Appendix B1 – Economic Assessment of Water pumping Options (courtesy of the solar working group)

Introduction

Economic considerations are important when comparing alternative pumping methods. In many cases hydrological, or climatological factors will limit the kind of pumping system that can be used. Where alternatives exist, the evaluation of the alternatives must include both economic and technical analysis.

There are 2 concepts to be understood before taking any economic assessment:

> ***Payback period***: the length of time required for the initial investment to be repaid by the benefits gained.
>
> ***Life Cycle costs***: the sum of all costs and benefits associated with the pumping system over its lifetime (or over a selected period of analysis), expressed in present day money. This is called the Present Worth or the Net Present Value of the system. For the system to be worthwhile, the benefits must be greater than the costs.

The most complete approach to ***economic appraisal*** is to use the life cycle cost analysis because all future expenses are then taken into account.

In this method, all the future costs and benefits are calculated in 'present day' values. Because the value of money changes with time, it would be unrealistic to add up the future costs as they stand. Future costs and benefits must be discounted to their equivalent value in today´s money, called their `Present Worth`. To do this, each future cost is multiplied by a discount rate.

Example: a discount rate of 10% per year would mean that in real terms, it makes no difference to a person whether he has 100$ now or 110$ in a year time. Conversely, a cost of 110$ in a year from now, would have a ´present worth 'of 100$.

Calculation of the Present Worth.

The calculation of PW involves the use of a discount rate which reflects the opportunity cost of capital.

It should be stressed that the change in the value of money expressed by the discount rate is NOT the change due to general inflation, but the difference in return between an investment one makes and another that one chooses not to make.

Values of discount rate that are used for other projects in the country concerned can usually be taken as a guide. High discount rates mean that a low value is put on future costs and benefits, so money available at present is of more value.

For a payment of Cr($) to be made in the future, the Present Worth (PW) is found by multiplying the payment Cr by a factor Pr:

(formula 1.1) $PW = Cr * Pr$, with $Pr = 1/(1+d)^N$

With time for the payment (N, in years) and discount rate (d) as main variables (note: if d=10%, d=0.1 in the formula 1.1)

Discount rate (d): also called Real Interest Rate, is calculated subtracting the real inflation rate to the nominal interest rate, both data to be taken for the country where we are considering the activity to take place (i.e. if the lender is receiving 9% from a loan and the inflation rate is 8%, then the Real Interest Rate= Nominal interest rate – Real inflation rate = 9 – 8 = 1).

Real Interest Rate per country can be found at http://data.worldbank.org/indicator/FR.INR.RINR?year_high_desc=false or in Annex A. In case there is no information for your country in Annex A, this will have to be searched for from reliable sources in internet or others.

It is advised to use an average of Real Interest Rates for the last **5 years**[1] as Discount Rate, as this will represent better this rate.

So overall the Total Present Worth would be,

(formula 1.2) Total PW = I + $\sum^{N}_{n=1}$Cr*[(1/(1+d)^{N}] ,with I= capital investment.

With I= initial or capital costs and Cr= O&M costs + Overhaul costs + Replacement costs –Salvage value

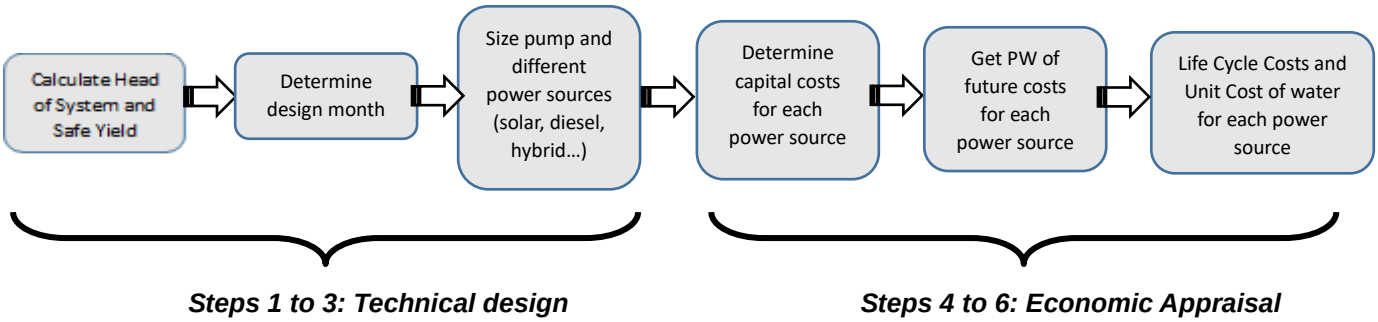
Economic Appraisal using Life Cycle costing for Water Pumping.

For each pumping system on which we are going to perform a life-cycle cost analysis by bringing cost to their Present Value, we need to identify all the initial and future costs. These can be generally divided into the following 4 categories:

-Initial capital costs (including installation). -Operation & Maintenance (minor and major services and fuel).

-Overhaul and Replacement of equipment during lifetime. -Salvage value (especially for generators).

