101 LIFT SCHEMES – COMPARING ELECTRIC LIFT AND SOLAR LIFT WATER SUPPLY SCHEMES IN WESTERN NEPAL

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ABSTRACT

The Rural Water Supply and Sanitation Project in Western Nepal core thrust is to reach the unreached and to serve-the-unserved. In Western Nepal this often means mountain top locations where gravity flow water systems are not possible. The Project has completed 101 lift water supply schemes (as of 08/2017) which serve 37% of the total population served by the project. Of these 101 schemes, 48% are solar lift water supply systems. This practice-focused paper presents the findings from the sustainability and functionality study that compares the electric lift and solar lift schemes, exploring technical, operational, social and financial aspects. There is a very high demand for the lift water supply. Overall, the schemes in this sample were found to be functional and appreciated, and well serving the unserved. There were not radical differences in between the electric and solar lift in terms of present functionality. The functionality problems stem from the same reasons as in the gravity flow systems.

KEYWORDS

solar pumps, water supply, rural, Nepal, functionality

INTRODUCTION

Solar water pumping has received increasing interest globally, and the technology has been developing rapidly. Many remote rural communities across the world face shortage of grid electricity, relying on local energy options. Photovoltaic (PV) water pumping is considered as one of the most promising applications of solar energy, see e.g. Chand et.al, 2015 who reviewed a large number of solar water pumping related literature. These authors note that the technology is similar to any other conventional water pumping system except that the power source is solar energy: the flow rate of pumped water is dependent on incident solar radiation and size of PV array. The authors highlighted that a properly designed PV system results in significant long-term cost savings as compared to conventional pumping systems. Where the batteries for electricity storage are not an option, water tanks and large enough reservoir capacity can be used to back up when the sun is not shining. Several authors concluded that PV water pumping technology is reliable and economically viable alternative to electric and diesel water pumps for irrigation of agriculture crops, but that for domestic water supplies it was still not widely utilized. (Chand et.al., 2015; Yorkor & Letton, 2017; Kebele et.al, 2013).

There appears to be a shortage of peer reviewed scientific articles that would have studied solar-powered drinking water pumping systems in rural communities. One of the studies was done by Kabade et.al. (2013) in Ethiopia. Also, this study was very positive that solar pumping indeed is a feasible option also financially: the authors concluded that while the initial cost of solar PV pumping subsystem was higher than that of diesel pumping system, it still got economic advantage after 4 years of working, and that with increasing fuel costs, the advantage were likely to come even earlier. Kebele et.al noted that "*When properly sized and* *installed, PV water pumps are very reliable and require little maintenance*" (Kebele et.al, 2013). Unfortunately, this study focused on theoretical comparison of diesel powered and solar powered pumping systems in the given geographical area, and hence lacked the sustainability aspect of real-life operation and maintenance. Similarly, also Yorkor & Leton 92017) explored the potential in Niger delta in Nigeria for pumping from boreholes with depth of 30 to 250 meters. Again, it was not conclusive on longer term sustainability and related issues.

Mc Loughlin et. al (2013) investigated the performance of five solar photovoltaic (PV) Multiple Use Systems (MUS) used for water pumping in Western Nepal. They concluded that the solar MUS system provides an alternative method for water pumping compared to the more traditional methods, and that the upfront capital costs can be high but compensated by having low operational costs and a relatively long project lifespan. They noted that the geographical parameters have a large bearing as to the overall performance of the system and hence heavily influence the initial design. The authors made a number of very practical technical observations and recommendations with regards to such as solar PV configuration and the influence of distance between the solar PV panels and the control drive. (Mc Loughlin et. al, 2013).

In Nepal, the lift water supply schemes are typically constructed where the gravity flow system simply cannot technically serve the community. In Western Nepal it is likely that if the gravity flow system *can* be built, it is probably already built. The unserved populations live at the mountain ("hill") tops where they are relying on multiple sources depending on the season, including rainwater harvesting and humans, often women, carrying water up. Unfortunately, due to missing winter rains, the rainwater harvesting systems are not an adequate option alone, and there is an increasing demand for lift water supply systems.

