the cost of the system*

C_{sub} = *possible financial subsidy on the initial cost*

Based on a review of available literature, installation may be expected to range between 2.8 JD/Wp and 8 JD/Wp. Discussions with a local vendor of small domestic PV systems indicated costs may be expected to be on the order of 1.8 JD/Wp. This value is consistent with the costs reported for the agricultural system found in Azraq, described in Section 2.3.4. Based on an interview with a farmer in Al-Azraq operating the PV powered center pivot irrigation equipment shown in **Figure 2-12**, the total cost of the 16-kWh system was about JD 27,000, including JD 20,000 solar panel, JD 4,000 – JD 5,000, for an imported inverter. This would be about 1.69 JD/Wp. These costs may be low since a larger system may require greater investment in site preparation.

In addition the cost of the PV modules there is the cost of balance of system (BoS) components. BoS components include the mounting structure (usually a metal framework to hold the module in the required position), invertors, wiring and control, in addition to the system design and installation fees. The BoS cost depends on the application and the use of the electricity produced by the system. Usually the cost of the PV panels is between 50 to 60 percent of the total cost of the PV system.



Based on the above, for purposes of this assessment we have selected 4 JD/Wp as an average market value. However the sensitivity of system viability to this initial cost is further discussed below.

Owing to the fact that the system performance is highly dependent on the light intensity, maintenance and operations are related to the measures that should be performed to ensure continuous access to sunlight through cleaning the panels at appropriate intervals, and to avoid shading for the modules. Requirements for cleaning are location dependant, frequent cleaning is expected when there is a high possibility of dust or sandstorms causing accumulation on the modules. Moreover electrical connections should be checked at regular intervals to avoid problems such as loose connections and corrosion. The LEC analysis is performed for a fixed operation and maintenance cost of 16 JD/kWp. Invertors were assumed to require replacement every 10 years, and their cost is assumed to be 18.5 percent of the capital cost of the system. In addition, it was assumed a site vehicle (pick up truck) would be needed with a useful life of 10 years.

The first-year energy production of the system is expressed in kilowatt hours generated per rated kilowatt peak of capacity per year (kWh/kWp). The kWh is a function of:

- The amount of sunshine the project site receives in a year
- How the system is mounted and oriented (i.e. flat, fixed tilt, tracking, etc.)
- The spacing between PV panels as expressed in terms of system ground coverage ratio (GCR)
- The energy harvest of the PV panel (i.e. performance sensitivity to high temperatures, sensitivity to low or diffuse light, etc.)
- System losses from soiling, transformers, inverters and wiring inefficiencies
- System availability largely driven by inverter downtime

Estimates of the first year production were developed in Section 4.5. A system degradation rate was applied to the initial system performance to reflect the wear of system components. The system degradation is largely a function of PV panel type and manufacturing quality. Silicon PV systems have been operating outdoors for more than 20 years and therefore the performance and degradation mechanisms are well understood. Most investors finance a solar system based on an assumed panel degradation rate of 0.5 to 1.0 percent per year. In this analysis a system degradation rate of 1 percent is assumed.

Silicon solar panels carry performance warranties for 25 years and have a useful life that is significantly longer, throughout this analysis a 25 years life cycle is assumed.

The discount rate is a measure of time value of money, and is often used to account for the risk inherent in an investment, a discount rate of 5 percent is assumed for this analysis.

A salvage value of 20% of the system initial capital cost is assumed. The salvage value is an estimate of the value of the asset at the end of its useful life, moreover a salvage value of 50% of the last invertor and last pickup costs, as those are replaced every 10 years.

Table 5-1 summarizes costs of the three conceptual systems sized at 500-kW, 1,000-kW and 1,500-kW based on a system capital cost of 4 JD/Wp.

Table 5–1 Baseline PV Costs Summary

System Capacity (kW)	Capital Cost (4 JD/Wp)	Yearly O & M Before Degradation (JD/y)	Inverter Replacement (JD/every 10 years)	Vehicle (JD, every 10 years)	LEC (JD/mWh)
500	2,000,000	8,000	370,200	25,000	222.9
1,000	4,000,000	16,000	740,400	25,000	221.5
1,500	6,000,000	24,000	1,110,600	25,000	220.5

5.1.1 Capital Cost Sensitivity

The computation of the LEC for the three conceptual systems was also performed for a variety of system capital cost ranging from 2.8 to 8 JD/Wp. The results are summarized in **Table 5-2**. The analysis is based on a discount rate of 5 percent, a life cycle of 25 years, a degradation rate of 1 percent for the system generated electricity, a maintenance and operation cost of 16 JD/KWp, and invertors replacement cost of 18.5 percent of the capital cost and every 10 years.

Table 5–2 LEC's (JD/mWh) Sensitivity to Capital Costs

System Cost (kW)	LEC at 2.8 JD/Wp Capital	LEC at 3 JD/Wp Capital	LEC at 4 JD/Wp Capital	LEC at 5 JD/Wp Capital	LEC at 6 JD/Wp Capital	LEC at 7 JD/Wp Capital	LEC at 8 JD/Wp Capital
500	160.8	171.1	223.0	274.8	326.7	378.5	430.4
1,000	159.1	169.5	221.5	273.5	325.5	377.6	429.6
1,500	158.2	168.5	220.5	272.5	324.4	376.4	428.4

The LEC is highly sensitive to the assumptions and input variables. Within the range of capital costs obtained from the literature, LEC is seen to more than double.

5.2 ECONOMIC COMPARISON

Table 5-3 below shows average cost of generation, transmission and distribution per 1 mWh of electricity in Jordan based on information presented in the 2008 and 2010 ERC Annual Report.

Table 5–3 Generation Transmission and Distribution Costs for Jordan's Conventional System

Sector	Item	JD/mWh 2007	JD/mWh 2008	JD/mWh 2010
Generation	Fuel	23.6	35.4	43.39
	Administrative, maintenance, funding and miscellaneous	7.6	8.1	22.61
Transmission	Cost of the national network, for each sold unit	4.8	4.4	
Distribution	Distribution costs per unit sold	7.3	8.8	12
Total costs of sold units from distribution networks		43.6	56.6	78

Comparison of the conventional power generation transmission and distribution costs with the LEC for PV electrical generation (**Table 5-3**) suggests PV power is nearly 2.8 times as costly as power currently being provided. It is noteworthy that this comparison doesn't include transmission or distribution in the PV power costs, but as stated earlier the 2010 annual report combines the administrative, maintenance, funding and miscellaneous cost under the generation cost with the transmission cost. Assuming that the transmission cost constitutes a ratio similar to its ratio in 2007 and 2008, which is almost 35% of the 22.61 JD/mWh, a generation cost in 2010 of 58 JD/mWh is estimated. In this case, the PV generation cost is almost 3.8 times the 2010 conventional system generation cost. Furthermore, even if the low end of the range of capital costs were used (See **Table 5-2**), PV generated power is still nearly 2.7 times as costly as that currently being produced.

Calculation for the initial capital cost of the system to produce LEC values equivalent to the conventional system generation cost of 58 JD/mWh was performed. The results indicate that the system cost needs to be 0.8 JD/Wp, 0.84 JD/Wp, and 0.86 JD/Wp systems of 500 KW, 1,000 KW and 1,500 KW, respectively. Thes costs area much lower than the lower bound of the current market prices. This exercise was also performed on the recent electricity production cost of 156 JD/mWh resulting from using heavy fuel in the absence of gas supply from Egypt. It was assumed that the transmission and distribution costs follow linear rate of increase similar to their 2007/2008 rates. The calculated generation cost is 137.2 JD/mWh. Calculations suggest that the system needs to have an initial capital cost of 2.39 JD/Wp, 2.37 JD/Wp, 2.34 JD/Wp, for systems of 500 KW, 1,000 KW and 1,500 KW respectively. These costs might be attainable in the near future since PV technology cost has seen a continuous decrease since the 1970s.

Comparison of the current domestic electricity tariffs with the LEC for PV electrical generation (**Table 5-1**) suggests PV power is more than 1.76 times the highest tariff rate (Table 2-14) for consumption over 500 kWh per month and more than 2.2 times the average domestic tariff rate.

5.2.1 LEC Values with a Crop Profit Equivalent

To further explore the potential economic viability of harvesting solar energy in place of crops, LEC calculations were performed to determine the price at which electricity would have to be sold to the grid to provide a similar profit to that currently being made through agriculture. To perform the calculations, profit was added into the numerator of the LEC calculation as a cost. The calculation was repeated for successful crops only, those with positive profits. The amount of profit, developed for the Al-Azraq area in Section 3.2 was based on the agricultural profit calculated per dunum multiplied by the number of dunums occupied by the three conceptual systems evaluated (500-kW, 1,000-kW and 1,500-kW). Possible water tariffs have not been included in the calculations. **Table 5-4** presents the annual profits for crops grown in an area equivalent to that which would be occupied by the three conceptual PV layouts.

Table 5–4 Yearly Profit for the Successful Crops and Fruit Trees in Al-Azraq (JD)

	Concept System 500-kW (area 12 Du)	Concept System 1,000-kW (area 20 Du)	Concept System 1,500-kW (area 30 Du)
Grape	1,785	2,975	4,463
Alfalfa	850	1,416	2,125
Tomato	1,861	3,101	4,652
Apple	5,573	9,288	13,932
Apricot	3,608	6,014	9,021
Pear	11,202	18,670	28,005
Cherry	5,191	8,652	12,978
Pomegranate	19,229	32,048	48,072

Table 5-5 below presents the cost at which electricity generated from these modules should be sold to produce an annual profit equivalent to that of growing up certain crops or trees.

Table 5–5 LEC Values for Similar Successful Crops Profit (JD/mWh)

System Capacity 5.3 (kW)	LEC (JD/mWh)								
	Base LEC	Grape	Alfalfa	Tomato	Apple	Apricot	Pear	Cherry	Pomegranate
500	223.0	225.5	224.2	225.6	230.7	228.0	238.6	230.2	249.8
1,000	221.5	223.6	222.5	223.7	228.0	225.7	234.5	227.5	243.9
1,500	220.5	222.6	221.5	222.7	227.0	224.7	233.5	226.6	242.9

The results suggest a relatively small increase in the LEC when including offsets for agricultural profits, up to about 12 percent depending on the crop. However, the costs for PV energy production are so much higher than existing conventional energy production that the approach is unlikely to be viable without significant subsidies as explored in the following section.

5.3.1 Water Saving as a National Investment

The preceding sections compares the value of electricity generated using PV to current power generation costs. This analysis neglects the benefit gained by reducing the rate of over abstraction of groundwater. The analysis that follows attempts to incorporate this benefit by accounting for the value of water saved. In order to incorporate this benefit, the water not used for agriculture is quantified as a financial benefit using benchmark water production costs in Jordan. This financial benefit may be used as a subsidy toward the capital investment in the system implementation as part of a national investment in the technology.

Current costs to provide water in the highlands is 0.35 JD/m^3, which is expensive by global standards. Yet the cost is expected to increase dramatically to ranges between 0.82 JD/m^3 up to 1.4 JD/m^3 after the implementation of the large scale projects which will help secure a sustainable water supply for the country. This indicates that water saved through converting to solar harvesting is expected to have a higher value in the near future, and the prevention of over abstraction can be viewed as an investment in the future.

In order to compute the economic benefit resulting from reducing agricultural water use by converting to farming to solar harvesting, three benchmark water rates were used:

- The current irrigation water fees for the highlands = 0.35 JD/m^3
- The anticipated irrigation water fees for water generated from As Samra expansion project = 0.82 JD/m^3
- The anticipated irrigation water fees for the water generated from the Red Dead connector = 1.4 JD/m^3.

These unit rates were multiplied by the annual consumption of an agricultural area of various successful crops, equivalent to that which would be occupied by a PV system of 500-kW, 1,000-kW and 1,500-kW to yield an annual cash flow equivalent of the saved water. The resulting annual cash flow for each crop is calculated, and expressed in terms of a present value. Conceptually this may be considered as the present value of water saved through implementing the system. The present value of water saved was then incorporated into the LEC calculation as a subsidy offsetting the capital investment, to determine if the approach may be economically viable when compared to conventional energy production. The annual water saved and total over 25 years for various crops is summarized in **Table 5-6**.

