Small Solar Pumps

Manual for configuration and installation

Basic Water Needs

Copyright and disclaimer

This manual is for 2 small solar pumps that are fit for household use and small-scale irrigation.
If water is used for drinking, make sure that water is treated with a point of use treatment like boiling, chlorine, or a good quality household water filter.

Selection and installation of solar pumps have details which can be best learned with practical training.

If you have observations or suggestions on this technology and or manual, please contact us at info@basicwaterneeds.com.

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1. Introduction

This document describes the configuration, installation, and practical issues to consider with electrical submersible pumps. The selection procedure (Chapter 2) is applicable for all types of pumps. The rest of the chapters focus on the ZL38-13N and ZL50-20N pumps on offer, suitable for one household with a small garden and few livestock or other small-scale applications, with water availability at a maximum of approximately 30 meters deep. We have not included the technical datasheets in this manual, but you can download them here.

If you are interested in bigger systems, we recommend studying:
https://globalwatercenter.org/solar-guide-access.

2. Pump selection

The best fitting type of pump depends on:

1. Cleanliness of the water
2. Required flow = how much water does the customer need per time frame.
3. Required pressure = How high must the pump be able to deliver water.

2.1 Test if water is clean enough

To test the turbidity (visual cleanness) of the water, get a (at least 1 Litre) plastic clean transparent empty water bottle and fill it with water from the well or source where the pump needs to go. Put the full bottle on a paper with some text or a drawing and look from the top through the bottle down. If you can read the text or the drawing without any problem, then you can assume the water is clean enough. If not, don't install an electrical pump and (in case of a well) ask drillers if they can clean the well for you (that is not always possible). Normal electrical pumps will damage quickly if they pump dirty water.

Very OK

OK

NOT OK

2.2 Required flow

*Flow is the **amount** of water per minute, it is different from pressure.*

Flow, also sometimes called "Yield", is often mentioned in Litres per minute or Litres/hour (1 L/h=1/60=0.017 L/min) or cubic meter per hour (1m3/h=1000/60=17L/min) or cubic meter per day (1m3/day=1000/24/60=0.7L/min). In this manual we will use L/min.

To define the required flow (=yield) of a pump the following things are essential:

- How many Litres of water does the customer need per day divided by the number of minutes that the pump will be functioning in a day.
- Now you must check if the borehole or well is able to provide that amount of water per minute. This information comes from the pump test.
    - If the pump test shows that the borehole or well cannot deliver the required yield, then you need to inform your customer. Because no pump can pump water that is not there. A slow well can be caused by many things but nature plays an important role. Some soils simply don't allow water to pass quickly. In this case choose a pump yield equal to the borehole or well yield.
    - If the borehole or well delivers water faster than the flow required by the customer, then use that customer required flow to select your pump.
- Find the number of sun hours per day that the pump will work (if unknown, use 5 hours/day).

2.2.1 Tool to calculate flow

The Excel sheet "Pump selection.xlsx" assists you to translate flow requirements between different units, like Litre/min, Litre/hour, Litre/day, m3/h and m3/day.

This Excel sheet also helps with other parts of the design and can be down loaded here together with this manual.

Example

The household only uses water for the house and needs 1000 Litre per day. The customer wants a solar powered pump. There are 5 hours of sufficient sun every day. Then the minimum yield of the pumps should be 1000/5=200 Litre/hour = 200/60 = **3.3 L/min**.

2.3 Required pressure

*Pressure is the **force** per square meter, it is different from flow.*

Pressure is sometimes called "Head" and is often mentioned in meter water column or in bar (1 bar ≈ 10 m water column) or in Pascal (1 kPa ≈ 0.1 m water column). In this manual we use meter water column.

To find the required pressure that a pump has to provide, you need to add up all vertical lengths of the outlet pipe until the water level during pumping (*) (H_out+H_dwl) plus a *part* of all horizontal pipe lengths (L_h). The last is to compensate for horizontal pressure loss due to friction in the pipe. This gives you the required pump head in meters water column.