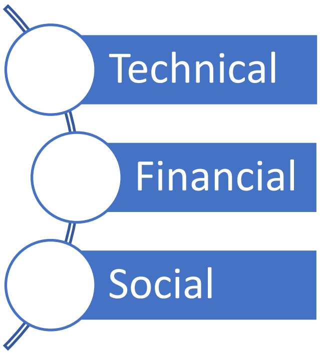
The Rural Water Supply and Sanitation Project in Western Nepal (RWSSP-WN) is a bi-lateral water, sanitation and hygiene (WASH) project funded by the Governments of Nepal and Finland. It operates under the Ministry of Federal Affairs and Local Development, its implementing partners being the local governments (municipalities) in 14 districts. The core thrust of RWSSP-WN is to *reach the unreached and to serve-the-unserved*. Support to the dry mountain ("hill") tops and unserved communities is in line with this. As of 01/2018, the Project had completed 101 lift schemes, hence the title of this study. The Project's 11th Supervisory Board meeting raised the question about the sustainability and cost-effectiveness of these lift schemes.

OBJECTIVES AND METHODOLOGY

This practice-focused paper presents some of the findings from the sustainability and functionality study. It compares electric lift with solar lift water supply schemes implemented in RWSSP-WN. The focus is on rural mountain context where water is lifted into reservoir tanks from where it flows as piped water system in the same as the gravity flow system. The overhead tank water systems in Tarai plains are studied separately as these are best described as 'small towns' or 'peri-urban' type of services with high population density and growth, with different technical and social dynamics.

This study compares the electric and solar systems from three points of view: technical, financial and social. Since gravity flow system is not an option in these locations, we cannot compare the lift schemes with the gravity flow drinking water systems. The comparison is done in between electric lift and solar lift. Two sources of data are used: the RWSSP-WN Management Information System (MIS) and the field survey that covered 89 cases as of

30/01/2018. The field survey was prepared using a mobile phone app (www.kobotoolbox.com). This puts the schemes and results on the map and gives an opportunity for spatial analysis.



As of 01/2018, the RWSSP-WN Management Information System had 712 water supply schemes with population of 273,029. Even if 44 of these were marked as 'dropped', there were still 668 cases listed benefiting 264,907 people. Out of all schemes, not considering the dropped cases, 60% were gravity flow water supply system, 25% were various types of lift schemes, and the rest included rainwater harvesting, point source improvement and tube wells. When considering the population served, 54% benefited from the gravity flow water supply schemes and 38% from the lift water supply schemes. Considering all schemes at various stages of planning and implementation, but not those that are dropped, the solar systems at mountain ('hill') areas benefited 16,992 people and electric lift systems 22,913. This is not pilot scale anymore. The highest number of lift schemes are in Syangja and Tanahun districts, while the highest number of over-head tank lift schemes in Tarai are in Kapilvastu. Of all 101 lift schemes, 48% are solar lift water supply systems.

Out of 89 cases that have been surveyed as of 30/01/2018, total 47 were electrical lift and 42 were solar lift. Out of 42 solar cases, there were 36 stand-alone off-grid systems while six schemes had hybrid system with on-grid connections. At this point, the survey covers only eight overhead tank schemes of which seven are electric and one is solar lift. The 89 schemes have been completed over the past eight years, with 33 completed in Phase I, ten were carry over schemes from Phase I to Phase II, and 46 started and completed in Phase II.

At the time of writing this paper, the field work is still going on. The aim is to cover all 101 lift schemes. As of 30/01/2018, the total number of 89 lift water supply schemes in ten districts have been surveyed for technical, social and financial aspects, and overall functionality. We acknowledge that functionality is something that changes in time, and that what we have as one-time entry in our MIS, may not represent the present status of the schemes.