Table 5-6 Water Saved through System Implementation

Crop Type	Crop Water Requirement (m^3/du)	500-kW (12 du)		1,000-kW (20 du)		1,500-kW (30 du)	
		Annual (m^3)	25 years (m^3)	Annual (m^3)	25 years (m^3)	Annual (m^3)	25 years (m^3)
Olive	1,575	18,900	472,500	31,500	787,500	47,250	1,181,250
Grape	1,525	18,300	457,500	30,500	762,500	45,750	1,143,750
Alfalfa	2,749	32,988	824,700	54,980	1,374,500	82,470	2,061,750
Tomato	1,423	17,076	426,900	28,460	711,500	42,690	1,067,250
Barley	814	9,768	244,200	16,280	407,000	24,420	610,500
Apple	1,640	19,680	492,000	32,800	820,000	49,200	1,230,000
Peach	1,579	18,948	473,700	31,580	789,500	47,370	1,184,250
Apricot	1,579	18,948	473,700	31,580	789,500	47,370	1,184,250
Pear	1,640	19,680	492,000	32,800	820,000	49,200	1,230,000
Cherry	1,640	19,680	492,000	32,800	820,000	49,200	1,230,000
Pomegranate	1,640	19,680	492,000	32,800	820,000	49,200	1,230,000
Date Palm	2,314	27,768	694,200	46,280	1,157,000	69,420	1,735,500

The present value of the water savings after applying a discount rate of 5 percent and considering a lifecycle equivalent to the PV system of 25 years is shown in the **Table 5-7.** **Table 5-8** presents the calculated LEC if the present value of the water saved were used to offset the capital investment as a subsidy.

Table 5-7 Present Value of Water Savings at a Discount Rate of 5 percent and a Life Cycle of 25 Years

Crop Type	Current Highland Cost (0.35 JD/m^3)			As Samra Fees (0.82 JD/m^3)			Red Dead Connector Fees (1.4 JD/m^3)		
	500-kW (12 du)	1,000-kW (20 du)	1,500-kW (30 du)	500-kW (12 du)	1,000-kW (20 du)	1,500-kW (30 du)	500-kW (12 du)	1,000-kW (20 du)	1,500-kW (30 du)
Date	97,893	163,155	244,733	229,349	382,249	573,373	391,572	652,620	978,930
Pomegranate	94,785	157,976	236,963	222,068	370,114	555,171	379,141	631,902	947,853
Cherry	170,862	284,770	427,155	400,306	667,176	1,000,764	683,449	1,139,081	1,708,622
Pear	88,446	147,409	221,114	207,215	345,359	518,038	353,782	589,637	884,456
Apricot	50,594	84,323	126,484	118,534	197,556	296,334	202,374	337,291	505,936
Peach	101,933	169,888	254,833	238,815	398,024	597,036	407,732	679,554	1,019,330
Apple	98,142	163,569	245,354	229,932	383,220	574,830	392,567	654,278	981,416
Barley	97,893	163,155	244,733	229,349	382,249	573,373	391,572	652,620	978,930
Tomato	101,933	169,888	254,833	238,815	398,024	597,036	407,732	679,554	1,019,330
Grape	101,933	169,888	254,833	238,815	398,024	597,036	407,732	679,554	1,019,330
Alfalfa	101,933	169,888	254,833	238,815	398,024	597,036	407,732	679,554	1,019,330
Olives	143,825	239,708	359,563	336,962	561,603	842,404	575,300	958,834	1,438,250

Table 5-8 LEC Values after initial cost Subsidy Equivalent to Crops Water Saving Net Present Value

Crop or Fruit Tree	Current Fees			As Samra			Red Dead Connector		
	LEC 500-kW	LEC 1,000-kW	LEC 1,500-kW	LEC 500-kW	LEC 1,000-kW	LEC 1,500-kW	LEC 500-kW	LEC 1,000-kW	LEC 1,500-kW
LEC values without Subsidy	222.9	221.5	220.5	222.9	221.5	220.5	222.9	221.5	220.5
Date Palm	209.45	210.18	209.21	191.28	201.78	194.03	168.85	176.23	175.30
Pomegranate	213.39	213.48	212.50	200.51	209.83	201.74	184.62	189.42	188.47
Cherry	213.39	213.48	212.50	200.51	209.83	201.74	184.62	189.42	188.47
Pear	213.39	213.48	212.50	200.51	209.83	201.74	184.62	189.42	188.47
Apricot	213.75	213.78	212.80	201.35	210.56	202.44	186.04	190.61	189.66
Peach	213.75	213.78	212.80	201.35	210.56	202.44	186.04	190.61	189.66
Apple	213.39	213.48	212.50	200.51	209.83	201.74	184.62	189.42	188.47
Barley	218.23	217.52	216.54	211.83	219.70	211.20	203.94	205.57	204.61
Tomato	214.66	214.54	213.56	203.49	212.42	204.23	189.69	193.66	192.71
Grape	214.07	214.04	213.06	202.09	211.20	203.06	187.31	191.66	190.71
Alfalfa	206.91	208.05	207.08	185.31	196.58	189.05	158.67	167.72	166.80
Olives	213.77	213.80	212.82	201.40	210.61	202.49	186.14	190.69	189.74

Table 5-8 shows that even if the capital cost for PV implementation were subsidized at the full value of the water saved over a period of 25 years, the LEC for the power generated is still well above that of conventional power generation. The maximum reduction occurs when converting from Alfalfa to solar harvesting. Based on an area of 12 du this reduction is almost 71 percent, the LEC value after a system subsidy of JD 407,732 is reduced from 222.0 JD/mWh to 158.67 JD/mWh, i.e. the LEC has dropped from almost 3.8 times the conventional system electricity generation cost to about 2.7 times. Economically this implies that the cost of water saved through converting to PV solar harvesting is of low value compared to the cost and expenditures required to purchase, install and operate the PV systems.

Since the primary objective of this study is to reduce the rate of groundwater abstraction, to the safe yield of the basin (24 MCM), calculations were performed to determine the the total reduction in area of cultivation needed be replaced by solar farms and thus the total electicity needed to be procuced and consumed. The yearly abstraction resulted from the estimated consumption for the predominate crops in Azraq is shown in **Table 5-9**.

Table 5–9 Yearly Water Consumption for the Predominate Crops in Azraq

Crop	Area (du)	Annual Consumption (m^3/du)	Total Water Consumption (MCM)
Alfalfa	4,900	2749	13.47
Barley	1,650	814	1.34
Grape	11,350	1525	17.31
Olive	82,000	1575	129.15
Fruit tress	7,200	1640	11.81
Tomato	3,600	1423	5.12
Total			178.20

The total cultivated land in Al-Azraq in 2010 is 114,5 du. Olive farms constitute almost 70% of the cultivated land, and consume 129.15 MCM. Section 3 revealed that growing olives in Al-Azraq is not profitable. If all of the olive farms are converted to solar farms then the yearly water abstraction will be reduced substantially to about 49 MCM. Further reduction could be achieved by converting barley and alfalfa farms to solar farms. Such areas are capable of hosting photovoltaic solar systems of huge capacities as shown in **Table 5-10**.

Table 5–10 Photovoltaic solar Systems Capacities after Converting Olives, Barley, and Alfalfa Farms to Solar Farms

Crop	Area (du)	System Rated Power (MW)	No of Panels	Produced Electricity (KWh)/year
Olive	82,000	4,100.0	14,924,000	6,449,287,143
Barley	1,650	82.5	300,300	129,772,241
Alfalfa	4,900	245.0	891,800	385,384,232
Total	88,550	4427.5	16,116,100	696,4443,616

The table above shows that replacing olive farms by solar harvesting will substantially reduce the abstraction from the basin and will provide a PV system of 4,100 mW capacity which is higher than the total current capacity of the power plants in the Kingdom of 3,069 mW. Taking this analyis to the national scale is beyond the objectives of this study, but it is worth noting that photovoltaic systems are highly efficient in terms of the capacity of the system compared to the system required area. However, in the absence of sufficient storage capacity these system cannot be used independently for electricity supply If Al-Azraq is to act as a central photovoltaic solar power plant for the nation, the current transmission network would need to be updated significantly to work in a reverse direction. This will increase the cost of the system and will produce higher LEC values, given that the produced electricity will no longer be used locally.

SECTION 6 - CONCLUSIONS

With limited resources, Jordan faces two critical problems; the availability of clean water and inexpensive energy. Nowhere is the water problem as acute as in Al-Azraq, where agricultural water demand is estimated to be more than 7 times the sustainable yield of the aquifer and precipitation is insignificant. Unless more effectively managed, dramatic growth in the agricultural sector in Al-Azraq will only exacerbate this problem in the future and most certainly impact the livelihood of local residents. Nearly all the generated electricity in Jordan is produced from fossil fuels and it relies almost solely on imported fossil fuel to satisfy its national energy demand. Jordan is spending more than 50 percent of its export earnings on petroleum, about 96% of Jordan's electricity generation is fuelled by imports, of which 80% is from the Egyptian natural gas.

The concept examined as part of this assessment is a logical solution of these two problems, producing clean sustainable solar electricity by reducing water abstraction for agriculture. Jordan is considered one of the sun-belt countries, it receives high solar radiation on its horizontal surface, therefore, switching to renewable energy sources for electricity generation is highly important on the national scale. Unfortunately this logical solution is not supported by economic analysis. At present, the capital investment needed to implement PV solar generation is too high and the water saved is too small for this approach to be considered viable. The economic model shows that the LEC values for the generation cost of the photovoltaic solar technology is between about 220.5 JD/mWh and 222.9 JD/mWh, almost 3.8 times the conventional system generation cost under the normal conditions and 2.2 times the average domestic tariff.

In 2011 the civil unrest in Egypt has resulted in several explosions to the Egyptian gas pipeline which has caused disruption of the gas supply to Jordan. As a result Jordan has relied on costlier heavy fuel oil for most of 2011 to produce electricity. This has pushed the electricity production cost to 156 JD/mWh, and has raised questions toward the reliability of this supply source. Moreover there has been a dramatic rise in the need to develop and consider alternate energy resources such as PV solar energy and its sister technology the CSP. If this geopolitical situation persists then installing PV systems to supplement the current system might become marginally economically viable. Under these conditions the estimated LEC of power generation is 137.2 JD/mWh, which is closer to the LEC values for PV as mentioned above.

Investment in PV is capital intensive. For purposes of this assessment an average unit capital cost of 4 JD/Wp was assumed based on a review of literature and interviews with local vendors. Calculations suggest that under 2010 conditions, the unit capital cost would need to be about 0.8 JD/Wp in order for a system to be economically viable. Under 2011 conditions with higher generation costs associated with the disruption of Egyptian gas, the unit capital cost would need to be about 2.34 JD/Wp, much closer to current market prices.

The use of subsidies may reduce the capital costs necessary. This assessment examined the subsidies in an amount of the value of water saved over a period. The subsidized LECs vary by the type of crop replaced, however, even under the most favorable conditions, the PV LEC is still above the 2011, inflated LEC of conventional production.

Considering the solar energy as part of national strategy to meet future energy needs is beyond the scope of this study. If Al-Azraq is to play a significant role as a central PV plant to supply Jordan, then converting the olive farms only to solar farms will be more than sufficient to satisfy the current required system capacity of 3,069 mW. It should be noted that the required system electrical capacity will double in 2030 due to the population growth, the industrial development and the need to support the major water projects such as Disi and the Red Dead connector. Such analysis would need to consider costs of expansion of the conventional electricity generation system to determine whether expansion with solar energy is viable.

In summary, investment in PV with an objective of reducing water abstraction in the Eastern Highlands is not currently economically viable. If the current geopolitical conditions persist and the associated disruption of gas from Egypt, such an investment may be marginally viable in the near future with the expected continued reduction in PV panel costs. Furthermore, the area of crop cultivation to accommodate solar farms to meet local demands, and thus the amount of water saved, is minimal. To make a significant difference in the amount of water abstracted in achieving the safe yield of the basin, a system on the scale of the current production capacity of Jordan would be needed.

SECTION 7 - REFEENCES

Agricultural Credit Corporation. 2005. *Agricultural Costs and Returns Guide*.

The Al-Azraq Oasis Restoration Project. 2008-2010.

Department of Statistics. 2010. *Agricultural Prices*.

Department of Statistics. 2009. *Agricultural Statistics Newsletter*.

Department of Statistics. 2010. *Statistics of Plant Production*.

Ministry of Agriculture. Al-Azraq Agricultural Directorate, 2011. Internal Records.