Step-by-step Procedure for a Techno- Economic Appraisal.



Step 1: it is assumed that WASH officers are familiar with H,Q calculations.

Step 2: for diesel based systems, the design month is the month with highest water demand. For Solar is the month that requires the largest array size for the estimated demand in that particular month[2]. If demand is estimated to be constant through the year, then the design month is the one with lowest solar irradiation.

Step 3: it is assumed WASH officers are familiar with sizing of pumps and different power sources (generators, stand alone solar PV systems, hybrid systems and others). For Solar systems, a computer based system should be preferably used. Access to COMPASS solar design software by Lorentz is available for free at solarquery@iom.int

Step 4 to 6: the data required for the last 3 steps are given in the below table,

Economic	Period of analysis (typically all systems are taken to the longest lifespan of any of the components, which sis 25 years for solar panels).
	Discount rate (=Nominal interest Rate – Inflation Rate)
	Relative inflation rate (typically zero)
	Capital cost[3]
	Annual O&M, Overhaul, Replacement cost and Salvage value
	Manpower cost
Technical	Lifetime of each component

[1] If Real Interest rate is not available at the World Bank page, this should be searched for the country given in other sources. Alternatively, an average for the last 5 years can be searched for Nominal interest rates and inflation rates in order to subtract one to the other and find the Real interest rate.

[2]Seasonal changes in per capita consumptions may be about 15% at either side of the mean.

[3]Database of quotations available at IOM Regional Office – Nairobi.

Annex A: Table of Real Interest Rates 2010-2015

Data Source World Bank: World Development Indicators
Last Updated Date 10/4/2016

Country Name	Country Code	Indicator Name	2010	2011	2012	2013	2014	2015
Afghanistan	AFG	Real interest rate (%)	5.71	4.15	6.18	9.89	14.72	13.93
Angola	AGO	Real interest rate (%)	0.12	-4.36	8.95	12.98	18.00	21.74
Albania	ALB	Real interest rate (%)	7.97	9.89	9.74	9.59	6.88	8.21
Argentina	ARG	Real interest rate (%)	-5.68	-3.15	-3.88	-2.14	-4.12	
Armenia	ARM	Real interest rate (%)	10.61	12.92	11.28	12.22	13.33	16.21
Antigua and Barbuda	ATG	Real interest rate (%)	9.50	9.47	7.47	9.95	13.45	7.16
Australia	AUS	Real interest rate (%)	6.21	1.46	4.82	6.39	4.47	6.25
Azerbaijan	AZE	Real interest rate (%)	6.10	-2.92	16.66	17.02	17.63	28.94
Burundi	BDI	Real interest rate (%)	0.10	-0.93	-0.95	1.75	6.80	11.18
Bangladesh	BGD	Real interest rate (%)	4.74	5.06	5.34	5.99	6.89	5.51
Bulgaria	BGR	Real interest rate (%)	9.79	3.51	8.03	9.87	7.80	7.14
Bahrain	BHR	Real interest rate (%)	-0.18	-3.47	3.72	4.40	7.50	13.71
Bahamas, The	BHS	Real interest rate (%)	5.92	5.97	2.59	2.32	4.84	1.57
Bosnia and Herzegovina	BIH	Real interest rate (%)	6.29	4.84	6.39	7.34	5.58	5.63
Belarus	BLR	Real interest rate (%)	-1.67	-33.65	-31.89	-1.62	0.76	
Belize	BLZ	Real interest rate (%)	12.60	8.77	10.20	9.40	9.17	9.56
Bolivia	BOL	Real interest rate (%)	1.04	-3.22	3.77	4.77	7.49	11.68
Brazil	BRA	Real interest rate (%)	29.12	32.83	26.73	18.63	23.53	33.33
Barbados	BRB	Real interest rate (%)	12.83	11.69	10.13	9.51	6.75	6.76
Brunei Darussalam	BRN	Real interest rate (%)	0.18	-12.34	5.55	8.93	-4.17	6.80
Bhutan	BTN	Real interest rate (%)	7.56	4.97	4.41	7.68	6.11	11.54
Botswana	BWA	Real interest rate (%)	2.33	-4.65	11.13	8.96	-1.84	5.27
Canada	CAN	Real interest rate (%)	-0.26	-0.23	1.76	1.42	1.22	3.35
Switzerland	CHE	Real interest rate (%)	2.44	2.51	2.91	2.71	3.42	4.02
Chile	CHL	Real interest rate (%)	-3.74	5.58	9.13	6.82	2.41	1.14
China	CHN	Real interest rate (%)	-1.05	-1.46	3.52	3.68	4.74	4.82
Colombia	COL	Real interest rate (%)	5.32	4.21	9.32	8.82	8.55	8.67
Comoros	COM	Real interest rate (%)	7.21	8.68	8.17	8.62	8.21	
Cabo Verde	CPV	Real interest rate (%)	10.48	6.95	9.30	10.00	11.89	8.64
Costa Rica	CRI	Real interest rate (%)	8.46	11.11	13.79	10.31	9.71	14.58
Czech Republic	CZE	Real interest rate (%)	7.45	5.95	3.96	3.51	2.11	3.52
Germany	DEU	Real interest rate (%)						
Djibouti	DJI	Real interest rate (%)	6.24	6.08	7.48	9.31	9.41	
Dominica	DMA	Real interest rate (%)	9.20	7.15	11.29	5.07	9.29	8.93
Dominican Republic	DOM	Real interest rate (%)	6.14	5.98	10.59	10.60	12.27	13.24