RESULTS

The beneficiaries and their connections

The number of beneficiaries at design were 10,464 households (population 62,575, average 6 persons per household), now 8,280 (population 47,090, average 5.7 persons per household). The difference is 15,485 which is on average 174 persons less per scheme. The biggest difference is in the electric lift schemes: the difference of population at design and population at present is 10,588, compared to 4,897. The first lesson learned comes already here: there is a tendency to over-estimate the population beneficiaries, sometimes in purpose, for various reasons. One of these is the per capita cost even if in RWSSP-WN Phase II there is no such limitation. The more critical question being whether the scheme can be maintained or not? Can the remaining households pay their electricity bill? Are households dropping out from the scheme when the actual electricity cost becomes evident, or there is a need for major capital maintenance?

In total 92 institutions, including schools, benefited from these 89 schemes. In addition, there are 1,167 public tap stands, 75% of which in electric lift schemes. At the moment, out of total present number of beneficiary households (8,280), 48% have a private connection. There are 3,531 connections are metered which means that 42% of the present beneficiary households and institutions have a metered connection. This is a problem if and when the water tariff should be according to the amount of water used to be fair. Out of all household connections, 78% of the metered connections are in the electric lift schemes. Out of all 89 schemes, 38% had meters installed and used, 56% had no meters at all and 6% had meters installed but these were not used.

Financial considerations

Only in five cases, all solar lift, the WUSC did not collected water tariff. Total 56% collected based on flat system, and 38% based on meter. One might expect that an electrical lift scheme with a monthly electricity bill would charge based on meters, but this not the case with more electric lift water tariffs being based on flat system that ranged from NPR 60 to NPR 500 (from EUR 0.50 to EUR 4 per month). Practically all WUSCs had Operation and Maintenance (O&M) Fund (93%). This was kept in a range of places from keeping it as cash in somebody's house (10), mobilizing it as a revolving fund in the community (19) and keeping it in a commercial bank (30). In RWSSP-WN the WUSC does the procurement, and for all scheme related fund flows they need to open a bank account in an acceptable financial institution. Yet, this may not be the long-term solution as it has been found that in some commercial banks. The interest rates are minimal while the inflation and administrative charges reduce any savings. Interestingly only 66% reported that the fund is used for repair and maintenance.

The monthly electricity bill varied from NPR 300 to NPR 35,000 (from EUR 2.4 to EUR 285). WUSCs have also invested already into capital maintenance, with sums varying from NPR 2,000 to NPR 1,500,000 (EUR 16 to EUR 12,195), both solar lift schemes. Interestingly even the WUSC that invested NPR 1,500,000 again into their scheme, stated at the end that they were very happy with it, and that the scheme was well-functioning! In nine electric lift and one solar lift case the expenditure was higher than the income, and in ten cases the total is zero. This means that 20 cases out of 89 are financially already now in trouble.

Technical characteristics

The 89 schemes have total 78,251 meters of transmission line and 374,412 meters of distribution line. For lift schemes, the transmission line refers to the pipe line that connects the water source to the top most reservoir tank. All pipelines together, there are 452,463 meters (452.5 km) of pipeline that has mostly been constructed manually, the distribution lines being typically provided by the community contribution. These are also the lines that are prone to a number of climatic and human-induced sustainability challenges, with such as road cutting and landslides challenging these in a similar way as they challenge any gravity flow system. The total vertical head, all schemes counted together, is 14,424 meters. Of this, 38% is lifted by solar (5,478 metres). The scheme-wise vertical heads vary from 11 meters to 581 meters, the median being 137 meters. Note that this describes only the vertical head, not the total length pumped or the dynamic head that the systems have to be able to manage.