Ministry of Agriculture. 2009. *Annual Statistical Report*.

Electricity Regulatory Commission. 2008. *Annual Report.*

Electricity Regulatory Commission. 2010. *Annual Report.*

Sills, B. Aug 29, 2011. "*Solar May Produce Most of World's Power by 2060, IEA Says* ". Bloomberg. http://www.bloomberg.com/news/2011-08-29/solar-may-produce-most-of-world-s-power-by-2060-iea-says.html

Allen, R. G.; L. S. Pereira; D. Raes; and M. Smith. 1998. *Crop Evapotranspiration - Guidelines for Computing Crop Water Requirements*. FAO Irrigation and Drainage Paper 56. Rome.

Ayers, S.R. and D.W. Cot. 1985. (reprinted 1989 and 1994). *Water Quality for Agriculture*. FAO Irrigation and Drainage Paper 29.

German-Jordan Programme "Management of Water Resources". 2010. *Farming in the Desert: Analysis of the Agricultural Situation in the Al-Azraq Basin*.

Fariz, Gh. and A. Hatough-Bouran (October 18-19, 1996). "The Al-Azraq Oasis Conservation Project". IUCN Montreal Workshop on Water and Population Dynamics: Local Approaches to Global Challenge.

Dottridge, J. and N. Abu Jaber. 1999. "Groundwater resources and quality in northeastern Jordan: safe yield and sustainability." Applied Geography 19 (1999) p. 313–323

REN21. 2011. "Renewables 2011: Global Status Report". p. 17. http://www.ren21.net/Portals/97/documents/GSR/GSR2011_Master18.pdf.

Renewable Energy Technologies. 2001. *World Energy Assessment*. p. 221

http://www.terhaal.com/jordan-Al-Azraq

http://www.rscn.org.jo/orgsite/Portals/0/maps/established%20reserves%20maps/Al-Azraq -wetland-reserve_B.jpg

APPENDIX A - SOLAR ENERGY SUPPORTING DATA

APPENDIX B - PHOTOVOLTAIC PANEL SPECIFICATIONS

APPENDIX C - ELECTRICAL CONNECTION DIAGRAM

APPENDIX D - CONCEPTUAL LAYOUTS

500kW

Summary Report

Solar Obstruction Data

Month	Actual Shaded Solar Radiation Azimuth=180.0 Tilt=0.0 KWH/m ^{2} /day	Actual Shaded AC Energy (KWH) Azimuth=180.00 Tilt=0.00	Actual Unshaded AC Energy (KWH) Azimuth=180.0 Tilt=0.00	Ideal Unshaded AC Energy (KWH) Azimuth=180.0 Tilt=31.50	PV Solar Cost Savings 0.2728 ($/KWH)	PVWatts Unshaded % Actual Site Azimuth=180.0 Tilt=0.00	Actual Site Efficiency % Azimuth=180.0 Tilt=0.00	Ideal Site Efficiency % Azimuth=180.0 Tilt=31.50
January	2.67	31,775.00	31,775.00	45,150.00	$8,668.22	99.73 %	72.43 %	99.98 %
February	3.57	39,130.00	39,130.00	50,957.00	$10,674.66	100.00 %	77.62 %	100.00 %
March	4.81	57,923.00	57,923.00	65,216.00	$15,801.39	99.95 %	88.21 %	100.00 %
April	6.11	69,360.00	69,362.00	70,774.00	$18,921.41	99.62 %	97.09 %	99.74 %
May	7.17	80,868.00	80,868.00	75,776.00	$22,060.79	99.95 %	100.00 %	100.00 %
June	8.07	88,518.00	88,518.00	78,788.00	$24,147.71	99.98 %	100.00 %	99.95 %
July	8.00	90,068.00	90,068.00	81,869.00	$24,570.55	99.93 %	100.00 %	99.99 %
August	7.28	81,531.00	81,531.00	81,475.00	$22,241.66	100.00 %	99.45 %	100.00 %
September	6.25	68,340.00	68,340.00	76,893.00	$18,643.15	99.85 %	88.03 %	99.87 %
October	4.69	53,471.00	53,471.00	67,739.00	$14,586.89	100.00 %	78.32 %	99.93 %
November	3.32	37,577.00	37,578.00	53,348.00	$10,251.01	99.47 %	70.69 %	99.69 %
December	2.45	28,353.00	28,353.00	42,295.00	$7,734.70	99.97 %	69.58 %	99.75 %
Totals	**64.39 Effect: 91.99% Sun Hrs: 5.37**	**726,914.00**	**726,917.00**	**790,280.00**	**$198,302.14**	**99.87 % Unweighted Yearly Avg**	**86.79 % Unweighted Yearly Avg**	**99.91 % Unweighted Yearly Avg**

Notes: [None]

IMW

Summary Report

Solar Obstruction Data

Month	Actual Shaded Solar Radiation Azimuth=180.0 Tilt=0.0 KWH/m ^{2} /day	Actual Shaded AC Energy (KWH) Azimuth=180.00 Tilt=0.00	Actual Unshaded AC Energy (KWH) Azimuth=180.0 Tilt=0.00	Ideal Unshaded AC Energy (KWH) Azimuth=180.0 Tilt=31.50	PV Solar Cost Savings 0.2728 ($/KWH)	PVWatts Unshaded % Actual Site Azimuth=180.0 Tilt=0.00	Actual Site Efficiency % Azimuth=180.0 Tilt=0.00	Ideal Site Efficiency % Azimuth=180.0 Tilt=31.50
January	2.67	63,341.00	63,341.00	90,004.00	$17,279.42	99.73 %	72.43 %	99.98 %
February	3.57	78,001.00	78,001.00	101,577.00	$21,278.67	100.00 %	77.62 %	100.00 %
March	4.81	115,468.00	115,468.00	130,001.00	$31,499.67	99.95 %	88.21 %	100.00 %
April	6.11	138,263.00	138,267.00	141,083.00	$37,718.15	99.62 %	97.09 %	99.74 %
May	7.17	161,202.00	161,202.00	151,051.00	$43,975.91	99.95 %	100.00 %	100.00 %
June	8.07	176,458.00	176,458.00	157,058.00	$48,137.74	99.98 %	100.00 %	99.95 %
July	8.00	179,546.00	179,546.00	163,202.00	$48,980.15	99.93 %	100.00 %	99.99 %
August	7.28	162,527.00	162,527.00	162,415.00	$44,337.37	100.00 %	99.45 %	100.00 %
September	6.25	136,231.00	136,231.00	153,281.00	$37,163.82	99.85 %	88.03 %	99.87 %
October	4.69	106,590.00	106,590.00	135,033.00	$29,077.75	100.00 %	78.32 %	99.93 %
November	3.32	74,908.00	74,910.00	106,346.00	$20,434.90	99.47 %	70.69 %	99.69 %
December	2.45	56,523.00	56,523.00	84,315.00	$15,419.47	99.97 %	69.58 %	99.75 %
Totals	**64.39 Effect: 91.99% Sun Hrs: 5.37**	**1,449,058.00**	**1,449,064.00**	**1,575,366.00**	**$395,303.02**	**99.87 % Unweighted Yearly Avg**	**86.79 % Unweighted Yearly Avg**	**99.91 % Unweighted Yearly Avg**

Notes: [None]

1.5MW

Summary Report

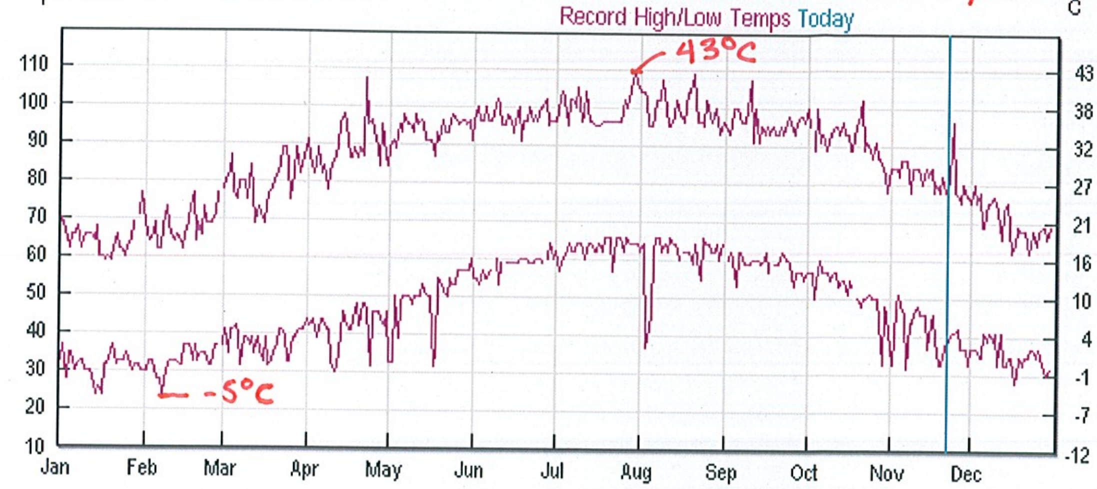
Solar Obstruction Data

Month	Actual Shaded Solar Radiation Azimuth=180.0 Tilt=0.0 $KWH/m^2/day$	Actual Shaded AC Energy (KWH) Azimuth=180.00 Tilt=0.00	Actual Unshaded AC Energy (KWH) Azimuth=180.0 Tilt=0.00	Ideal Unshaded AC Energy (KWH) Azimuth=180.0 Tilt=31.50	PV Solar Cost Savings 0.2728 ($/KWH)	PVWatts Unshaded % Actual Site Azimuth=180.0 Tilt=0.00	Actual Site Efficiency % Azimuth=180.0 Tilt=0.00	Ideal Site Efficiency % Azimuth=180.0 Tilt=31.50
January	2.67	95,117.00	95,117.00	135,152.00	$25,947.92	99.73 %	72.43 %	99.98 %
February	3.57	117,133.00	117,133.00	152,532.00	$31,953.88	100.00 %	77.62 %	100.00 %
March	4.81	173,392.00	173,392.00	195,216.00	$47,301.34	99.95 %	88.21 %	100.00 %
April	6.11	207,624.00	207,629.00	211,857.00	$56,639.83	99.62 %	97.09 %	99.74 %
May	7.17	242,071.00	242,071.00	226,825.00	$66,036.97	99.95 %	100.00 %	100.00 %
June	8.07	264,976.00	264,976.00	235,847.00	$72,285.45	99.98 %	100.00 %	99.95 %
July	8.00	269,614.00	269,614.00	245,070.00	$73,550.70	99.93 %	100.00 %	99.99 %
August	7.28	244,062.00	244,062.00	243,890.00	$66,580.11	100.00 %	99.45 %	100.00 %
September	6.25	204,569.00	204,569.00	230,174.00	$55,806.42	99.85 %	88.03 %	99.87 %
October	4.69	160,061.00	160,061.00	202,771.00	$43,664.64	100.00 %	78.32 %	99.93 %
November	3.32	112,487.00	112,489.00	159,693.00	$30,686.45	99.47 %	70.69 %	99.69 %
December	2.45	84,877.00	84,877.00	126,610.00	$23,154.45	99.97 %	69.58 %	99.75 %
Totals	**64.39**	**2,175,983.00**	**2,175,990.00**	**2,365,637.00**	**$593,608.16**	**99.87 %**	**86.79 %**	**99.91 %**
	Effect: 91.99%					**Unweighted Yearly Avg**	**Unweighted Yearly Avg**	**Unweighted Yearly Avg**
	Sun Hrs: 5.37							