Algeria	DZA	Real interest rate (%)	-6.99	-8.65	0.51	8.12	8.45	14.92
Egypt, Arab Rep.	EGY	Real interest rate (%)	0.81	-0.51	-5.27	3.02	0.18	0.62
Estonia	EST	Real interest rate (%)	6.12	0.81	2.96	1.34	2.69	3.03
Ethiopia	ETH	Real interest rate (%)						
Fiji	FJI	Real interest rate (%)	3.13	-7.27	3.36	3.00	2.18	2.51
Micronesia, Fed. Sts.	FSM	Real interest rate (%)	11.38	10.61	9.48	14.28	11.07	
United Kingdom	GBR	Real interest rate (%)	-2.53	-1.56	-1.11	-1.46	-1.31	
Georgia	GEO	Real interest rate (%)	6.73	5.06	13.59	14.47	7.83	6.34
Gambia, The	GMB	Real interest rate (%)	21.68	22.64	23.32	20.81	18.63	
Grenada	GRD	Real interest rate (%)	10.05	10.44	5.58	6.17	6.63	5.04
Greenland	GRL	Real interest rate (%)						
Guatemala	GTM	Real interest rate (%)	7.80	6.08	9.84	9.90	10.44	9.65
Guyana	GUY	Real interest rate (%)	7.35	5.62	7.67	13.31	13.27	12.93
Hong Kong SAR, China	HKG	Real interest rate (%)	4.72	1.06	1.41	3.08	2.04	1.02
Honduras	HND	Real interest rate (%)	13.55	9.97	14.36	18.45	14.29	15.01
Croatia	HRV	Real interest rate (%)	9.47	7.88	7.78	8.37		
Haiti	HTI	Real interest rate (%)	11.41	3.81	3.47	2.00	5.99	4.29
Hungary	HUN	Real interest rate (%)	5.21	5.98	5.31	3.14	1.17	1.11
Indonesia	IDN	Real interest rate (%)	-1.75	4.59	7.75	6.37	6.85	8.09
Iran, Islamic Rep.	IRN	Real interest rate (%)	-2.06	-12.11	-8.87	-17.37	1.57	
Iraq	IRQ	Real interest rate (%)	-2.80	-8.89	10.09	13.06		
Iceland	ISL	Real interest rate (%)	4.42	4.52	4.98	6.19	3.61	1.63
Israel	ISR	Real interest rate (%)	3.71	4.06	1.27	2.10	2.60	0.76
Italy	ITA	Real interest rate (%)	3.70	3.09	3.79	3.87	4.03	3.35
Jamaica	JAM	Real interest rate (%)	9.66	13.06	10.41	8.64	9.21	11.38
Jordan	JOR	Real interest rate (%)	0.56	2.16	4.10	3.23	5.36	6.06
Japan	JPN	Real interest rate (%)	3.84	3.42	2.36	1.87	-0.44	
Kenya	KEN	Real interest rate (%)	12.03	3.84	9.45	11.34	7.89	6.36
Kyrgyz Republic	KGZ	Real interest rate (%)	11.88	2.28	14.03	17.98	12.86	21.59
St. Kitts and Nevis	KNA	Real interest rate (%)	7.61	5.86	6.83	7.01	6.36	7.26
Korea, Rep.	KOR	Real interest rate (%)	2.28	4.11	4.31	3.76	3.64	1.29
Kosovo	KSV	Real interest rate (%)	8.86	8.37	9.81	8.94	5.88	7.87
Kuwait	KWT	Real interest rate (%)	-5.63	-10.27	-2.33	4.33	8.81	42.47
Lebanon	LBN	Real interest rate (%)	8.16	4.02	1.68	5.51	5.92	5.54
Liberia	LBR	Real interest rate (%)	8.31	2.95	9.17	9.99	10.52	11.72
Libya	LBY	Real interest rate (%)	-7.15	-10.36	-10.90	13.68	28.19	
St. Lucia	LCA	Real interest rate (%)	3.26	7.29	6.60	7.32	4.03	8.31
Sri Lanka	LKA	Real interest rate (%)	-10.83	4.50	-0.30	2.73	3.99	5.73
Latvia	LVA	Real interest rate (%)	10.63	0.03	1.86	4.56		
Macao SAR, China	MAC	Real interest rate (%)	0.45	-2.09	-1.57	-2.30	-3.09	0.83
Moldova	MDA	Real interest rate (%)	4.76	6.31	5.12	7.83	4.36	4.44
Madagascar	MDG	Real interest rate (%)	36.96	40.90	51.67	52.10	45.35	49.69