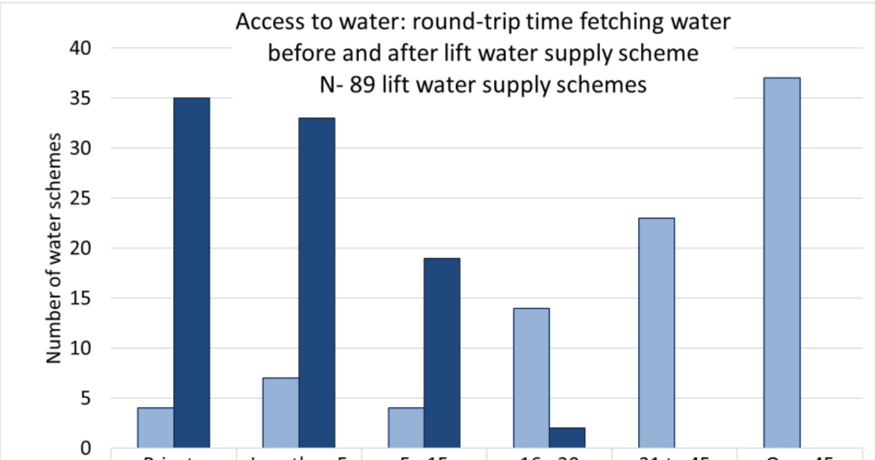
Total 77 schemes had only one lifting stage, this including all but one solar lift schemes. Total eight schemes had two stages lifting, and three schemes had three stages. The solar lift schemes pumping our per day varied from three to 12 while the electric lift schemes varied from one to nine. Total 83% of all electric lift schemes had average four or less pumping hours, while 79% of the solar systems pumped an average four or more hours. This is partly explained by the pumping capacity which is divided accordingly: while 95% of the solar pumps were pumping 3,600 liters per hour per one pump, 87% of the electrical pumps pumped more than that. The number varies: in 51 cases only one pump was used, in 27 schemes two pumps, in one scheme three pumps, in six schemes four pumps, and in three schemes six pumps. Majority of the solar systems (32 schemes) had only one pump. The pumps are typically submersible volumetric pumps, only in three cases this was not the case. The pumps had typically vertical position (67%).

Exploring service levels

The following describe the scheme functionality and service levels using the Q-A-R-Q indicators. Here 'Minor repair' below refers to something that a Village Maintenance Worker should be able to do without external support:

Quantity: the design flows tend to be smaller than what is expected for higher service levels: 63% of the electrical lift schemes and 65% of the solar lift schemes deliver in between 25 to 45 liters per capita per day. This is the single service level indicator that drops practically all lift schemes below the 'basic' service level. Only in six cases, all electric overhead tank schemes, the quantity was over 65 liters per capita per day. There are two limiting factors here: pump capacity and related pumping costs, and more to it, the yield in the water intake itself. The water sources are simply not enough.

Access: This indicator refers to the round-trip water fetching time for most of the beneficiaries. We define this as '*most* of the beneficiaries' as we do acknowledge that within a geographically spread out water supply network that has no private connections, it is possible to have a variation in between households with regards to the access to the nearest tap. Out of all 89 cases, 38% had private connections, and another 36% had access within less than five minutes return trip. The difference to the situation before the lift water supply scheme (Figure 1) shows that the lift schemes are serving the unserved, and the situation is radically better than before the lift scheme.



	Private connection	Less than 5 minutes	5 - 15 minutes	16 - 30 minutes	31 to 45 minutes	Over 45 minutes
Before	4	7	4	14	23	37
After	35	33	19	2	0	0

Figure 1. Access to water: round-time water fetching time before and after the lift water supply scheme

Reliability: This indicator refers to the water source water being available as per design flow. This does not seem to be the limiting factor albeit the chosen design flows are below the standard already as is: 96% of all schemes have the whole year availability as per design flow – which, as described earlier, can be very low.