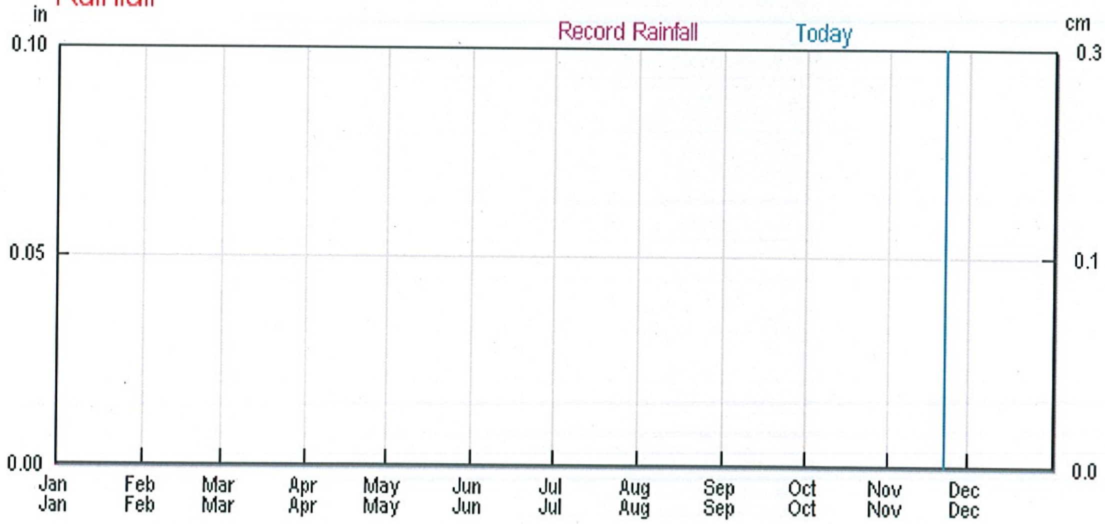
Notes: [None]

MARKA INTERNATIONAL AIRPORT
AMMAN, JORDAN

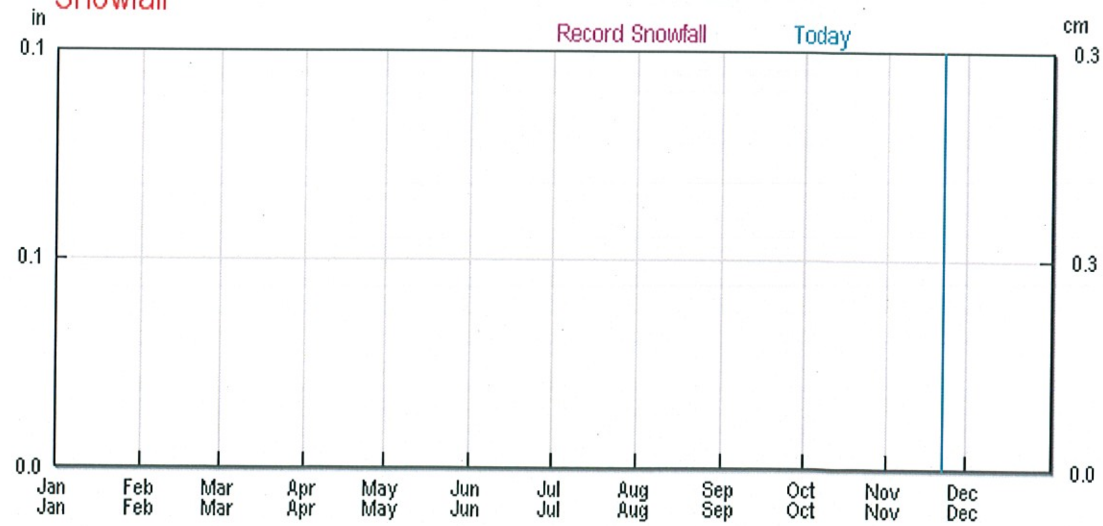
High / Low Temperature



Rainfall



Snowfall



SSE Homepage | Find A Different Location | Accuracy | Methodology | Parameters (Units & Definition)

ATMOSPHERIC SCIENCE DATA CENTER

NASA Surface meteorology and Solar Energy - Available Tables

Latitude 31.85 / Longitude 36.5 was chosen.

Geometry Information

Elevation: **708** meters
taken from the NASA GEOS-4 model elevation

Northern boundary
32

Western boundary
36

Center
Latitude **31.5**
Longitude **36.5**

Eastern boundary
37

Southern boundary
31

Show A Location Map

Parameters for Solar Cooking:

Monthly Averaged Insolation Incident On A Horizontal Surface (kWh/m²/day)

Lat 31.85 Lon 36.5	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
22-year Average	2.91	3.68	4.92	6.26	7.22	8.01	7.86	7.05	6.02	4.41	3.15	2.61

Parameter Definition

Monthly Averaged Midday Insolation Incident On A Horizontal Surface (kW/m²)

Lat 31.85 Lon 36.5	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
22-year Average	0.44	0.52	0.66	0.80	0.89	0.95	0.94	0.90	0.84	0.66	0.47	0.40

Parameter Definition

Monthly Averaged Clear Sky Insolation Incident On A Horizontal Surface (kWh/m²/day)

Lat 31.85 Lon 36.5	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
22-year Average	3.88	4.78	6.15	7.37	7.95	8.17	7.97	7.14	6.21	4.83	3.69	3.33

Parameter Definition

Monthly Averaged Clear Sky Days (days)

Lat 31.85 Lon 36.5	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
22-year Average	2	2	2	2	4	10	13	13	11	6	3	2

Parameter Definition

Parameters for Sizing and Pointing of Solar Panels and for Solar Thermal Applications:

Monthly Averaged Insolation Incident On A Horizontal Surface (kWh/m²/day)

Lat 31.85 Lon 36.5	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Average
22-year Average	2.91	3.68	4.92	6.26	7.22	8.01	7.86	7.05	6.02	4.41	3.15	2.61	5.34

Table No. (19)
Distribution Tariff Development (Fils/KWh)

	From 1993/6/15 to 1996/4/30	From 1996/5/1 to 2002/6/15	From 2002/6/16 to 2003/12/31	From 2004/1/1 to 2004/4/2	From 2004/4/3 to 2004/5/31	From 2004/6/1 to 2005/7/8	From 2005/7/9 to 2008/3/13	From 2008/3/14
Standard Domestic Tariff:								
From 1 - 160 KWh / Month	28.0	30.0	31.0	31.0	31.0	31.0	31.0	32.0
From 161 - 300 KWh / Month	52.0	52.0	55.0	55.0	57.0	57.0	59.0	71.0
From 301 - 500 KWh / Month	55.0	60.0	64.0	64.0	65.0	65.0	67.0	85.0
More than 500 KWh / Month	70.0	75.0	80.0	80.0	80.0	80.0	82.0	113.0
TV and Broadcasting	45.0	60.0	60.0	60.0	60.0	60.0	61.0	86.0
Commercial	50.0	60.0	62.0	62.0	62.0	62.0	63.0	86.0
Small Industrial Consumer	30.0	36.0	38.0	38.0	39.0	39.0	41.0	49.0
Medium Industrial Consumer :								
Night Energy	20.00	21.00	25.00	25.00	27.00	27.00	28.00	36.00
Day Energy	25.00	33.00	35.00	35.00	36.00	36.00	38.00	46.00
Maximum Load (JD / KW/ Month)	3.05	3.05	3.05	3.05	3.05	3.05	3.05	3.79
Agriculture	21.00	23.00	26.00	26.00	28.00	28.00	31.00	47.00
Three Part Tariff for Agriculture :								
Night Energy	-	-	-	-	-	-	30.00	36.00
Day Energy	-	-	-	-	-	-	20.00	46.00
Maximum Load (JD / KW/ Month)	-	-	-	-	-	-	3.05	3.79
Water Pumping	30.00	34.00	38.00	38.00	38.00	38.00	40.00	41.00
Hotels	50.00	60.00	60.00	60.00	59.00	59.00	60.00	86.00
Three Part Tariff for Hotels :								
Night Energy	-	-	-	-	-	44.00	45.00	70.00
Day Energy	-	-	-	-	-	55.00	56.00	81.00
Maximum Load (JD / KW/ Month)	-	-	-	-	-	3.05	3.05	3.79
Ports Corporation	-	-	-	-	44.60	44.60	46.60	58.00
Streets Lighting *	13.00	20.00	25.00	25.00	27.00	27.00	30.00	51.00
Jordan Armed Forces **				67.00	67.00	67.00	67.00	81.00
Mixed Tariff Commercial/ Agriculture								73.0
Minimum Charge for Domestic Consumers (JD) / Month	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Minimum Charge for Other Consumers (JD) / Month	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25

* above 1988 Consumption level
** Some Consumers have discount about 25 %

STP275 - 24/Vd
STP280 - 24/Vd

SUNTECH

Solar powering a green future™

280 Watt
POLYCRYSTALLINE SOLAR MODULE

Features

14.4%
High module conversion efficiency
(up to 14.4%), through superior cell technology and leading manufacturing capability

0/+5%
Positive tolerance
Guaranteed positive tolerance from 0/+5% ensures power output reliability

Self-clean
Self-cleaning & anti-reflective
Anti-reflective, hydrophobic layer improves light absorption and reduces surface dust

Weak light
Excellent weak light performance
Excellent performance under low light environments (mornings, evenings, and cloudy days)

3800Pa 5400Pa
Extended wind and snow load tests
Entire module certified to withstand extreme wind (3800 Pascal) and snow loads (5400 Pascal) *

2%
Suntech current sorting process
All Suntech modules sorted and packaged by amperage, maximizing system output by reducing mismatch losses by up to 2%

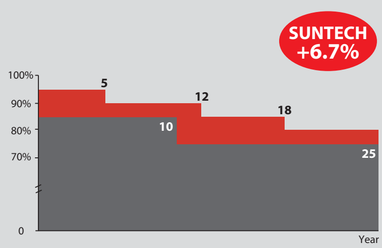
Certification and standards:
UL1703, IEC 61215, IEC 61730, conformity to CE

C US IEC CE

Trust Suntech to Deliver Reliable Performance Over Time

- World's No.1 manufacturer of crystalline silicon photovoltaic modules
- Unrivaled manufacturing capacity and world-class technology
- Committed to local manufacturing with our state-of-the-art module production factory located in Goodyear, Arizona
- Bankable brand; respected by global financial institutions

Industry-leading warranty based on Pnom



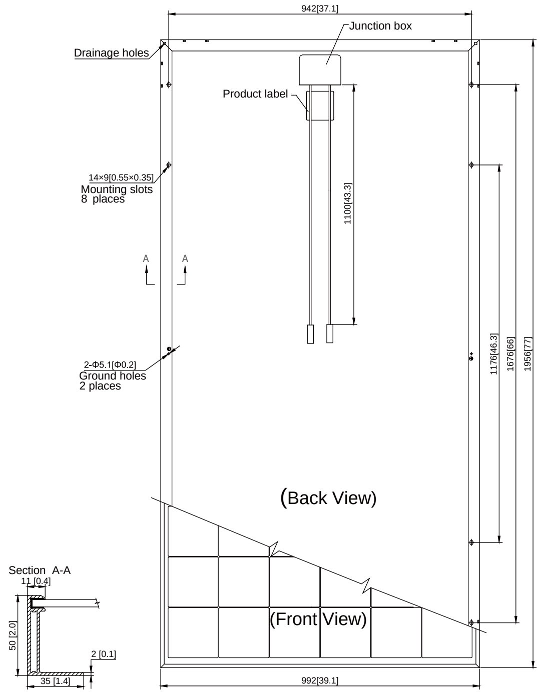
- Based on nominal power (Pnom)
- Warrants 6.7% more power than the market standard over 25 years
- 25-year transferrable power output warranty: 5 years/95%, 12 years/90%, 18 years/85%, 25 years/80% **
- 10-year material and workmanship warranty

Modules made in Suntech's Arizona factory fully meet the requirements of the American Recovery and Reinvestment Act (ARRA) and Buy American Act (BAA), and are Trade Agreement Act (TAA) compliant.

Strict production guidelines staffed by highly-trained manufacturing experts and rigorous quality control ensures we deliver only the highest quality products to our customers.

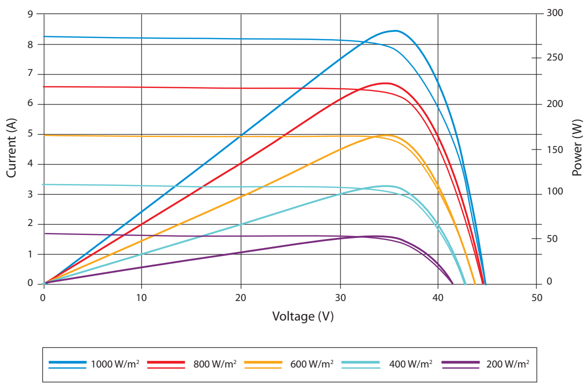
* Please refer to Suntech Standard Module Installation Manual for details.
** Please refer to Suntech Product Warranty for details.