(*) The dynamic water level
H_{dwl} is the depth of the water during pumping. If unknown, use the static water level H_{swl} (depth of water in well without pumping) and add: 0.5 meter for a high yield well and 5 meters for a low yield well.

***Note 1**: It is recommended to test the well with a (manual) pump before installing a solar pump! This prevents disappointments and work in case the borehole does not have sufficient recharge.*

***Note 2**: Consider that the water table might fluctuate with seasons.*

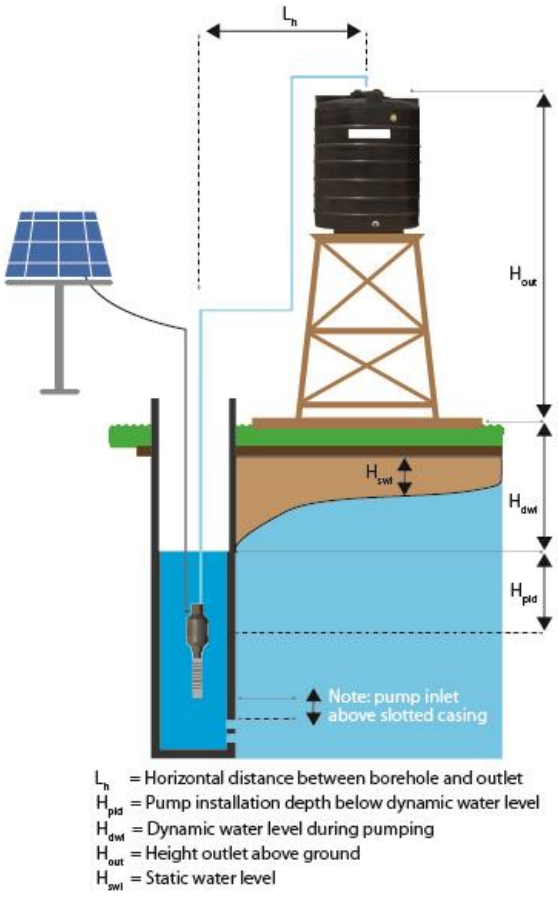


Figure 1 Pump installation and abbreviations

2.3.1 Calculate required pressure

The Excel sheet "Pump selection.xlsx" assists you in calculating the pump head.

The total pump head is calculated with:

$$Total\ Pump\ Head = \text{dynamic water level} + \text{height of pipe outlet} + \frac{\text{total length of pipe}}{x}$$

With the abbreviations used in Figure 1, the equation becomes:

$$Total\ Pump\ Head = \mathrm{H_{dwl}} + \mathrm{H_{out}} + \frac{\mathrm{H_{pid}} + \mathrm{H_{dwl}} + \mathrm{L_h} + \mathrm{H_{out}}}{x}$$

The factor x can be found in the following table[1]:

Outlet pipe inner diameter	Model ZL38-13N (assumed flow: <12L/min)	Model ZL50-20N (assumed flow: <19L/min)
Ca 18mm (Pipe ½")	x ≈ 31	x ≈ 13
Ca 23mm (Pipe ¾")	x ≈ 91	x ≈ 40

Table 1: Friction based on inner pipe diameter and pump type. In general PVC pipes ½" and ¾" have an inside diameter of 18 and 23mm and an outside diameter of respectively 20 mm and 25 mm.

2.3.2 The cable length

The required cable length is obtained by adding the horizontal distance of the solar panel to the borehole and the depth of the pump in the well or borehole.

2.3.3 The type of well

If it is a borehole, take care that the pump will fit in the casing. Find out at what depth the filter screen (slotted casing) is installed and if possible, install the pump above the filter screen so that particles entering the casing will settle on the bottom and do not enter the pump. If it is an open well, make sure that the pump is installed at least 0.2m above the bottom and avoid that dirt or sand will enter the pump.

2.4 Pump Diagram

Each pump has its own characteristics.