Availability: The availability of water over the day varies: while 28% had water availability 12 hours or more, 40% had less than two hours, the rest being in between these. In three cases there was no water at all, two of which were closed down. Yet, there are differences in between the overhead tanks and the hill lift schemes, and also in between electric and solar. It is hardly surprising that the overhead tanks have water available for 12 hours. It is more surprising that 53% of the hill electric lift schemes have water available only for less than two hours, the corresponding percentage for solar lift being 35%. In most cases this is because of the cost of electricity although it is also explained by the water availability at source.

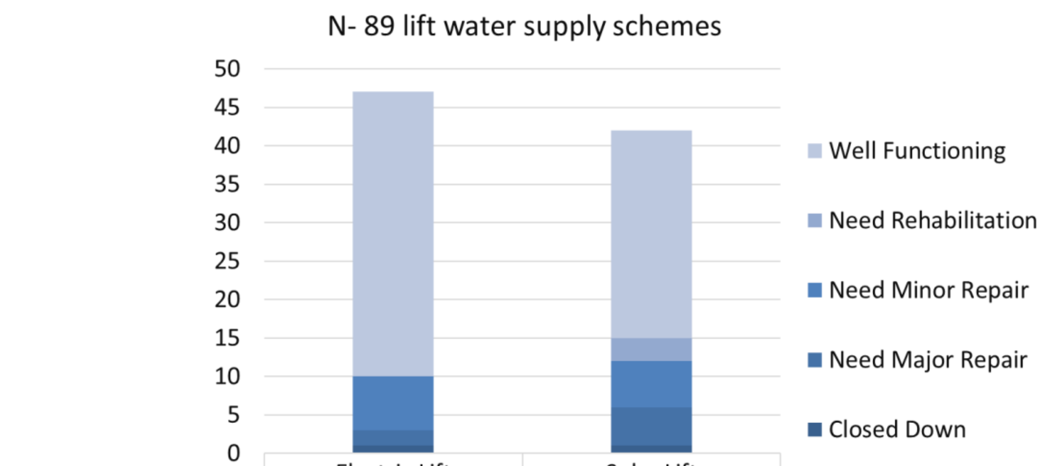
Quality: The water source was typically a spring source: 90% of electric lift schemes and 78% of solar lift schemes used spring sources. Total three cases used both spring and stream, two stream sources and the overhead tanks the groundwater. 78% did not have any water treatment. Some roughing filters have been constructed later on by WUSC itself, sometimes with financial but not technical support from such local sources as the Village Development Committee. This is a concern: if the dimensions are not be correct, the filter is not functioning as expected. Water quality of all cases out of 89 had tested the water quality at source, and out of these, 65% within the past 12 months. Out of 89, total 21% were tested with the Presence-Absence-vial only, and 78% with the ENPHO Kit for various other parameters as well as the Presence-Absence-vial. The presence of bacteria was reported only in three cases.

Exploring physical condition and technical functionality

Majority of the intakes and collection tanks needed no repair or only minor repair (91%), more specifically, ‘need no repair at all’ 69% and ‘need minor repair’ (23%). In this regard, there is no difference in between electric and solar lift schemes. With regards to the transmission lines and its’ crossings, it was found that 88% needed no repair and 10% needed minor repair, with only one case needing major repair and one needing rehabilitation (both solar lift schemes). With regards to the overall physical conditions of distribution lines, 88% needed no repairs and 10% needed minor repairs, with one case only needing major repair and one case rehabilitation. Overall physical conditions of reservoir tanks, valve chambers and distribution chambers was also good with 76% needing no repair and 23% needing minor repair, with only one case where a new structure was needed. With regards to water tap functionality, the percentage of taps with water flow was assessed as 100% in 60% of the cases, and in between 90% to less than 100% in 31% of the cases. These were equally divided in between electric and solar systems.