Maldives	MDV	Real interest rate (%)	9.05	-0.40	4.68	4.83	8.14	10.05
Mexico	MEX	Real interest rate (%)	0.77	-0.35	1.43	2.44	-1.09	0.89
Macedonia, FYR	MKD	Real interest rate (%)	7.29	4.96	7.42	3.41	6.24	4.16
Mali	MLI	Real interest rate (%)						
Myanmar	MMR	Real interest rate (%)				7.16	6.01	1.52
Montenegro	MNE	Real interest rate (%)	7.05	8.38	9.37	7.17	8.29	8.17
Mongolia	MNG	Real interest rate (%)	-13.73	1.29	4.73	15.13	10.77	17.35
Mozambique	MOZ	Real interest rate (%)	8.01	15.26	10.35	10.97	11.94	10.43
Mauritania	MRT	Real interest rate (%)	-1.58	0.95	15.86			
Mauritius	MUS	Real interest rate (%)	6.97	4.80	5.34	5.12	6.64	7.48
Malawi	MWI	Real interest rate (%)	11.15	8.48	12.47	14.70	19.36	19.43
Malaysia	MYS	Real interest rate (%)	-2.11	-0.47	3.75	4.43	2.06	4.99
Namibia	NAM	Real interest rate (%)	5.94	4.74	-3.75	-0.45	1.88	9.25
Niger	NER	Real interest rate (%)						
Nigeria	NGA	Real interest rate (%)	-42.31	5.94	6.88	10.25	11.36	13.60
Nicaragua	NIC	Real interest rate (%)	6.77	0.21	5.25	9.89	4.29	4.02
Netherlands	NLD	Real interest rate (%)	0.89	1.86	0.20			
New Zealand	NZL	Real interest rate (%)	2.85	3.95	6.35	0.50	5.21	5.88
Oman	OMN	Real interest rate (%)	-7.61	-9.34	0.68	6.95	3.35	26.24
Pakistan	PAK	Real interest rate (%)						
Panama	PAN	Real interest rate (%)	4.79	0.55	0.47	1.24	3.37	7.20
Peru	PER	Real interest rate (%)	12.23	12.84	16.76	16.43	12.34	12.83
Philippines	PHL	Real interest rate (%)	3.31	2.54	3.64	3.60	2.25	6.31
Papua New Guinea	PNG	Real interest rate (%)	0.51	6.15	14.00	7.75	-1.44	
Paraguay	PRY	Real interest rate (%)	18.79	10.54	11.85	18.28	15.26	18.22
Qatar	QAT	Real interest rate (%)	0.27	-11.87	-1.37	3.61	5.08	36.18
Romania	ROU	Real interest rate (%)	8.21	7.05	6.35	6.87	6.64	3.73
Russian Federation	RUS	Real interest rate (%)	-2.95	-12.28	0.74	4.48	1.98	7.46
Rwanda	RWA	Real interest rate (%)	13.94	8.78	9.90	11.61	13.51	15.64
Sudan	SDN	Real interest rate (%)						
Senegal	SEN	Real interest rate (%)						
Singapore	SGP	Real interest rate (%)	5.43	4.22	4.62	6.12	5.30	3.65
Solomon Islands	SLB	Real interest rate (%)	8.75	2.18	4.63	11.19	1.99	6.42
Sierra Leone	SLE	Real interest rate (%)	3.47	3.08	7.98	13.18	18.48	-5.74
Somalia	SOM	Real interest rate (%)						
Serbia	SRB	Real interest rate (%)	10.79	6.94	11.23	11.03	11.78	
South Sudan	SSD	Real interest rate (%)			7.74	0.95	16.30	12.02
Sao Tome and Principe	STP	Real interest rate (%)	16.40	13.61	10.20	15.36	9.59	
Suriname	SUR	Real interest rate (%)	4.09	-2.37	1.28	11.77	12.61	17.92
Swaziland	SWZ	Real interest rate (%)	15.14	-20.84	0.11	2.28	2.36	2.48
Seychelles	SYC	Real interest rate (%)	17.66	6.41	1.54	8.79	8.24	10.01