- It will pump a bigger amount of water per minute if it does not need to pump very high (low pressure),
- it will pump less water if it must pump to a higher level (high pressure).

2.4.1 Diagram

These characteristics are presented in a pump diagram. Each type of pump has its own line in a diagram. Pump diagrams show:

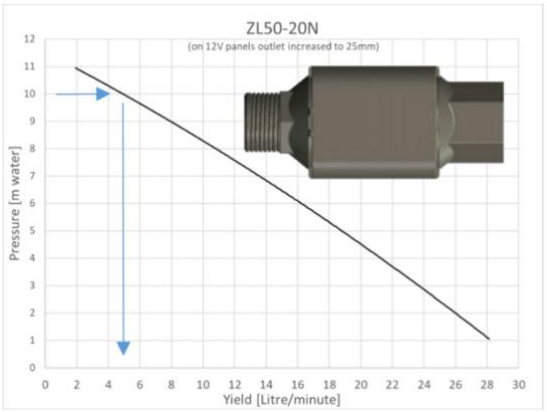


Figure 2 Example pump curve

- Pressure (head) in [meters water] is on the vertical axis.
- Yield (or flow or how much water) in [Litre/minute] is on the horizontal axis.

[1] This is based on the flow the pumps can deliver at 3 meters of head. In most cases this is an over estimation: in reality, the pipe friction will be lower, and the yield higher. For an exact calculation of the pressure drop in pipes see: http://www.pressure-drop.com/Online-Calculator

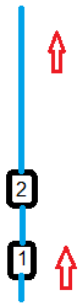
The diagonal line shows how much water the pump will deliver per minute when it must pump to a given height (pressure).

Example

Let's use the same customer as in the examples above. The required pressure is 10-meter water column. In that situation the diagram above shows that the ZL50-N20 pump will deliver 5 Litres each minute (follow the arrows in the diagram above). That is 60*5= 300 Litre/hour. If this pump is directly powered by the sun, then it runs about 5 hours in a day, meaning it will deliver 5*300 = 1500 Litres/day. The customer only needed 1000 Litre per day.

3 Scalability, combining two or more pumps

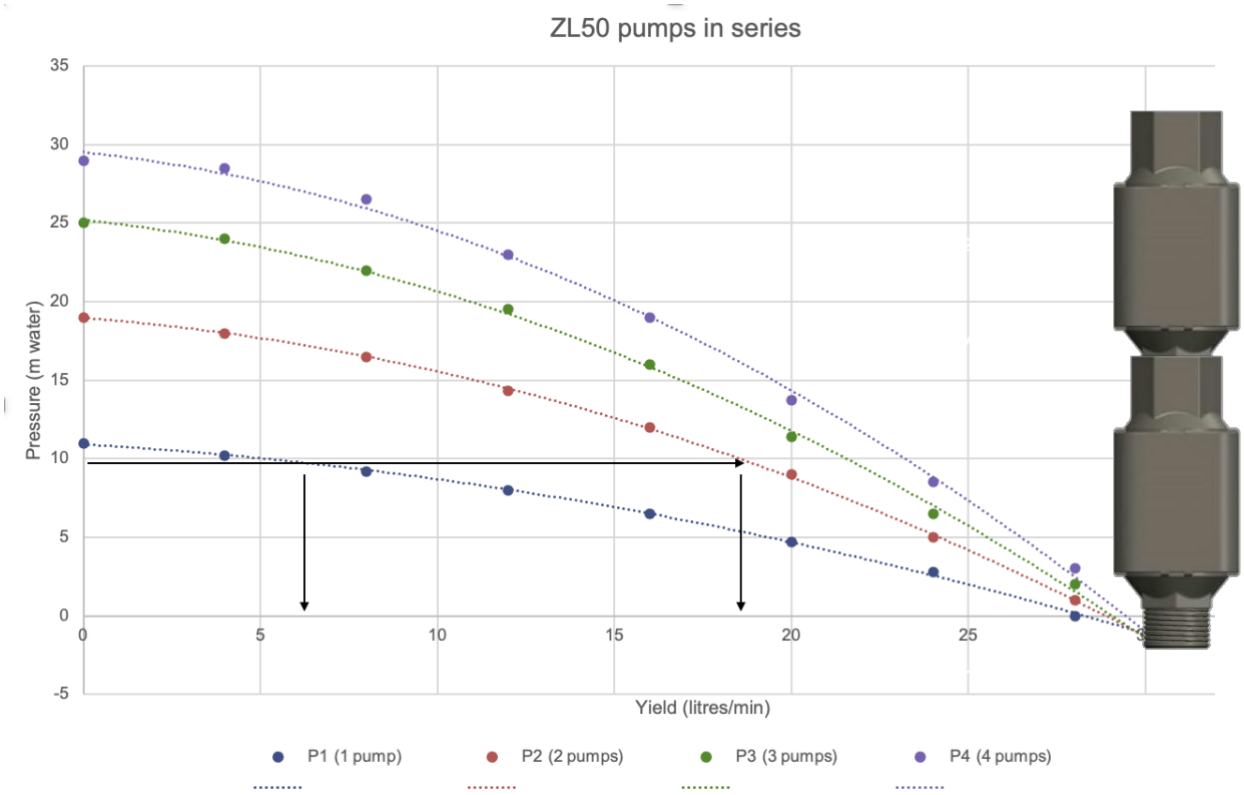
Most customers have limited budget. The ZL series pumps however allow you to combine two or even more pumps to serve your customer.