Overall, 87% of all lift schemes were described as ‘well-functioning’ if we accept that the need for minor repairs are not affecting the overall functionality. The percentage is 72% if counting only those schemes that do not need even minor repair (Figure 2). Considering the electric lift schemes only, 79% (with minor repairs 94%) were considered as ‘well-functioning’, the corresponding figures for solar lift schemes being 64% (79%). All overhead tanks were described as ‘well-functioning’. The ‘minor repairs’ mean such repairs that the Water Users and Sanitation Committee (WUSC) and their Village Maintenance Worker (VMW) should be able to carry out themselves. The following map (Figure 3) shows how the entire sample cases are distributed geographically.

Out of all 89 schemes, 67% had had no technical failures over the past year, while 17% had one and 10% had two. The 89 schemes reported total 60 failures over the past year. The worst case had seven. Out of all WUSCs, 89% know how to claim warranty. Most of the electrical pumps have one-year warranty (23 cases), while most solar pumps have two years (25 cases), but there were also eight electric and two solar cases where there was no warranty at all. Out of 89 schemes, 80% had never claimed warranty. Five electric lift and 11 solar lift schemes had claimed warranty once, and one electric and one solar had claimed twice. The pump warranty periods vary from one to seven years. The PV panels tend to have very long warranty periods up to 15-20 years. The challenge for WUSC is how to save the relevant documents over the lengthy period of time, and also how to claim if the suppliers change.



	Electric Lift	Solar Lift
Well Functioning	37	27
Need Rehabilitation	0	3
Need Minor Repair	7	6
Need Major Repair	2	5
Closed Down	1	1