Syrian Arab Republic	SYR	Real interest rate (%)						
Chad	TCD	Real interest rate (%)						
Togo	TGO	Real interest rate (%)						
Thailand	THA	Real interest rate (%)	1.78	3.05	5.09	5.14	5.75	6.29
Tajikistan	TJK	Real interest rate (%)	9.73	8.06	8.25	19.15	18.08	23.55
Timor-Leste	TLS	Real interest rate (%)	6.35	-0.18	4.87	13.41	14.54	14.87
Tonga	TON	Real interest rate (%)	7.75	4.98	7.34	9.29	6.51	
Trinidad and Tobago	TTO	Real interest rate (%)	-1.27	-7.43	8.08	-1.57	2.84	14.03
Tunisia	TUN	Real interest rate (%)						
Turkey	TUR	Real interest rate (%)						
Tuvalu	TUV	Real interest rate (%)						
Tanzania	TZA	Real interest rate (%)	4.85	3.06	4.26	7.58	11.07	10.36
Uganda	UGA	Real interest rate (%)	6.50	16.22	4.49	18.35	18.79	18.35
Ukraine	UKR	Real interest rate (%)	1.86	1.58	9.79	13.05	1.72	-13.12
Uruguay	URY	Real interest rate (%)	5.17	0.71	2.43	3.96	5.63	6.57
United States	USA	Real interest rate (%)	2.00	1.16	1.38	1.59	1.58	2.24
Uzbekistan	UZB	Real interest rate (%)						
St. Vincent and the Grenadines	VCT	Real interest rate (%)	4.52	9.49	8.23	6.99	8.49	7.70
Venezuela, RB	VEN	Real interest rate (%)	-18.91	-8.58	2.03	-14.47		
Vietnam	VNM	Real interest rate (%)	0.95	-3.55	2.29	5.36	4.83	7.32
Vanuatu	VUT	Real interest rate (%)	2.81	2.33	5.61	2.28	2.63	
West Bank and Gaza	PSE	Real interest rate (%)	-6.35	2.24	5.48	-0.64	4.22	10.83
Samoa	WSM	Real interest rate (%)	9.12	7.48	5.68	8.34	9.66	6.47
Yemen, Rep.	YEM	Real interest rate (%)	8.83	8.41	23.30	13.15		
South Africa	ZAF	Real interest rate (%)	3.27	2.20	3.07	2.37	3.15	5.44
Congo, Dem. Rep.	COD	Real interest rate (%)	33.31	30.25	19.49	18.50	17.75	18.61
Zambia	ZMB	Real interest rate (%)	6.11	7.00	4.80	-0.12	6.21	6.19
Zimbabwe	ZWE	Real interest rate (%)						

Annex B: Charts for Reference Calculation of Costs and others.

Genset Fuel Consumption chart

Generator		Liter/hour			
kVA	kW	Load 25%	Load 50%	Load 75%	Load 100%
25	20	2.3	3.4	4.9	6.0
38	30	4.2	6.8	9.1	11.0
50	40	6.0	8.7	12.1	15.1
75	60	6.8	11.0	14.4	18.1
94	75	9.1	12.9	17.4	23.1
125	100	9.8	15.5	21.9	28.0
156	125	11.7	18.9	26.8	34.4
169	135	12.5	20.4	28.7	37.0
188	150	13.6	22.3	31.8	41.2
219	175	15.5	25.7	36.7	48.0
250	200	17.1	29.1	41.6	54.4
288	230	20.0	33.3	47.3	62.7
313	250	21.6	35.9	51.4	68.0
375	300	25.7	42.7	60.9	81.3
438	350	29.9	49.5	70.7	94.9
500	400	33.6	56.3	80.5	108.1
625	500	41.6	69.9	99.8	134.9
750	600	49.9	83.2	119.1	161.8
938	750	61.6	103.6	148.6	201.9
1250	1000	81.6	137.6	196.9	268.8
1563	1250	101.7	171.2	245.7	335.7
1875	1500	121.7	205.3	294.1	402.6
2188	1750	141.8	238.9	342.8	469.5
2500	2000	161.8	272.9	391.5	536.4
2813	2250	181.8	306.6	440.0	603.3

General Reference for Maintenance of Gensets

Genset Maintenance	Good Quality Engine		Low Quality Engine	
Maintenance and Replacement	Frequency of change (h)	Price (USD)	Frequency (hours)	Price (USD)
Minor Service	250	20	250	20
Major Service	1000	180	1000	125
Overhaul	10000	30% of new	5000	60% of new
Replacement	35000	See 'Cost of New Gensets'	10000	See 'Cost of New Gensets'

Soruce: Namibia report, 2015

-Average lifespan of an inverter: 6-7 years.

-Average lifespan of a water pump: 6-7 years.

-O&M cost of a stand-alone Solar system: 150USD (cleaning of panels by guard of water points).

-Costs common to all different systems can be excluded from the analysis in order to simplify it (i.e. guards at water point, replacement of water pump).

Examples

1) It is estimated that a new pump will be required for a certain solar pumping system in 10 years. Presently the pump cost is 2,000$, and the discount rate is 10%. Calculate the Present Worth (PW) of this future cost.

Using (formula 1.1): PW = Cr*Pr, where Cr=2,000$ and Pr = $1/(1+d)^N = 1/(1+0.1)^{10}$= 0.385,

so PW = 2000 * 0.385 = 770$

2) An existing borehole has been running with a generator for some time, pumping 70m3/day and working 6h/day . It has been calculated that same amount of water could be extracted by using a 100% solar pumping system. A Life Cycle cost analysis is to be performed to estimate the savings incurred over a period of 25 years if the system was to be replaced fully by solar. The Present Worth of the current generator system (all costs included) for the 25 year period has been calculated and is 50,000$, for a discount rate d=10%. Taking into account that the best quotation for the solar equipment is 4,500$, that O&M of solar system is 150$/year and that the invertor lifespan is 6 year, costing 1,500$ a unit, estimate the PW of the solar system.