It is possible to combine pumps in series.
If you connect two of the same pumps in **series**, in theory you will double the **pressure** looking at the same flow.

This way you can provide a scalable solution to your customer. Maybe next year after harvest, he is ready to expand the system.

Here is a diagram that shows what happens when you put 2, 3 or 4 the ZL50-20N pump in series:



Example

The same customer as above, who needed a pressure of 10m water, decided one day to buy a second ZL50-N20 pump and solar panel. Then the system will give him 18 L/min (=18*60=1080 L/h = 5*1080=5400 L/day) compared to the 6L/min=1800 L/day that he got from one pump. Follow the arrows above.

4 Pump protection

1. When a pump is running without water it will damage very quickly. So we have to make sure the pump is switched off when the borehole or well cannot deliver sufficient water. The ZLDC series pumps have a run-dry protection.
2. Pumps also do not like sand or other particles. Sand will wear out the pump fast or it can even jam the pump completely.
3. Some pumps do not like a voltage that is too low or too high. The ZLDC series pumps switch off if the voltage exceeds 30 V DC or 50 V DC for the ZL-50 35 V version.

4.1 Protection against dirt and sand

As mentioned above most submersible electrical pumps do not like sand or other particles.

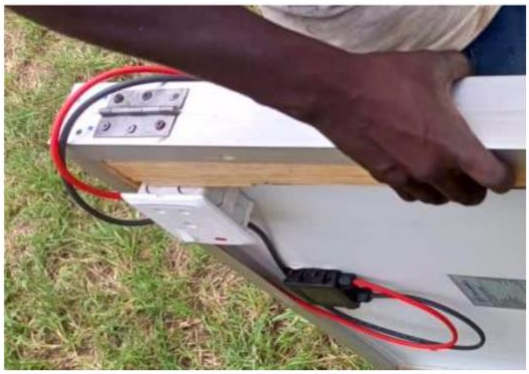
The position of the pump in the borehole or well or other type of source must be so that there is minimum chance for the pump to suck in sand. Do not place the pump at the bottom of a well or borehole. If possible, place the pump intake at a place where the casing (in case of a borehole) has no slots.

During installation or maintenance: make sure that the pump pipe is closed on the top so sand cannot enter.

For the ZLDC pumps it is good if water flows back down when the pump stops. It will clean the filter (back washing) and it makes sure that the pump can start smoothly without having to push water in a full pump pipe first. So don't put none-return valves in these systems.