Figure 2. Functionality status of lift schemes

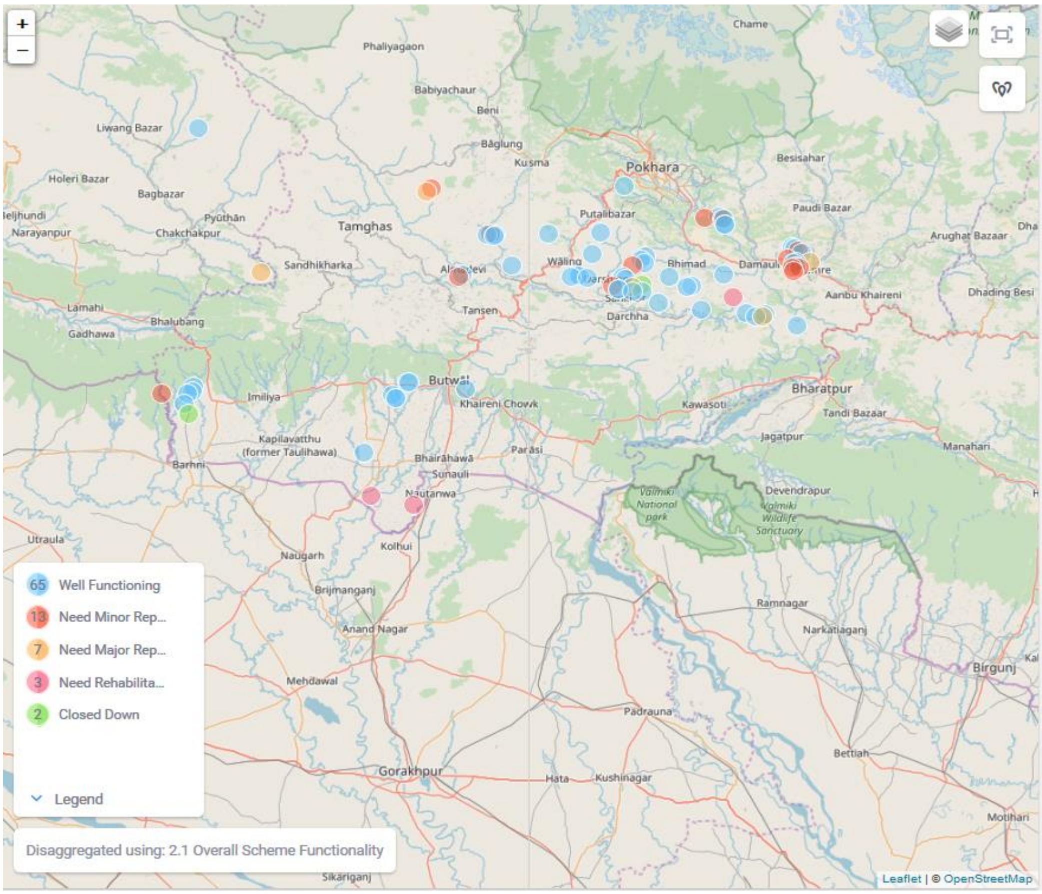


Figure 3. Sample locations with functionality status

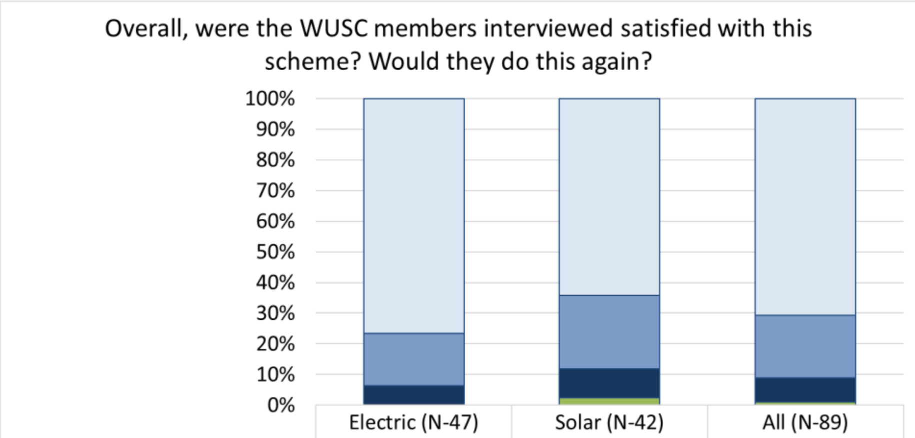
Exploring Water Users and Sanitation Committees (WUSCs) management practices

The Government of Nepal and RWSSP-WN Phase I gender target was to have one-third of the WUSC members women. RWSSP-WN Phase II increased this to 'about half'. Since the total number of WUSC members is always at odd number, exactly half is mathematically not possible. In this sample, 75% had gender balance in WUSC (70% of Phase I schemes and 80% of Phase II schemes). The percentage is similar in the well-functioning schemes: 47 well-functioning schemes out of 58 had the gender balance in WUSC. The corresponding percentages for ethnic/caste balance is 93% of all schemes (86% of Phase I and 100% of Phase II schemes).

Out of 89 WUSCs, 81 had registered and had a statute. Yet, only third had an Annual General Meeting/Assembly: 32% of the solar lift and 23% of electrical lift WUSCs. Total 73% had the Operation & Maintenance (O&M) Plan, and out of these, 85% had also Water Safety Plan. There is no difference in between the electric and solar schemes in this regard. There were 14 schemes that were described as 'well-functioning' even if the WUSC did not have any O&M plan. Two of these cases are overhead tanks. At the same time, there were two closed down schemes, four in need of major repair and 12 in need of minor repair, all with O&M Plan that had WSP included. Plan is only a plan if it is not implemented!

Most WUSCs (80%) considered that they had adequate tools and equipment. Out of all 'adequate tools' cases, 75% were defined as 'well-functioning', while out of 'inadequate tools' cases 69% were defined the same. Practically all WUSCs (94%) reported as having appointed a Village Maintenance Worker (VMW) for the schemes. In total there were 123 VMWs of which 110 were men and only 13 were female; 78% of the VMWs had received training. Considering that these are all lift schemes, the number of Pump Operators raises some worry: in 76% of the schemes there was a Pump Operator. Out of all hill solar lift schemes, only 63% had a Pump Operator while 95% of the hill electric lift schemes had the same. Only 50% of the Overhead tanks had a Pump Operator. Out of 68 cases with the Pump Operator, only 65% had received training.