STP275 - 24/Vd
STP280 - 24/Vd



Note: mm [inch]

Current-Voltage & Power-Voltage Curve (280-24)



Exellent performance under weak light conditions: at an irradiation intensity of 200 W/m² (AM 1.5, 25 °C), 95.5% or higher of the STC efficiency (1000 W/m²) is achieved

Electrical Characteristics

STC	STP275-24/Vd	STP280-24/Vd
Optimum Operating Voltage (Vmp)	35.1 V	35.2 V
Optimum Operating Current (Imp)	7.84 A	7.95 A
Open - Circuit Voltage (Voc)	44.7 V	44.8 V
Short - Circuit Current (Isc)	8.26 A	8.33 A
Maximum Power at STC (Pmax)	275 W	280 W
Module Efficiency	14.2%	14.4%
Operating Module Temperature	-40 °C to +85 °C	
Maximum System Voltage	600 V DC (UL)/ 1000 V DC (IEC)	
Maximum Series Fuse Rating	20 A	
Power Tolerance	0/+5 %	

STC: Irradiance 1000 W/m², module temperature 25 °C, AM=1.5;
Best in Class AAA solar simulator (IEC 60904-9) used, power measurement uncertainty is within +/-3%

NOCT	STP275-24/Vd	STP280-24/Vd
Maximum Power (W)	201 W	204 W
Maximum Power Voltage (V)	31.9 V	32.0 V
Maximum Power Current (A)	6.29 A	6.39 A
Open Circuit Voltage (Voc)	40.7 V	40.8 V
Short Circuit Current (Isc)	6.68 A	6.74 A

NOCT: Irradiance 800 W/m², ambient temperature 20 °C, wind speed 1 m/s;
Best in Class AAA solar simulator (IEC 60904-9) used, power measurement uncertainty is within +/-3%

Mechanical Characteristics

Solar Cell	Polycrystalline 156 × 156 mm (6 inches)
No. of Cells	72 (6 × 12)
Dimensions	1956 × 992 × 50 mm (77.0 × 39.1 × 2.0 inches)
Weight	27.0 kgs (59.5 lbs.)
Front Glass	4.0 mm (0.16 inches) tempered glass
Frame	Anodized aluminium alloy
Junction Box	IP67 rated
Output Cables	UL 4703, TUV (2Pfg1169:2007)
	4.0 mm² (0.006 inches²), symmetrical lengths (-) 1100 mm (43.3 inches) and (+) 1100 mm (43.3 inches)
Connectors	H4 connectors (MC4 compatible)

Temperature Characteristics

Nominal Operating Cell Temperature (**NOCT**)	45±2°C
Temperature Coefficient of Pmax	-0.44 %/°C
Temperature Coefficient of Voc	-0.33 %/°C
Temperature Coefficient of Isc	0.055 %/°C

Packing Configuration

Container	20' GP	40' GP	40' HC
Pieces per pallet	21	21	21
Pallets per container	5	12	24
Pieces per container	105	252	504

Dealer information

Specifications are subject to change without further notification

PowerGate Plus 500 kW UL

PVS-500-UL

Satcon PowerGate Plus PV inverters are the world's most widely deployed solutions, powering many of the largest commercial and utility-scale solar installations.

Advanced Performance

With their advanced system intelligence, next-generation Edge® MPPT technology, and industrial-grade engineering, PowerGate® Plus inverters maximize system uptime and power production, even in cloudy conditions.

Utility-Ready Features

- Open communication protocol, compatible with virtually any third-party monitoring system and easily integrated into SCADA systems allowing fast communications
- Remote control of real and reactive power
- Low-voltage ride through
- Power factor control
- Simplified grid interconnection

Edge MPPT

- Provides rapid and accurate control that boosts PV plant kilowatt yield
- Provides a wide range of operation across all photovoltaic cell technologies

Printed Circuit Board Durability

- Conformal coated to withstand extreme humidity and air-pollution levels

Profitable PV Power

The Satcon® PowerGate® Plus 500 kW PV inverters have a significant impact on the profitability dynamic of large-scale solar PV systems. With its system intelligence, next-generation Edge® MPPT technology and industrial-grade engineering, the PowerGate Plus 500 kW inverters maximize system uptime and power production, even in the harshest environments.

Advanced, Rugged, and Reliable

Engineered from the ground up to meet the demands of large-scale installations, Satcon PV inverters feature an outdoor-rated enclosure, advanced monitoring and control capabilities and Edge, Satcon's next-generation MPPT solution.

Proven Performance

The proven leader in solar PV inverter solutions for commercial installations, Satcon sets the standards for efficient large-scale power conversion.

Increased PV Plant Yield

At the heart of PowerGate Plus is Edge, Satcon's next-generation power optimization solution. With rapid and accurate MPPT control, Edge increases PV plant kilowatt yield by extending the production window of arrays, enabling them to operate at optimal voltage and current levels for longer periods of time—even in varied sun conditions. To maximize efficiency, Edge improves the performance of all PV technologies, including fixed and tracking solar arrays, enabling you to get the most from your investment.

Satcon®
Utility-Ready Solar Inverters

PowerGate Plus 500 kW UL

Streamlined Design

With all components encased in a single, space-saving enclosure, PowerGate Plus PV inverters are easy to install, operate and maintain.

Rugged Construction

- Engineered for outdoor environments
- Wide thermal operating range: from -4° F to +122° F (-20° C to +50° C) without derating
- Solar shield attached to exterior of enclosure dissipate solar radiation, reduce heat buildup
- Dual cooling fans
- Single cabinet with small footprint

Easy Maintenance

- Modular components make service efficient
- Convenient access to all components
- Customizable large in-floor cable gland plates make installation of DC and AC cables easy
- Integrated DC two-pole disconnect switch isolates the inverter, with the exception of the GFDI (Ground Fault Detection and Interruption) circuit, from the photovoltaic power system to allow inspection and maintenance

Proven Reliability

Rugged and reliable, PowerGate Plus PV inverters are engineered from the ground up to meet the demands of large-scale installations.

Safety

- UBC seismic Zone 4 compliant
- Built-in DC and AC disconnect switches
- Protective covers over exposed power connections

Output Transformer

- Provides galvanic isolation
- Matches the output voltage of the PV inverter to the grid

PowerGate Plus 500 kW Specifications		UL/CSA		
Input Parameters				
Input Voltage Range		320-600 VDC	333-600 VDC	320-600 VDC
Maximum Array Input Voltage		600 VDC		
Maximum Operating Input Current[1]		1628 ADC	1565 ADC	1628 ADC
PV Array Configuration	Negative Ground	•		
	Positive Ground	•		
DC Input Combiner Options				
Combiner Bus Bar Inputs	•	30		
Number of Inputs and Fuses	○ ○ ○	20 x 160A 24 x 110A 30 x 100A		
Transformer				
Integrated Transformer[2]		No	No	Yes[3]
Efficiency				
Maximum[4]		97.5%	–	96.5%
CEC		97%		96%
Output Parameters				
Nominal Power		500 kW		
Nominal Output Voltage		200 VAC	208 VAC	480 VAC
Output Voltage Range, [-12%/10%]		176-220 VAC	183-229 VAC	422-528 VAC
Maximum Output Current/Phase		1443 A	1388 A	602 A
Standby Consumptions (tare losses including control power and aux.)		138 W	138 W	138 W
Nominal Output Frequency, 3-Phase		60 Hz		
Harmonic Distortion		<3%		
Power Factor, Full Load		>99%		
Dynamic Power Factor Control		+/- 0.8		
Power Curtailment		0-100%, 1% steps		
Environment				
Operating Temperature Range (Nominal Power)		-4° F to +122° F (-20° C to +50° C)		
Storage Temperature Range		-22° F to +158° F (-30° C to +70° C)		
Cooling		Forced Air		
Noise Level (Distance of 3 m)		<65 dB(A)		
Relative Humidity (Non-Condensing)		Up to 90%		

Satcon®
Utility-Ready Solar Inverters

PowerGate Plus 500 kW Specifications	UL/CSA	
Enclosure		
Dimensions (H x W x D)	93 x 139 x 43 in. (235 x 353 x 108 cm)	93 x 199 x 43 in. (235 x 506 x 108 cm)
Weight[5]	5,900 lbs. (2682 kg)	10,150 lbs. (4614 kg)
Finish	RAL 7032[6]	
Protection Rating	NEMA 3R/IP44	
Warranty and Services		
Five Year Warranty	•	
Extended Warranty (1 and 5 year increments)	○	
Preventative Maintenance Agreement	○	
Uptime Guarantee[7]	○	
Design Services	○	
APEX Project Management	○	
Communication Interface		
Modbus RS485	•	
Modbus TCP/IP	○	
Monitoring		
PV View Plus	○	
PV Zone	○	
Third-Party Compatibility	•	
Regulations and Standards Conformity		
UL1741, CSA 107.1, IEEE 1547, IEEE C62.41.2	•	
UBC Zone 4 Seismic Rating	•	

• Standard / Standard Option
○ Optional

1 Calculated at nominal power and minimum DC voltage.
2 The 20% boost tap on the isolation transformer increases the AC voltage output range for applications where the solar array DC operating voltage is at or near the lower end of the DC input range. This boost allows for continued inverter operation at lower DC voltage input levels.
3 Inverter and transformer are connected via a 12" throat. See product manual for details.
4 Calculated without auxiliary power.
5 Dependent on options selected.
6 Stainless Steel Finish optional.
7 Requires Preventative Maintenance Agreement.

NOTE: All specifications are subject to change.

Output Options

PowerGate Plus 500 kW	
UL/CSA	200 VAC Output
	208 VAC Output
	480 VAC Output

Power Efficiency

Power Level	Efficiency with transformer*	Efficiency without transformer
10%	92.2%	97.08%
20%	95.6%	97.52%
30%	96.2%	97.58%
50%	96.5%	97.46%
75%	96.4%	97.09%
100%	96.0%	96.52%

* 480V model

Energy Equity Protection (EEP)

Satcon provides a wide range of optional value-added services to protect your investment across the entire lifecycle of your project.

Design Services

Satcon's Design Services organization can guide you through all phases of project development using our broad experience and engineering skills.

APEX Project Management

Satcon APEX™ Project Management ensure that your project comes in on time and on budget.

- Project planning
- Logistics
- Project supervision
- Mitigating risk, maximizing ROI

Warranty and Services

- Help desk
- Training programs
- Support services
- Extended warranty
- Preventative maintenance plans
- 99% Uptime Guarantee

PowerGate Plus Options

- Satcon Smart Subcombiners: Intelligent string monitoring
- Fused input combiners
- Satcon communication card: CCM Gateway
- Weather station
- PV View Plus monitoring system

www.Satcon.com

Please visit Satcon's Resource Library for additional tools and product information, including:

- Satcon's product configurator
- Satcon's string sizing calculator
- Training and support resources:
  - On-demand video training
  - Articles, white papers and case studies

Satcon®
Utility-Ready Solar Inverters

Satcon Corporate
25 Drydock Avenue, 7th Floor
Boston, MA 02210
USA
P: +1.617.910.5500
F: +1.617.910.5501
E: sales@satcon.com

Satcon West
46441 Landing Parkway
Fremont, CA 94538
USA
P: +1.510.897.4900
F: +1.510.897.4901
E: sales@satcon.com

Satcon Canada
835 Harrington Court
Burlington, ON L7N 3P3
Canada
P: +1.905.639.4692
F: +1.905.639.0961
E: sales@satcon.com

Satcon Germany
An der Welle 4
60322 Frankfurt Main
Germany
P: +49 (0)69 7593 - 8620
F: +49 (0)69 7593 - 8200
E: sales.eu@satcon.com

Satcon International s.r.o.
Jankovcova 1037/49
170 00 Praha 7
Czech Republic
P: +420.255.729.610
F: +420.255.729.611
E: sales.eu@satcon.com

Satcon Greece
1A Iraklitou St.
Patima Halandriou – 152 38
Greece
P: +30.210.6654424
F: +30.210.6654425
E: sales.gr@satcon.com

Satcon Shenzhen China
Unit C101-C102, Tower C,
Unisplendour Info. Harbor,
Langshan Road, Nanshan Dist.
Shenzhen 518057, China
P: +86.755.6168.2588
F: +86.755.6168.2599
E: sales@satcon.com

Satcon Shanghai China
Unit 2902-3, Tower A,
City Center of Shanghai,
100 Zun Yi Road,
Shanghai 200051, China
P: +86.21.6236.8236
F: +86.21.6236.8240
E: sales@satcon.com

www.Satcon.com

Satcon®
Utility-Ready Solar Inverters

 PGP500ULNAEWR092611MS

CROUSE-HINDS COMMERCIAL PRODUCTS

Solar Combiner Solutions

Providing the most complete offering of combiners, smart combiners, recombiners, disconnects and pass through boxes for your grid-tied solar applications.