It is strongly recommended that the pump uses a suction filter. The ZLDC pumps come with standard suction filters.

If the pump is used in for instance a shallow well, an extra protection is needed to prevent to pump from being in direct contact with sand or dirt. We recommend using a bucket as shown in this picture.



5 Other components

5.1 Solar panels

In general, the required solar panel output in Watt peak (Wp) must be 30% higher than the rated power of the installed pump(s). Also, to compensate for partly cloudy weather it is recommended to choose a larger panel size.

- The recommended panel size for model ZL 38-13N is 60 Wp.
- The recommended panel size for model ZL 50-20N is 100 Wp or 2 * 80 Wp panels for the ZL 50-20N 35 V version (in series).

If you buy more panels make sure to buy identical panels (same brand, same features). Note that the power (Watt) indicated on a panel is often less than the real output in Watt. If more brands of panels are available, find the most effective panel by testing several brands with the same pump configuration and compare head or flow.

The panels need to be close to the pump to prevent losses in cables and high cable costs. Make sure the panel(s) are fixed securely on a panel stand so nobody can steal them or, if the customer wants, make them removable so they can be stored in house at night.

5.2 Wire size

Wire size for DC pumps is **extremely important**, the system will not work if the wire is too thin.

Remember: Watt = Volt X Amps.

DC pumps normally run on low voltage. Meaning the Amps need to be high to get the same Watts. For instance, a 12 Volt DC pump of 50 Watt needs 50 W /12 V= 4 Amps. A pump of the same power running on 240 V AC requires 50W/250V = 0.2 Amps.

- one pump ZL 38-13N has a current of approximately 1.7 Ampere.
- one pump ZL 50-20N has a current of approximately 3 Ampere.

High Amps in a thin wire is like pushing a lot of water through a tiny pipe. It results in high friction and resistance and therefore heat and losses. If wires are too thin most of the power from your panel will go into heating the wire and parts of the electrical system might even burn.

The Excel sheet "Pump selection.xlsx" assists you in calculating the optimal wire size.

In general, a bigger wire is never bad, but there comes a point that the extra costs are not benefitting the system.

In general, we recommend the following:
ZL38-13N:

- 1.5 mm² if cable length is < 30m
- 2.5 mm² if length is 30 to 50m
- 4 mm² if length is 50 to 90m

ZL50-20N:

- 2.5 mm² if cable length is < 30m
- 4 mm² with lengths of 30m to 50m
- 6 mm² with lengths of 50m to 70m

To reduce the electric losses in the cable to a minimum, mount the panels as close as possible to the pump.
Use good quality cable. Cheap cable may have a high resistance.

If two or more 12 Volt panels are used, they need to be connected in parallel.