Overall, the WUSCs appeared to be satisfied with what they had chosen (Figure 4).



	Electric (N-47)	Solar (N-42)	All (N-89)
Yes, very happy	36	27	63
Yes, it is ok	8	10	18
Yes, average, could be better	3	4	7
No, this was not a good choice	0	1	1

Figure 4. Water Users Committees satisfaction with their schemes

CONCLUSIONS AND RECOMMENDATIONS

There is an increasing interest in lift water supply schemes from both the unserved rural villages as well as sector professionals alike. For RWSSP-WN, the lift schemes are not a pilot option anymore but a technology choice among other options. There are many issues in favour of solar when compared to electrical lift: no electricity cost; low maintenance if the initial setup is well done; no need for costly and time consuming process of constructing electricity transmission lines and related administrative processes for such as transformers and connections; and since no transmission lines and pump houses for controls are needed, solar pumping system is quicker to construct as the panel array installation is likely to be easier to install.

Overall, the schemes in this sample were found to be functional and appreciated, and well serving the unserved. There were no essential differences in between the electric and solar lift in terms of present functionality. The functionality problems stem from the same reasons as in the gravity flow systems and as such, are not necessarily specific for the lifting system itself. However, the lift water supply systems suffer from the fact that those working with rural water schemes tend to come from the civil engineering background, with less formal training, real experience and operational understanding with the electromechanical issues. WUSCs, municipalities and project staff alike rely on the suppliers who may not always realize this. Their advice is not easily questioned. At the same time, these suppliers may not be that familiar with such as water quality concerns and civil structures, and hence, such as water intake structures get overlooked.

Water quality is a critical issue. Even if only three schemes out of 89 tested for presence of bacteria, the problem is sand, silt and mud. While in all cases, lift or gravity, the water source should be safe and clean, this is often not the reality, especially during the monsoon time. Pumping systems cannot accept the same water as the gravity water supply systems. Considering the high investment costs related to the lifting system, and the usual very hard labour in terms of community contribution, it is astonishing how little attention the water source itself gets. This is a challenge to any rural water supply system, and it appears that it is time to look at the standard drawings in this regard. Covering a water source with a plastic does not make it safe.

Operation and maintenance by trained VMWs is a challenge for functionality of any rural water supply system, even a simple gravity system. Various studies in Nepal have drawn attention to the poor functionality. This is even more critical for a lift system: pumps do need a skilled operator. These systems cannot rely on any Village Maintenance Worker who works on ‘when-needed-if-available’-basis. Even if both electric and solar pumps have increasingly better automatic systems to prevent such as dry run, they cannot be left on their own device. Since lifting systems are new technology, we cannot expect that experienced pump operators exist in the same way as skilled maintenance workers (‘*mistries’*) do. Capacity building of the local pump operators as well as strengthening the capacity of the engineers and other WASH sector professionals with regards to lifting systems needs to increase at par with the increasing number of lift schemes.

The financial analysis at the planning stage is a must. While there are tools for this (see e.g. Shrestha et.al, 2014:118), and the design software used in RWSSP-WN itself has a template for it, the financial analysis remains incomplete. In this sample it was very positive that the WUSCs did have an O&M fund, and that in average there were good balances available (NPR 250,000) and that in half of the schemes studied the users had invested later on capital maintenance expenditure themselves. This study did not do financial analysis in terms of initial capital expenditure, operational costs and capital maintenance expenditure – that will be a study of its own right. At the time of completing this paper, the survey is still going on, aiming to cover all 101 cases. The more detailed financial analysis will be done at that time – the sample is certainly highly valid.

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