Discount rate (d):	10%

Total PW= I + ∑ Cr*[1/(1+d)^N]

Year (N)	Capital cost	O&M cost ($)	Replacement cost ($)	Discount Factor	Present Worht ($)
0	4500			1.000	4500
1		150		0.909	136
2		150		0.826	124
3		150		0.751	113
4		150		0.683	102
5		150		0.621	93
6		150	1500	0.564	931
7		150		0.513	77
8		150		0.467	70
9		150		0.424	64
10		150		0.386	58
11		150		0.350	53
12		150	1500	0.319	526
13		150		0.290	43
14		150		0.263	39
15		150		0.239	36
16		150		0.218	33
17		150		0.198	30
18		150	1500	0.180	297
19		150		0.164	25
20		150		0.149	22
21		150		0.135	20
22		150		0.123	18
23		150		0.112	17
24		150	1500	0.102	168
25		150		0.092	14
				Total PW:	**7608**

Total Saving incurred by adopting Solar = 50,000 – 7,608 = 42,392$

Cost of water (total cost over 25 years / total water pumped in 25 years):

with genset= = 0.08 $/m3 , with Solar=0.01$/m3.

For this example and from strictly an economic perspective, pumping system should be converted to Solar as soon as possible as it would be 8 times cheaper to provide water with Solar system. If the breakdown of costs incurred per year for the genset system was available, it would be possible to estimate the Recovery Period for the Solar investment by comparing year-per-year the Total PW for both systems.

3) A large borehole supplying water in a refugee camp is being exploited with a diesel based generator. The pumping rate is the maximum allowed by the safe yield of the borehole at 60m3/h, and it is being exploited for 10h/ day.

a) Discuss whether this system could be converted to Solar stand-alone. What other possibilities could be analysed to replace the stand alone diesel based system?

That is not possible if the same amount of water is to be provided. The borehole is exploited at its full capacity (60m3/h) for 10h. Solar PV systems can make pumps work at its full capacity between up to 9 hours/day (depending on location and time of the year). We will never be able to provide 10h of pumping only with Solar. Sometimes the other possibility is to install a bigger pump so that more water is extracted per hour which might compensate shorter number of hours of pumping per day. However this is not possible either cause we are already exploiting the borehole at its full yield, so if we pump more than 60m3/h we might dry the borehole.

b) Analyze the life cycle cost of the diesel system for a period of 25 years using the data on Annexe A and the following:

Pump power (kW):	24	**Current pumping regime, m3/h:**	60	**TDH (m):**	150
Genset Power (kVA):	80	**Total current pumping hours/day:**	10	**Discount rate (d), %:**	0.05
Genset Price (USD)	14910	**Safe yield (m3/h):**	60	**Life Cycle (N, in years):**	25
Fuel consumption (L/h)	12.5	**annual average solar pumping hours/day:**	6	**PW (present worth) =**	1/(1+d)^N

Genset only

Power of Genset	Genset Capital cost (USD)	Year	Number of working hours/ day on generator	Number of working hours/ year on generator	Cost of Minor Service (/250h at 20USD)	Cost of Major Service(/1000 h at 180USD)	Overhaul (/ 10,000h at 30% of cost, USD)	Replacement cost in USD (/ 35000h)	Fuel consumption l/h	Cost of 1L diesel, USD	Total cost of diesel per year, USD	Total Minor+Major+Fuel, USD
80kVA	14,910	0	10.0	3,650	292	657			12.5	1.1	50,188	51,137
		1	10.0	3,650	292	657					50,188	51,137
		2	10.0	3,650	292	657	4473				50,188	51,137
		3	10.0	3,650	292	657					50,188	51,137
		4	10.0	3,650	292	657					50,188	51,137
		5	10.0	3,650	292	657	4473				50,188	51,137
		6	10.0	3,650	292	657					50,188	51,137
		7	10.0	3,650	292	657					50,188	51,137
		8	10.0	3,650	292	657	4473				50,188	51,137
		9	10.0	3,650	292	657		14910			50,188	51,137
		10	10.0	3,650	292	657					50,188	51,137
		11	10.0	3,650	292	657					50,188	51,137
		12	10.0	3,650	292	657	4473				50,188	51,137
		13	10.0	3,650	292	657					50,188	51,137
		14	10.0	3,650	292	657					50,188	51,137
		15	10.0	3,650	292	657	4473				50,188	51,137
		16	10.0	3,650	292	657					50,188	51,137
		17	10.0	3,650	292	657	4473				50,188	51,137
		18	10.0	3,650	292	657					50,188	51,137
		19	10.0	3,650	292	657		14910			50,188	51,137
		20	10.0	3,650	292	657					50,188	51,137
		21	10.0	3,650	292	657	4473				50,188	51,137
		22	10.0	3,650	292	657					50,188	51,137
		23	10.0	3,650	292	657					50,188	51,137
		24	10.0	3,650	292	657	4473				50,188	51,137
		25	10.0	3,650	292	657					50,188	51,137