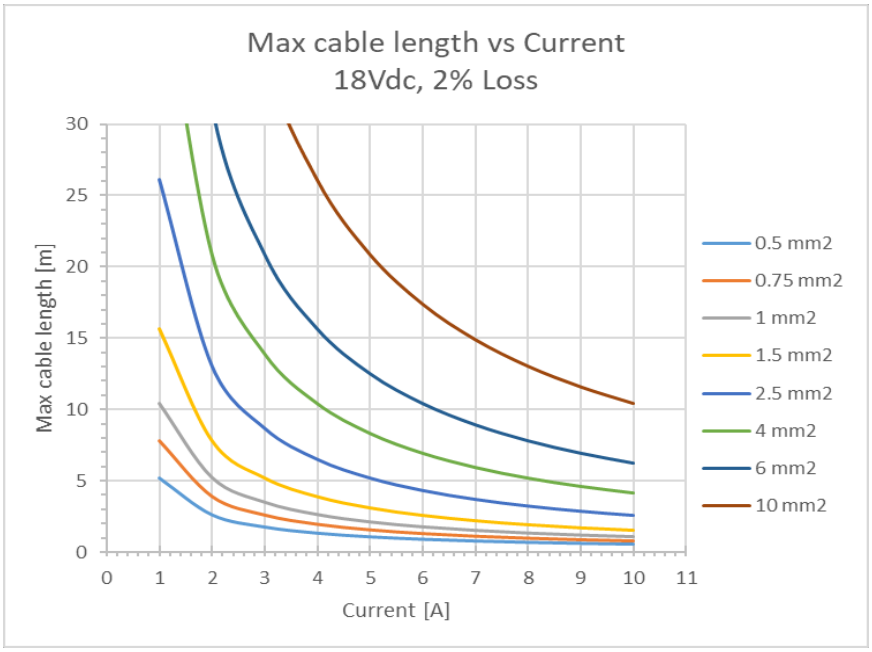


Figure 3 Maximum cable length per type of cable at a 2% loss. The length is measured from pump to solar panel. Do not use cables of less than 1,5 mm²

6 Example of pump selection

Note: The Excel sheet "Pump selection.xlsx" assists you in every step of selecting the right pump (configuration) and cable size.

Example
A client needs 3.000 Litre per day and wants to fill an elevated tank of which the top is 6 meters high. The dynamic water level is at 7 meters. The horizontal distance from the well to the tank is 10 meters. The client does not want a tank sensor. If the tank is full, the water will come out of the overflow. The client will disconnect the pump manually.

Step 1: Calculate the required flow of the pump.
Assuming there are 5 hours of sun every day, then the minimum pump yield (Flow) should be 3000/5 = **600 Litre/hour** = 600/60 = **10 Litre/minute**.

Step 2: Calculate the pump head
A simple calculation of the total pump head is done by adding the dynamic water level, the height of the tank and 10% of the horizontal pipe so 7m + 6m+1m = 14 meter.

Step 3: Pump model and number of pumps
To select a pump, we look at the pump curves of both models.
Select the flow of 10L/min on the horizontal axis, go up until you hit the pump curve and you find the corresponding pump head on the vertical axis.

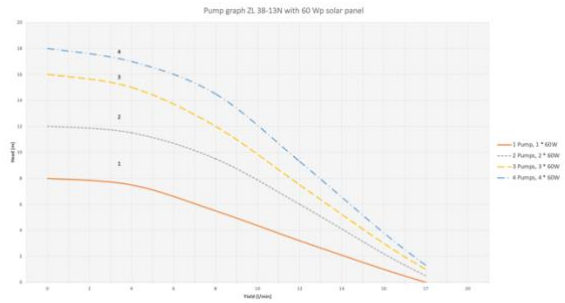


Figure 4 Pump graph ZL38-13N

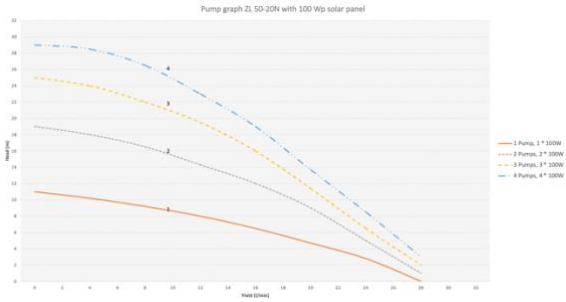


Figure 5 Pump graph ZL50-20N

At 10 l/min the model ZL38-13N one pump has a head of 4 meters.
With 4 pumps in series the pump head is 10 meters, so we select two pumps of model ZL50-20N.

Step 4: Select cable size
With two pumps ZL50 and two panels in series the current is 6 Ampere.
We assume that the solar panels are mounted 2 meters from the borehole. The cable length than is the sum of the dynamic water level, the depth of the pump under water and the 2 meters distance
If the pump is 2 meters under water the total cable length is 7+2+2 = 11 meters.
In figure 6 we find the correct cable size at a length of 11 meters and 6 Ampere is 6mm^2.

Note: The pump will also function with a smaller cable size, but the smaller size will increase electric losses resulting in less pump efficiency.