COOPER Crouse-Hinds

Third Party Certified to UL1741!

Leading the way in Solar Technology

Cooper Crouse-Hinds® solar combiner boxes and recombiner boxes for the solar market integrate a comprehensive line of electrical products with expert support, industry insights, and local availability to improve safety and productivity in the most demanding industrial, commercial and residential environments worldwide.

Solar Background Information

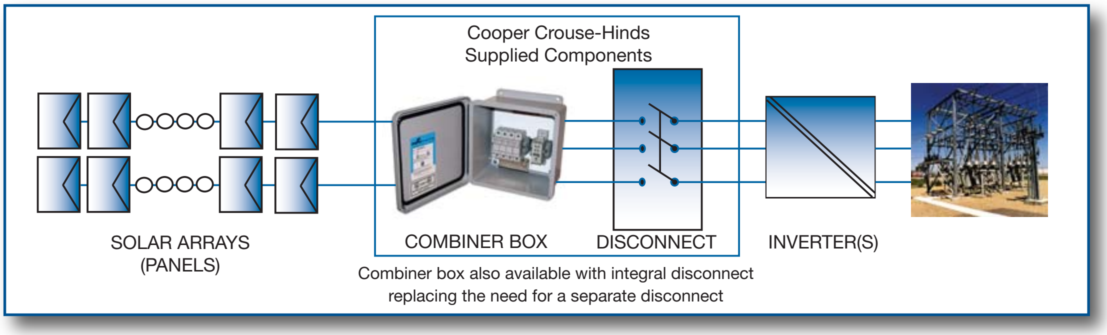
A solar array may be one panel or many in series, and may range from a single 12 volt panel to high voltage multi-panel arrays for grid-tie systems. Grid-tied systems can go as high as 1000 VDC, while battery systems are typically 12, 24, or 48 V.

Higher voltage systems (over 48 V) have different NEC code requirements than those for low voltage battery systems, and the two types are NOT interchangeable.

Cooper Crouse-Hinds Solar Combiners are designed for higher voltage circuits used in grid-tied applications. All meet NEC requirements, are made in accordance with UL requirements and are protected by Cooper Bussmann® families of fast-acting fuses specifically designed for the protection and isolation of photovoltaic strings.

Typical Solar Grid System Diagram

(CCBF04 setup shown)



Cooper Crouse-Hinds Solar Protection for Fiberglass Enclosures

The Cooper Crouse-Hinds solar protection formula provides the enclosure strength and durability to provide long, dependable service even in the most demanding environmental conditions. Cooper Crouse-Hinds fiberglass enclosures retain gloss and color when exposed to harsh UV light, offer superior resistance to chemicals and are fire retardant.

A special UV absorber is added into this solar protection formula and works to absorb UV energy and release it without damaging the fiberglass enclosure thus providing increased protection of the polyester material and increased resistance to the damaging effects of UV radiation. For additional information on Cooper Crouse-Hinds Solar Protection, choose Fiberglass Enclosures from: http://www.crouse-hinds.com/contractorcorner

How to size a Solar Combiner*:

Current Inputs: Cooper Crouse-Hinds provides a "Max Short Circuit Current Rating per string" (Isc) for use as a direct comparison between the published Isc of the PV module. De-rating requirements per article 690 of the NEC are applied and should be used to make a direct comparison with the PV module Isc ratings (i.e. CCBF18 has an Isc rating of 8.8A. PV modules with Isc ratings at or below 8.8A would be acceptable).

Consult electrical ratings table found in the technical section of this brochure.

Voltage Inputs: (600VDC/1000VDC systems) – Cooper Crouse-Hinds provides the total system voltage ratings to be used in comparison with the sum of the max number of modules in series per string.

Consult NEC, ANSI and local codes when designing a system.

Integral Disconnect Switch Sizing:

To determine the rating of the integral disconnect, simply multiply the number of input circuits by the ampacity rating of each fuse in the circuit. Round to the next (higher) trip rating. In NO case can the max current exceed the trip rating of the disconnect switch. Example: a 12 string combiner box with each input circuit with a fuse rated at 15 Amps is 12 x 15 = 180. Minimum rating for the switch would be 200 Amps.

*The information above is provided for reference and information only. All statements, technical information and recommendations contained herein are based on information and test we believe to be reliable. The accuracy or completeness thereof are not guaranteed. In accordance with Cooper Crouse-Hinds' Terms and Conditions of Sale, and since conditions of use are outside our control, the purchaser should determine the suitability of the product for his/her intended use and assumes all risk and liability whatsoever in connection therewith.

COOPER Crouse-Hinds

Solar Combiners

Cooper Crouse-Hinds Solar Combiners are used to group input wires/circuits from several arrays and/or solar panels. The combined circuit results in fewer output circuits and combines them into one main buss or feed going to the inverter saving labor and material costs. Available with optional integral disconnect and DC string monitoring capabilities.

Application:

Cooper Crouse-Hinds Solar Combiner Solutions are designed and built to minimize system costs by providing maximum flexibility. Solar Combiner Solutions offer a range of 1 to 48* input circuits, with a durable non-metallic (NEMA 4X) enclosure, engineered and manufactured to perform in the harshest environmental conditions. UL 1741 Listed* as standard, providing peace of mind and plenty of wiring room for ease of installation.

Features:

- Rated for 600 VDC or 1000VDC - continuous duty
- Touch-Safe fuse holders and power distribution blocks for safe operation
- 90°C output terminals
- NEMA 4X Fiberglass enclosures with captive stainless steel screws and formed-in-place polyurethane seamless gasket provided as standard
- Also available in NEMA 3R painted steel, NEMA 4 powder coated steel or NEMA 4X stainless steel
- Configured for positive and negative grounded arrays

Standard Materials and Finishes:

Fiberglass Enclosure:

- Hot compression molded fiberglass-reinforced thermoset polyester
- Non-conductive, impact resistant, UV resistant, flame retardant
- Captive cover screws can't be dropped or lost
- Poured polyurethane seamless gasket provides watertight, dust-tight environmental seal
- Stainless steel used on all external hardware

Certification and Compliances:

- cULus 1741 Listed* - UL File No. E330318
- cETLus 1741 Listed*
- NEMA 4X (fiberglass and stainless steel)
- NEMA 4 (powder coated steel)
- NEMA 3R (painted steel)
- Made in America

Options:

- Fuses (shipped uninstalled)
- Surge protection
- NEMA 3R Painted Steel
- NEMA 4 Powder Coated Steel
- NEMA 4X Stainless Steel
- Solar Cable Whips (preassembled and installed)
- Busbar Design
- Smart combiners available (DC string monitoring)
- Factory drilled entrance holes
- Factory installed connectors/cable glands
- Dual output lugs
- Custom options available - Consult factory

Catalog Numbering System

Use the table below to build a catalog number for a combiner configuration that matches your specific project requirement

BASE SOLAR COMBINER		WITH OPTIONAL FACTORY SUPPLIED FUSES	W/OPTIONAL SURGE PROTECTION	DC MONITORING	VOLTAGE
CCBF	12	F15	SP	DCM	
Enclosure Type	Number of Input Circuits	Fuse Amperage	Surge Protection	DC Monitoring	Voltage
CCBF (Fiberglass N4X) **CCBS** (Painted Steel N3R) **CCBSS** (Stainless Steel N4X) **CCB4S** (Powder Coated Steel N4)	**01** (1 input circuit) **02** (2 input circuit) **03** (3 input circuit) **04** (4 input circuit) **05** (5 input circuit) **06** (6 input circuit) (Offered up to 48 circuits*)	**F08** (8A fuse) **F10** (10A fuse) **F12** (12A fuse) **F15** (15A fuse) (Offered up to 30A) **BLANK** (Fuses not provided by factory) • Cooper Bussmann fuses recommended - DCM fuses for 600VDC combiner boxes - PV fuses for 1000VDC combiner boxes	**SP** (Surge Protection) • 30kA/600VDC Interrupting Rating • IP20 finger-safe construction • Small size takes up minimal space in enclosure (Only 2 inches wide) **BLANK** (No surge protection) 	**DCM** Pre-installed DC current monitoring unit (qty 1 per 8 strings) **BLANK** (No DC current monitoring) 	**1000V** (1000V) **BLANK** (600V)

*Combiners with 37-48 input circuits are not third party certified, but are constructed to UL 1741 standards

Solar Combiners with Integral Disconnect

Application:

Cooper Crouse-Hinds Solar Combiners with Integral Disconnects provide all the strong and durable features of our standard Solar Combiners, are available with 1-48 input circuits* and save material costs, installation time and labor by joining the combiner box and disconnect within one enclosure and eliminating the need for a disconnect switch in a separate enclosure.

Features:

- Rated for 600 VDC or 1000VDC - continuous duty
- Integral Disconnects available in 100A, 200A, 250A and 400A†
- Touch-Safe fuse holders and power distribution blocks for safe operation
- 90ºC output terminals
- NEMA 4X Fiberglass enclosures with captive stainless steel screws and formed-in-place polyurethane seamless gasket provided as standard
- Also available in NEMA 3R painted steel, NEMA 4 powder coated steel or NEMA 4X stainless steel
- Configured for positive and negative grounded arrays

Standard Materials and Finishes:

Fiberglass Enclosure:

- Hot compression molded fiberglass-reinforced thermoset polyester
- Non-conductive, impact resistant, UV resistant, flame retardant
- Captive cover screws can't be dropped or lost
- Poured polyurethane seamless gasket provides watertight, dust-tight environmental seal
- Stainless steel used on all external hardware

Integral Disconnect Switch Sizing:

To determine the rating of the integral disconnect, simply multiply the number of input circuits by the ampacity rating of each fuse in the circuit. Round to the next (higher) trip rating. In NO case can the max current exceed the trip rating of the disconnect switch. Example: a 12 string combiner box with each input circuit with a fuse rated at 15 Amps is 12 x 15 = 180. Minimum rating for the switch would be 200 Amps.

Certification and Compliances:

- cETLus 1741 Listed
- NEMA 4X (fiberglass and stainless steel)
- NEMA 4 (powder coated steel)
- NEMA 3R (painted steel)
- Made in America

Options:

- Fuses (shipped uninstalled)
- Surge protection
- NEMA 3R Painted Steel
- NEMA 4 Powder Coated Steel
- NEMA 4X Stainless Steel
- Solar Cable Whips (preassembled and installed)
- Busbar Design
- Smart combiners available (DC string monitoring)
- Factory drilled entrance holes
- Factory installed connectors/cable glands
- Dual output lugs
- Custom options available - Consult factory

Catalog Numbering System

Use the table below to build a catalog number for a combiner configuration that matches your specific project requirement

BASE SOLAR COMBINER		WITH OPTIONAL FACTORY SUPPLIED FUSES	WITH OPTIONAL INTEGRAL DISCONNECT	W/OPTIONAL SURGE PROTECTION	DC MONITORING	VOLTAGE
CCBF	12	F15	DS200	SP	DCM	
Enclosure Type	**Number of Input Circuit**	**Fuse Amperage**	**Rating for Integral Disconnect**	**Surge Protection**	**DC Monitoring**	**Voltage**
CCBF (Fiberglass N4X) **CCBS** (Painted Steel N3R) **CCBSS** (Stainless Steel N4X) **CCB4S** (Powder Coated Steel N4)	**01** (1 input circuit) **02** (2 input circuit) **03** (3 input circuit) **04** (4 input circuit) **05** (5 input circuit) **06** (6 input circuit) (Offered up to 48 circuits*)	**F08** (8A fuse) **F10** (10A fuse) **F12** (12A fuse) **F15** (15A fuse) (Offered up to 30A) **BLANK** (Fuses not provided by factory) • Cooper Bussmann fuses recommended - DCM fuses for 600VDC combiner boxes - PV fuses for 1000VDC combiner boxes	**DS** (Disconnect Switch for use with 1 - 48 input circuits) **DS100** (100A) **DS200** (200A) **DS250** (250A) **DS400** (400A) **BLANK** (No integral disconnect)	**SP** (Surge Protection) • 30kA/600VDC Interrupting Rating • IP20 finger-safe construction • Small size takes up minimal space in enclosure (Only 2 inches wide) **BLANK** (No surge protection) 	**DCM** Pre-installed DC current monitoring unit (qty 1 per 8 strings) **BLANK** (No DC current monitoring) 	**1000V** (1000V) **BLANK** (600V)

*Combiners with 37-48 input circuits are not third party certified, but are constructed to UL 1741 standards
†UL98B Listed Disconnect Switch 1000V

Solar Recombiners

Cooper Crouse-Hinds Recombiner boxes are used in larger photovoltaic systems. A Recombiner box effectively groups the output wires from several combiner boxes into one main output feed which then goes to the inverter, saving labor and material costs

Application:

In large photovoltaic (PV) systems, multiple combiner boxes are often necessary, and the outputs of these combiner boxes may need to be combined again—recombined—before reaching a central inverter. Cooper Crouse-Hinds Recombiner Boxes allow for ease of installation, saving time, labor, and most importantly, system costs. Solar Recombiners range from 2 to 12 input circuits, with a durable non-metallic (NEMA 4X) or metallic (NEMA 3R) painted steel enclosure.