	Capital cost, Existing Borehole	O&M	Overhaul & Replacement	Salvage	Discount Factor for Yearly Costs	Present Worht (USD), Existing
Yr	Genset	Genset	Genset	Genset		Genset
0	14,910	0	0	0	1.000	14,910
1		51,137	0	0	0.952	48,701
2		51,137	4,473	0	0.907	50,439
3		51,137	0	0	0.864	44,174
4		51,137	0	0	0.823	42,070
5		51,137	4,473	0	0.784	43,571
6		51,137	0	0	0.746	38,159
7		51,137	0	0	0.711	36,342
8		51,137	4,473	0	0.677	37,639
9		51,137	14,910	746	0.645	42,094
10		51,137	0	0	0.614	31,393
11		51,137	0	0	0.585	29,898
12		51,137	4,473	0	0.557	30,965
13		51,137	0	0	0.530	27,119
14		51,137	0	0	0.505	25,827
15		51,137	4,473	0	0.481	26,749
16		51,137	0	0	0.458	23,426
17		51,137	4,473	0	0.436	24,262
18		51,137	0	0	0.416	21,248
19		51,137	14,910	746	0.396	25,842
20		51,137	0	0	0.377	19,273
21		51,137	4,473	0	0.359	19,961
22		51,137	0	0	0.342	17,481
23		51,137	0	0	0.326	16,649
24		51,137	4,473	0	0.310	17,243
25		51,137	0	0	0.295	15,101
					Total	**770,537**
					USD/ m3	**0.14**

c) Repeat the Life cycle cost analysis considering a hybrid Solar-Generator system and having these additional data into account:

Solar equipment cost + installation: 85,250 USD / Annual average of solar pumping per day: 6h

Cost of invertor: 9,000 USD / O&M solar equipment: 150USD/ year

Life span of invertor: 7 years / Life span warranty for Solar panels: 25 years

Hybrid (genset 4h + solar 6h)

Power of Genset	Genset Capital cost (USD)	Year	Number of working hours/ day on generator	Number of working hours/ year on generator	Cost of Minor Service (/250h at 20USD)	Cost of Major Service(/1000h at 180USD)	Overhaul (/ 10,000h at 30% of cost, USD)	Replacement cost in USD (/ 35000h)	Fuel consumption l/h	Cost of 1L diesel, USD	Total cost of diesel per year, USD	Total Minor+Major+Fuel, USD
80kVA	14,910	0	4.0	1,460	117	263			12.5	1.1	20,075	20,455
		1	4.0	1,460	117	263					20,075	20,455
		2	4.0	1,460	117	263					20,075	20,455
		3	4.0	1,460	117	263					20,075	20,455
		4	4.0	1,460	117	263					20,075	20,455
		5	4.0	1,460	117	263					20,075	20,455
		6	4.0	1,460	117	263	4,473				20,075	20,455
		7	4.0	1,460	117	263					20,075	20,455
		8	4.0	1,460	117	263					20,075	20,455
		9	4.0	1,460	117	263					20,075	20,455
		10	4.0	1,460	117	263					20,075	20,455
		11	4.0	1,460	117	263					20,075	20,455
		12	4.0	1,460	117	263					20,075	20,455
		13	4.0	1,460	117	263	4,473				20,075	20,455
		14	4.0	1,460	117	263					20,075	20,455
		15	4.0	1,460	117	263					20,075	20,455
		16	4.0	1,460	117	263					20,075	20,455
		17	4.0	1,460	117	263					20,075	20,455
		18	4.0	1,460	117	263					20,075	20,455
		19	4.0	1,460	117	263					20,075	20,455
		20	4.0	1,460	117	263	4,473				20,075	20,455
		21	4.0	1,460	117	263					20,075	20,455
		22	4.0	1,460	117	263					20,075	20,455
		23	4.0	1,460	117	263		14910			20,075	20,455
		24	4.0	1,460	117	263					20,075	20,455
		25	4.0	1,460	117	263					20,075	20,455