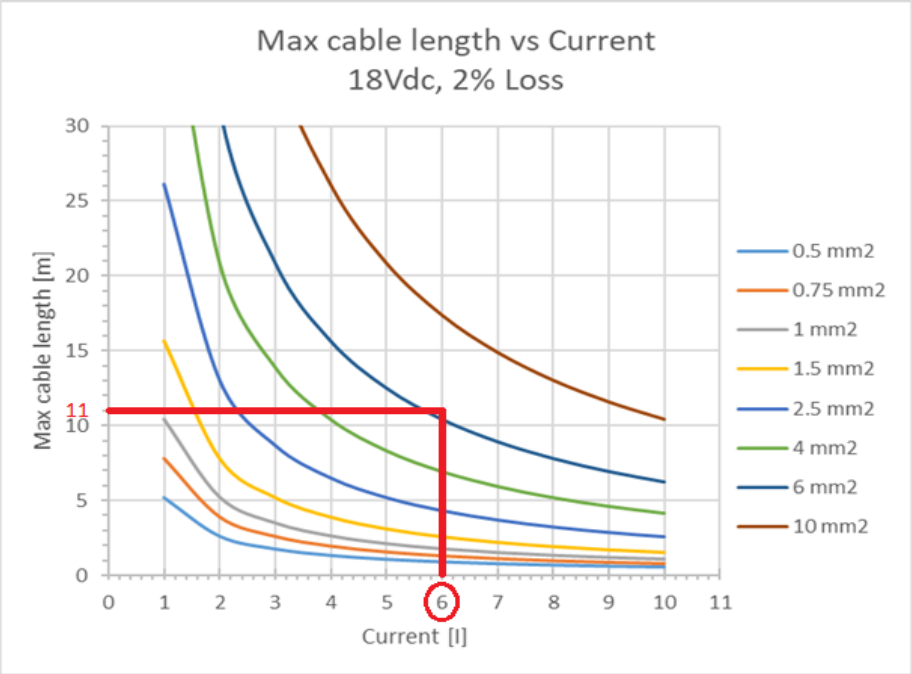


Figure 6 Selection of cable size using length and current

Step 5: Cost calculation

From the above calculations, we can make the list of required materials and calculate the total cost.

Item	Quantity	Price/unit	Price total	Observations
Pump ZL50-20N	2			
Solar panel 100Wp	2			
Pipe (inner diameter 22mm)	23 meters			
Cable, 2 core 6mm^2	11 meters			