Features:

- Rated for 600 VDC or 1000VDC - continuous duty
- 2 -12 input circuits
- Installed fuses included
- Lexan shield covers all live components
- 90°C output terminals
- NEMA 4X Fiberglass enclosures with captive stainless steel screws and formed-in-place polyurethane seamless gasket provided as standard
- Also available in NEMA 3R painted steel, NEMA 4 powder coated steel or NEMA 4X stainless steel
- Configured for positive and negative grounded arrays

Options:

- Surge protection
- NEMA 3R Painted Steel
- NEMA 4 Powder Coated Steel
- NEMA 4X Stainless Steel
- Smart recombiners available (DC string monitoring)
- Factory drilled entrance holes
- Factory installed connectors
- Custom options available - Consult factory

Certification and Compliances:

- Constructed to UL 1741 Standards
- NEMA 4X (fiberglass)
- NEMA 4 (powder coated steel)
- NEMA 3R (painted steel)
- Made in America

Catalog Numbering System

Use the table below to build a catalog number for a combiner configuration that matches your specific project requirement

BASE SOLAR RECOMBINER		WITH OPTIONAL FACTORY SUPPLIED FUSES	W/OPTIONAL SURGE PROTECTION	DC MONITORING	VOLTAGE
CRBF	02	F100			
Enclosure Type	**Number of Input Circuits**	**Fuse Amperage**	**Surge Protection**	**DC Monitoring**	**Voltage**
CRBF (Fiberglass N4X) **CRBS** (Painted Steel N3R) **CRBSS** (Stainless Steel N4X) **CRB4S** (Powder Coated Steel N4)	**02** (2 input circuit) **03** (3 input circuit) **04** (4 input circuit) Consult factory for available configurations greater than 4 input circuits (up to 12 circuits available)	**F60** (60A fuse) **F70** (70A fuse) **F80** (80A fuse)* **F100** (100A fuse) **F125** (125A fuse) **F150** (150A fuse) **F160** (160A fuse)* **F175** (175A fuse) **F200** (200A fuse) Consult factory fuse sizing above 200A *1000V Only • Cooper Bussmann fuses recommended	**SP** (Surge Protection) • 30kA/600VDC Interrupting Rating • IP20 finger-safe construction • Small size takes up minimal space in enclosure (Only 2 inches wide) **BLANK** (No surge protection) 	**DCM** Pre-installed DC current monitoring units **BLANK** (No DC current monitoring)	**1000V** (1000V) **BLANK** (600V)

Wire Size & Torque Table

Strings	Positive Input Terminal		Negative & Ground Input		Positive Output Terminal		Negative Output Teminal		Ground Output Terminal		Bolted Connections
	Wire Size (AWG/kcmil)	Torque (in-lbs)	Wire Size (AWG/kcmil)	Torque (in-lbs)	Wire Size (AWG/kcmil)	Torque (in-lbs)	Wire Size (AWG/kcmil)	Torque (in-lbs)	Wire Size (AWG/kcmil)	Torque (in-lbs)	Torque (in-lbs)
01	#16-#8	20-25	#14-#4	20-35	#4-350 *#10-1/0***	110-325 *20-35***	#4-350 *#8-2/0***	110-325 *120-500***	#14 -250	110-325	80 *275‡*
02											
03											
04											
05											
06											
07					#3-350	150-325	#3-350	150-325			
08					#2-350		#2-350				
09					#1-350		#1-350				
10					1/0-350	180-325	1/0-350	180-325			
11					1/0-350		1/0-350				
12					2/0-350		2/0-350				
13	#18-#8	20-25			1/0-350		1/0-350				
14					2/0-350		2/0-350				
15											
16					3/0-350	250-325	3/0-350	250-325			
17					2/0-350	180-325	2/0-350	180-325			
18					3/0-350	250-325	3/0-350	250-325			
19											
20											
21											
22											
23											
24					4/0-350		4/0-350				
25					4/0 - 500	250-375	4/0 - 500	250-375			
26											
27											80 *398‡*
28											
29											
30											
31											
32											
33											
34											
35											
36											

Note: '**' Indicates Sizing for Models with No Integral Disconnect Switch
"‡" Indicated Torque values for accessories of the Disconnect Switch including jumpers and lugs

Standard Enclosure Sizing

	String Count	NEMA Type	Size
Base Models	1-6	4X	12X10X05
		3R	12X10X06
	7-12	4X	16X14X06
		3R	16X16X06
	13-20	4X	18X16X08
		3R	18X18X06
	21-24	4X	20X16X08
		3R	20X16X06
	25-36	4X	36X30X12
		3R	36X30X12
With Disconnect Switch	1-15	4X	18X16X08
		3R	18X18X10
	16-19	4X	20X16X08
		3R	24X24X10
	20-24	4X	24X24X10
		3R	24X24X10
	25-36	4X	36X30X12
		3R	36X30X12
With DC Monitoring	1-8	4X	20X16X08
		3R	24X20X08
	9-16	4X	30X24X10
		3R	30X24X08
	17-24	4X	36X30X12
		3R	36X30X12
	25-36	4X	36X30X12
		3R	36X30X12
1000V with Disconnect Switch	1-6	4X	12X10X05
		3R	12X10X05
	7-12	4X	24X20X08
		3R	24X20X08
	13-24	4X	30X30X12
		3R	30X30X12
	25-36	4X	36X30X12
		3R	36X30X12

* Not all configurations and enclosure types are listed above, customer specifications and construction requirements impact sizing

COOPER Crouse-Hinds

Electrical Properties (600Vdc)

	Catalog number (i.e. CCBF12) Base	String Input	Maximum Input Fuse Rating (A)	Maximum Continuous Operating Current (A)	Maximum Input Short Circuit Current (Isc) (A)	Maximum Voltage (VDC)
1 Through 12 String	CCBF_ CCBS_	01	30	100	13.20	600
	CCBF_ CCBS_	02	30	100	13.20	
	CCBF_ CCBS_	03	30	100	13.20	
	CCBF_ CCBS_	04	30	100	13.20	
	CCBF_ CCBS_	05	30	100	13.20	
	CCBF_ CCBS_	06	30	100	13.20	
	CCBF_ CCBS_	07	30	100	13.20	
	CCBF_ CCBS_	08	30	100	13.20	
	CCBF_ CCBS_	09	30	200	13.20	
	CCBF_ CCBS_	10	30	200	13.20	
	CCBF_ CCBS_	11	30	200	13.20	
	CCBF_ CCBS_	12	30	200	13.20	

	Catalog number (i.e. CCBF12) Base	String Input	Maximum Input Fuse Rating (A)	Maximum Continuous Operating Current (A)	Maximum Input Short Circuit Current (Isc) (A)	Maximum Voltage (VDC)
12 Through 24 String	CCBF_ CCBS_	13	30	200	8.80	600
	CCBF_ CCBS_	14	30	200	8.80	
	CCBF_ CCBS_	15	30	200	8.80	
	CCBF_ CCBS_	16	30	200	8.80	
	CCBF_ CCBS_	17	30	200	8.80	
	CCBF_ CCBS_	18	30	200	8.80	
	CCBF_ CCBS_	19	30	250	8.80	
	CCBF_ CCBS_	20	30	250	8.80	
	CCBF_ CCBS_	21	30	250	8.80	
	CCBF_ CCBS_	22	30	250	8.80	
	CCBF_ CCBS_	23	30	400	8.80	
	CCBF_ CCBS_	24	30	400	8.80	

	Catalog number (i.e. CCBF12) Base	String Input	Maximum Input Fuse Rating (A)	Maximum Continuous Operating Current (A)	Maximum Input Short Circuit Current (Isc) (A)	Maximum Voltage (VDC)
25 Through 36 String	CCBF_ CCBS_	25	30	400	7.60	600
	CCBF_ CCBS_	26	30	400	7.60	
	CCBF_ CCBS_	27	30	400	7.60	
	CCBF_ CCBS_	28	30	400	7.60	
	CCBF_ CCBS_	29	30	400	7.60	
	CCBF_ CCBS_	30	30	400	7.60	
	CCBF_ CCBS_	31	30	400	7.60	
	CCBF_ CCBS_	32	30	400	7.60	
	CCBF_ CCBS_	33	30	400	7.60	
	CCBF_ CCBS_	34	30	400	7.60	
	CCBF_ CCBS_	35	30	400	7.60	
	CCBF_ CCBS_	36	30	400	7.60	

Electrical Properties (1000Vdc)

	Catalog number (i.e. CCBF12) Base	String Input	Maximum Input Fuse Rating (A)	Maximum Continuous Operating Current (A)	Maximum Input Short Circuit Current (Isc) (A)	Maximum Voltage (VDC)
1 Through 12 String	CCBF_ CCBS_	01	20	100	8.80	1000
	CCBF_ CCBS_	02	20	100	8.80	
	CCBF_ CCBS_	03	20	100	8.80	
	CCBF_ CCBS_	04	20	100	8.80	
	CCBF_ CCBS_	05	20	100	8.80	
	CCBF_ CCBS_	06	20	100	8.80	
	CCBF_ CCBS_	07	20	100	8.80	
	CCBF_ CCBS_	08	20	100	8.80	
	CCBF_ CCBS_	09	20	100	8.80	
	CCBF_ CCBS_	10	20	200	8.80	
	CCBF_ CCBS_	11	20	200	8.80	
	CCBF_ CCBS_	12	20	200	8.80	

	Catalog number (i.e. CCBF12) Base	String Input	Maximum Input Fuse Rating (A)	Maximum Continuous Operating Current (A)	Maximum Input Short Circuit Current (Isc) (A)	Maximum Voltage (VDC)
12 Through 24 String	CCBF_ CCBS_	13	20	200	8.80	1000
	CCBF_ CCBS_	14	20	200	8.80	
	CCBF_ CCBS_	15	20	200	8.80	
	CCBF_ CCBS_	16	20	200	8.80	
	CCBF_ CCBS_	17	20	200	8.80	
	CCBF_ CCBS_	18	20	200	8.80	
	CCBF_ CCBS_	19	20	250	8.80	
	CCBF_ CCBS_	20	20	250	8.80	
	CCBF_ CCBS_	21	20	250	8.80	
	CCBF_ CCBS_	22	20	250	8.80	
	CCBF_ CCBS_	23	20	400	8.80	
	CCBF_ CCBS_	24	20	400	8.80	

	Catalog number (i.e. CCBF12) Base	String Input	Maximum Input Fuse Rating (A)	Maximum Continuous Operating Current (A)	Maximum Input Short Circuit Current (Isc) (A)	Maximum Voltage (VDC)
25 Through 36 String	CCBF_ CCBS_	25	20	400	6.40	1000
	CCBF_ CCBS_	26	20	400	6.40	
	CCBF_ CCBS_	27	20	400	6.40	
	CCBF_ CCBS_	28	20	400	6.40	
	CCBF_ CCBS_	29	20	400	6.40	
	CCBF_ CCBS_	30	20	400	6.40	
	CCBF_ CCBS_	31	20	400	6.40	
	CCBF_ CCBS_	32	20	400	6.40	
	CCBF_ CCBS_	33	20	400	6.40	
	CCBF_ CCBS_	34	20	400	6.40	
	CCBF_ CCBS_	35	20	400	6.40	
	CCBF_ CCBS_	36	20	400	6.40	