	Capital cost, Existing Borehole		O&M		Overhaul & Replacement		Salvage		Discount Factor for Yearly Costs	Present Worht (USD), Existing Borehole	
Yr	Hybrid	Genset	Hybrid	Genset	Hybrid	Genset	Hybrid	Genset		Hybrid	Genset
0	100,160	14,910	0	0	0	0	0	0	1.000	100,160	14,910
1			20,605	51,137	0	0	0	0	0.952	19,623	48,701
2			20,605	51,137	0	4,473	0	0	0.907	18,689	50,439
3			20,605	51,137	0	0	0	0	0.864	17,799	44,174
4			20,605	51,137	0	0	0	0	0.823	16,951	42,070
5			20,605	51,137	0	4,473	0	0	0.784	16,144	43,571
6			20,605	51,137	4,473	0	0	0	0.746	18,713	38,159
7			20,605	51,137	9,000	0	0	0	0.711	21,039	36,342
8			20,605	51,137	0	4,473	0	0	0.677	13,946	37,639
9			20,605	51,137	0	14,910	0	746	0.645	13,282	42,094
10			20,605	51,137	0	0	0	0	0.614	12,649	31,393
11			20,605	51,137	0	0	0	0	0.585	12,047	29,898
12			20,605	51,137	0	4,473	0	0	0.557	11,473	30,965
13			20,605	51,137	4,473	0	0	0	0.530	13,299	27,119
14			20,605	51,137	9,000	0	0	0	0.505	14,952	25,827
15			20,605	51,137	0	4,473	0	0	0.481	9,911	26,749
16			20,605	51,137	0	0	0	0	0.458	9,439	23,426
17			20,605	51,137	0	4,473	0	0	0.436	8,990	24,262
18			20,605	51,137	0	0	0	0	0.416	8,562	21,248
19			20,605	51,137	0	14,910	0	746	0.396	8,154	25,842
20			20,605	51,137	13,473	0	0	0	0.377	12,843	19,273
21			20,605	51,137	0	4,473	0	0	0.359	7,396	19,961
22			20,605	51,137	0	0	0	0	0.342	7,044	17,481
23			20,605	51,137	14,910	0	746	0	0.326	11,320	16,649
24			20,605	51,137	0	4,473	0	0	0.310	6,389	17,243
25			20,605	51,137	0	0	0	0	0.295	6,085	15,101
Note:									Total	416,901	770,537
									USD/ m3	0.10	0.18

d) A second borehole is drilled, similar to the existing one. For this situation it is possible now to provide water without using a generator in any of the 2 boreholes. Repeat the life cycle cost analysis for the case of 2 solar stand alone systems considering all before data plus:

-Cost of new borehole: 15,000 USD

-Cost of O&M of 2 boreholes=525 USD

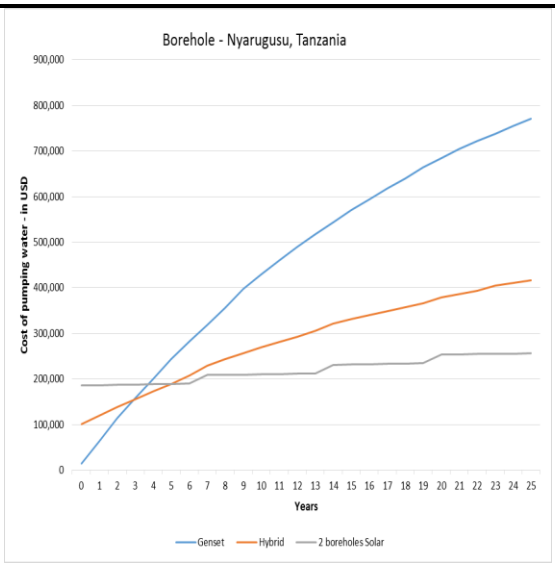
2 solar PV stand-alone boreholes

	Capital cost, Existing Borehole	O&M	Overhaul & Replacement	Salvage	Discount Factor for Yearly Costs	Present Worht (USD), Existing Borehole
Yr	Solar	Solar	Solar	Solar		Solar
0	185,500	525			1.000	186,025
1		525			0.952	500
2		525			0.907	476
3		525			0.864	454
4		525			0.823	432
5		525			0.784	411
6		525			0.746	392
7		525	18,000		0.711	13,165
8		525			0.677	355
9		525			0.645	338
10		525			0.614	322
11		525			0.585	307
12		525			0.557	292
13		525			0.530	278
14		525	18,000		0.505	9,356
15		525			0.481	253
16		525			0.458	241
17		525			0.436	229
18		525			0.416	218
19		525			0.396	208
20		525	18,000		0.377	6,982
21		525			0.359	188
22		525			0.342	179
23		525			0.326	171
24		525			0.310	163
25		525			0.295	155
					Total	222,092
					USD/ m3	0.04
(with 60m3/h x 2 boreholes x 6h/day of pumping provided)						

85,250 USD per solar scheme x 2 boreholes
15.000 drilling 2nd borehole

Summary - Borehole 1

	Generator	Hybrid (1 borehole)	100% Solar (2 boreholes)
Capital Investment Cost	14,910 $	100,160 $	185,500 $
Breakeven point*	_	2.9 years	3.5 years
Life Cycle Cost (USD)	770,537 $	416,901 $	222,092 $
Pumping cost (USD/m3)	0.14 $/ m3	0.08 $/m3	0.04 $/ m3
Comments	Current system, running 10h/ day	4h on genset, 6h on solar	Need drilling of 2nd borehole + fencing site and hiring guards



Recommendation: depending on funds available go for hybrid or solar.