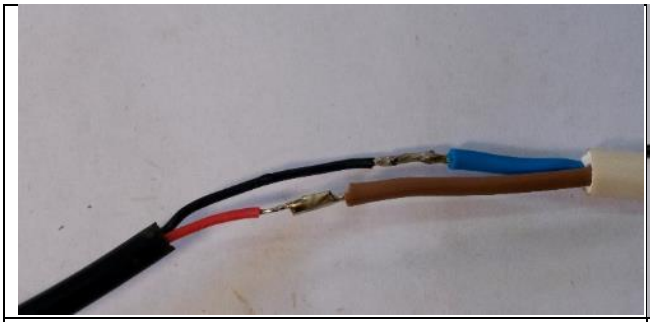
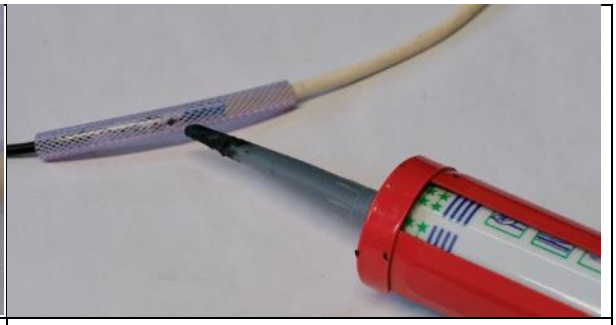
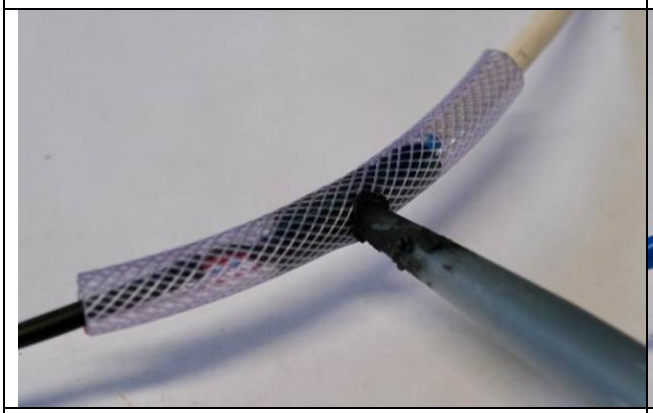
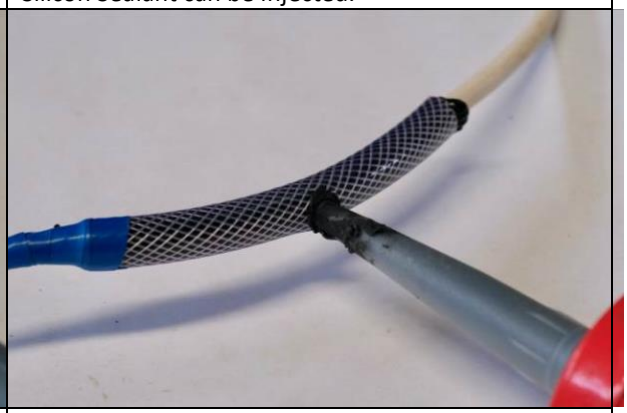
7 Appendix

7.1 Wire connection to panel

If you want to make the panels removable use a high-power connector. The standard solar MC4 connectors are not designed for frequently unplugging. If it is not possible to find a good DC connector, then you could use for example the round pin South African type of plug and socket. In this case connect the minus to the Earth pin and the positive to the Neutral pin. This way you avoid the tiny switch which will get damaged quickly.

7.2 Connection of electric cable to pump

To ensure a long functionality of the pump, the electric cables must relate to a waterproof connection. If moisture can enter in exposed copper wires, it will corrode them within a few months and the pump stops working.
There are several options to make waterproof connections (e.g. sealing heat shrink sleeves or pump splice kits). This is an example of a simple and affordable solution.

	
Solder wires of pump together at different lengths, so exposed wires cannot touch each other and shortcut.	Slide a flexible tube over the soldered connection with a small hole in the middle. From the hole, Silicon Sealant can be injected.
	
Inject the Silicon sealant, so it spreads to both sides of the flexible tube.	When sealant is coming out of one side, close it with tape. Insert sealant until it comes out the other side.

	
Close the other end with electric tape and wipe the excess silicon from the injection hole.	Seal the hole with electric tape to avoid spreading silicon sealant everywhere.

7.3 Pump assembly

	
Model ZL 50-20N can be disassembled with a screwdriver (PH2)	Model ZL30-13N can be disassembled without tools by turning the end covers anti clockwise. If the top cap is loose, mount it with some drops of super glue

7.4 Example of installation and applications

	
Installation of 2 pumps model ZL 50-20N	Installation in a casing of 90 mm
	
Slot in the casing to accommodate cabling in the well head.	Cover the borehole

	
A pump, panel, hose and cable mounted on a wheelbarrow. It is easily transported to distance fields for irrigation	The wheelbarrow pump is pumping from a river to irrigate vegetables
	
1 pump ZL 50-20N is replacing a Rope pump. It pumps into a tank and is used for drip irrigation.	4 pumps ZL50-20N in series powered by 4 panels of 100 Watt. Water is used for communal water supply
	
Sometimes the top cap of the pump model 38 can become loose, especially if more pumps are mounted in series	To prevent this, mount the cap with a few drops of super glue or other glue. Gluing is OK since there is no need to open this cap.