*Note: PV-20 fuse is to be used for max 900V systems
Ratings vary based on input fuse size
Ratings vary based on construction

Overcurrent Protection - PV Fuse-Links

Current Rating	Energy Integrals (A2s)		Power Loss (watts)	
	Pre-Arcing	Total at 1000V	0.8 In	In.
8A	3	32	0.5	2.0
10A	7	50	0.6	2.1
12A	10	100	1.3	2.6
15A	20	200	1.8	3.0

For more information:
If further assistance is required, please contact an authorized Cooper Crouse-Hinds Distributor, Sales Office, or Customer Service Department

U.S. (Global Headquarters):
Cooper Crouse-Hinds
Wolf & Seventh North Streets
Syracuse, NY 13221
(866) 764-5454
FAX: (315) 477-5179
FAX Orders Only: (866) 653-0640
crouse.customerctr@cooperindustries.com

Canada:
Cooper Crouse-Hinds Canada
Toll Free: 800-265-0502
FAX: (800) 263-9504
FAX Orders only: (866) 653-0645

Mexico/Latin America/Caribbean:
Cooper Crouse-Hinds, S.A. de C.V.
52-555-804-4000
FAX: 52-555-804-4020
mxmercadotecnia@cooperindustries.com

Europe (Germany):
Cooper Crouse-Hinds GmbH
49 (0) 6271 806-500
49 (0) 6271 806-476
sales.CCH.de@cooperindustries.com

Middle East (Dubai):
Cooper Crouse-Hinds LLC
971 4 4272500
FAX: 971 4 4298521
sales.CCH.me@cooperindustries.com

Singapore:
Cooper Crouse-Hinds Pte. Ltd.
65-6297-4849
FAX: 65-6297-4819
chsi-sales@cooperindustries.com

China:
Cooper Crouse-Hinds Pte. Ltd.
86-21-2899-3600
FAX: 86-21-2899-4055
cchsales@cooperindustries.com

Korea:
Cooper Crouse-Hinds Korea
82-2-3484-6783
82-2-3484-6778
CCHK-sales@cooperindustries.com

Australia:
Cooper Electrical Australia
61-2-8787-2777
FAX: 61-2-9609-2342
CEASales@cooperindustries.com

India:
Cooper India Pvt. Ltd.
91-124-4683888
FAX: 91-124-4683899
cchindia@cooperindustries.com

www.crouse-hinds.com

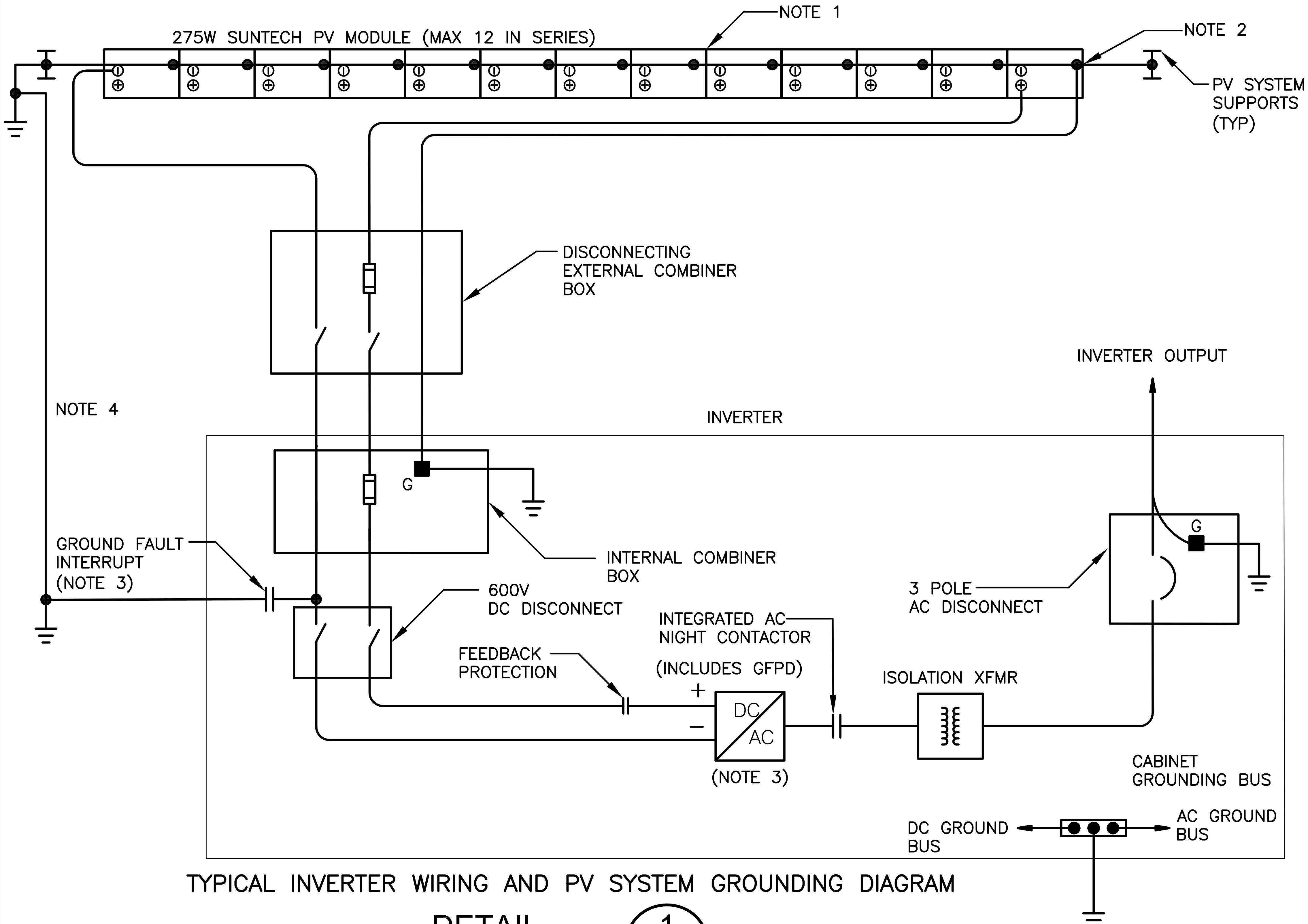
Your Authorized Cooper Crouse-Hinds Distributor is:

Cooper Industries, Ltd.
600 Travis, Ste. 5800
Houston, TX 77002-1001
P: 713-209-8400
www.cooperindustries.com

4959-0811

Printed in USA

COOPER Crouse-Hinds



TYPICAL INVERTER WIRING AND PV SYSTEM GROUNDING DIAGRAM

DETAIL 1 / –

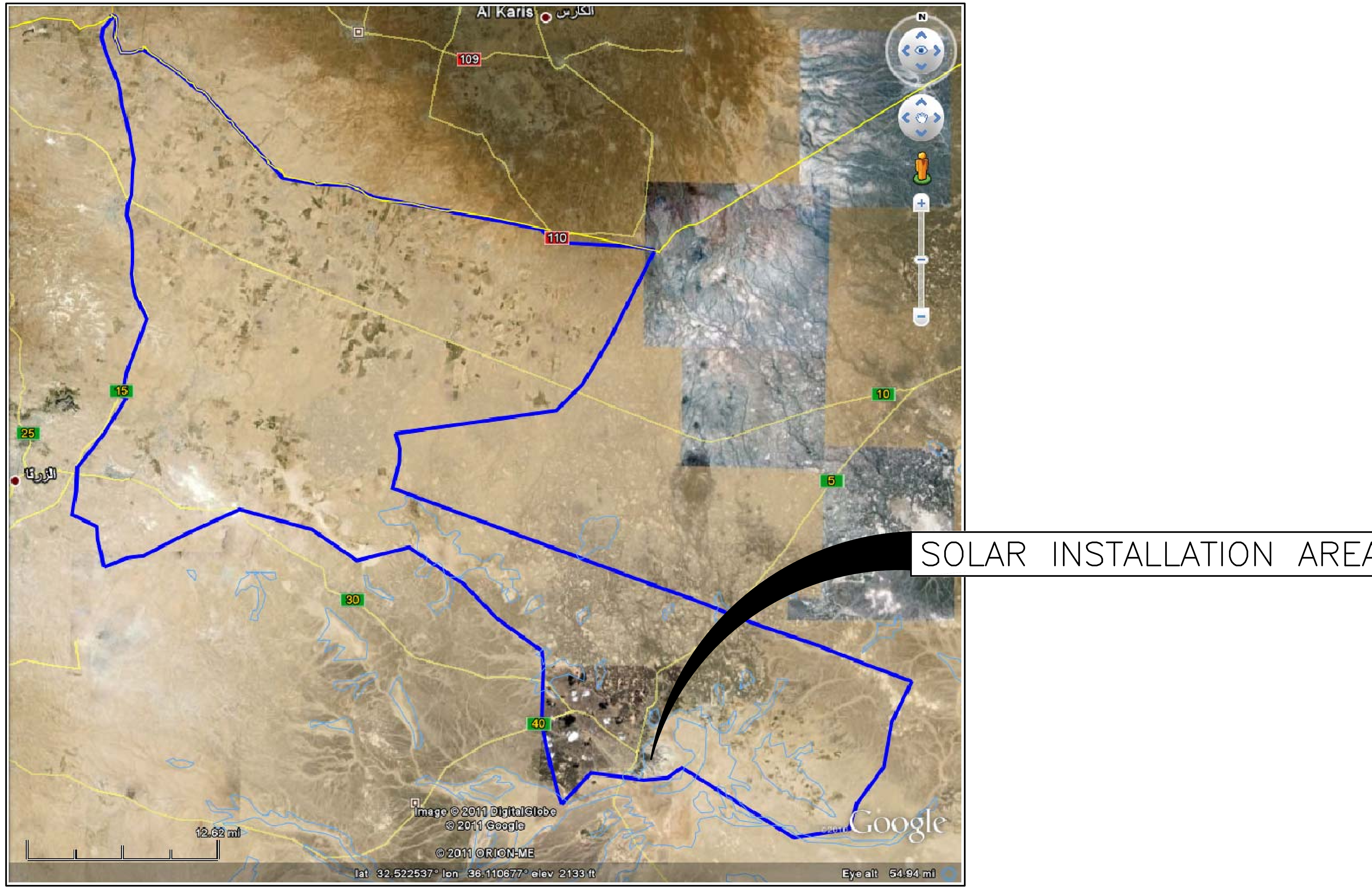
N.T.S.

NOTES:

1. WIRE PANELS WITH VENDOR SUPPLIED CABLE BETWEEN PV MODULES.
2. GROUND METAL EQUIPMENT (I.E. PANEL FRAMES AND MOUNTING HARDWARE) IN ACCORDANCE WITH NEC 690.43. MODULE HOLD DOWN CLAMPS SHALL BE GROUNDING TYPE FOR BONDING PV MODULE TO THE RACKING/SUPPORT SYSTEM, OR AN EQUIPMENT GROUNDING CONDUCTOR SHALL BE INSTALLED AND CONNECTED TO EACH PANEL.
3. BOND DIRECT CURRENT (DC) GROUNDING CONDUCTOR TO ALTERNATING CURRENT (AC) GROUNDING CONDUCTOR.
4. THIS IS REPRESENTIVE OF THE PV ARRAY GROUNDING RING.

CDM Camp Dresser & McKee Inc.

DATE NOVEMBER 2011	ADDENDUM SHEET NO.	ADDENDUM LOCATION	NO.	FIGURE NO.
				D



PROJECT AREA

PLAN

N.T.S.

CDM Camp Dresser & McKee Inc.

DATE	SHEET NO.	LOCATION	ADDENDUM NO.	FIGURE NO.
NOVEMBER 2011				1.1

500kW SOLAR INSTALLATION

PLAN

1" = 100m

CDM Camp Dresser & McKee Inc.

DATE	SHEET NO.	LOCATION	ADDENDUM NO.	FIGURE NO.
NOVEMBER 2011				1.2

1.0MW SOLAR INSTALLATION

PLAN

1" = 100m

CDM Camp Dresser & McKee Inc.	DATE NOVEMBER 2011	SHEET NO.	LOCATION	ADDENDUM NO.	FIGURE NO.
					1.3

1.5MW SOLAR INSTALLATION

PLAN

1" = 100m

CDM Camp Dresser & McKee Inc.

DATE	SHEET NO.	LOCATION	ADDENDUM NO.	FIGURE NO.
NOVEMBER 2011				1.4