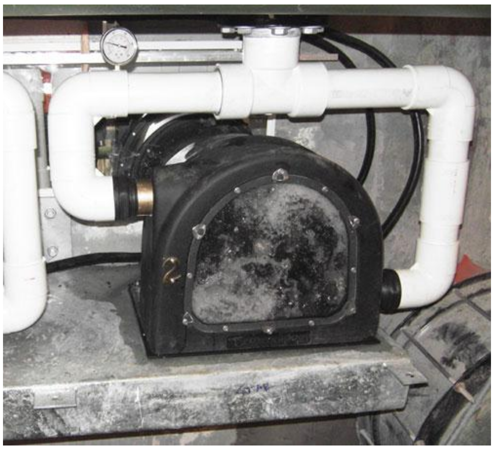
July 2011

The Advanced Calculator for PowerSpout






Please read this manual carefully to ensure you obtain valid calculation results for your site. Worked examples are given at the end of this document.

If you cannot find the answers to your questions about your site's potential or designing your system with the Advanced Calculator, please email us at questions@powerspout.com

Please accept that we may answer your question by directing you back to a certain part of this manual.

If you are having technical difficulties with the website, please email us at support@powerspout.com

If you are having problems with your existing order, please email us at orders@powerspout.com

Advanced Calculator and this manual update July 2011

- Login procedure removed
- New product options
- Automatic SD calculator tool
- More unit conversion added
- Saving features and email your dealer etc
- New examples added for new products

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1. Introduction

We take the pain out of hydro design for everyone!

The **Advanced Calculator** is an easy to use software tool that helps you determine how much electricity you can produce at your site from one to ten PowerSpout generators.

Anyone can use the calculator – we certainly do. We have developed it to do all the complex calculations for you, incorporating factors such as water friction and cable resistance losses. Hydro design is now easy, even for non engineers. If you are an engineer the **Advance Calculator** will still save you time.

You can trial possible system designs and quickly realize the consequences of any changes you make. This will enable you to find a good economic solution to your hydro needs.

A basic principle of hydro design is that if you want more power then you need more water and/or more head (i.e. height of fall between the intake and the generator). It is often true that there is less water higher up a stream, hence increasing the head might also mean less water. However, it is generally more cost efficient to go as high as you can since:

- a smaller diameter (cheaper) pipe can be used
- less water is needed
- each hydro turbine can generate more power/turbine
- you tend to be less exposed to flooding on higher heads

The PowerSpout turbine has been designed to operate at up to 100m of head which has been sufficient for 99% of our clients. One big advantage of this is that the rotor does not need to be made of brass or stainless-steel, and hence we can avoid the use of expensive materials. Siting the intake further up the stream valley to get more head will increase your pipe length and hence cost for the pipe, but the smaller diameter pipe required tends to mean reduced overall costs.

Moving the generator further downstream can increase the length of cable required to transfer the power to the house. If the cable is too thin, or long, or both, the cabling will limit the electricity delivered. To avoid high cable costs changing the cable voltage and cable material may result is a good solution for your site.

The **Advance Calculator** is intended to be simple. As each input is entered the calculator recalculates all items. It can also serve as an educational tool for a student learning about hydro design.

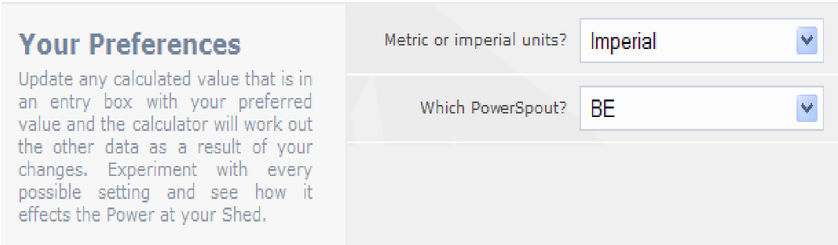
2. How do I use it?

Before you go to the Advanced Calculator it is worth knowing data about your site. You should measure the head and flow rate you have available and the length of pipe and cables that you will need. If you have more than one potential location for the intake or generator, take note of the distances for each so you can investigate your options.

Then go to www.powerspout.com and click on

2.1. Getting started

Use the first drop down box to select metric or imperial units for input and display. You can change this at any time and enter values with your choice of units.



Select which PowerSpout you want to design with. The summary description of each is given below and more detail is provided in the Installation Manual and the Technical Manual, both available for download from the www.powerspout.com website.

Cable length is a key factor in selecting your PowerSpout version since this can have a significant impact on the installed system cost. You can often reduce cable costs by increasing the system voltage, but this can affect who is allowed to install the system:

- If you are living off grid and cable cost for your hydro is affordable (e.g. the cable costs less than the hydro turbine cost) then you should use the **BE version** (at 12, 24 or 48 V DC) direct to your battery bank. The BE turbine may be installed by the owner.
- If you are living off grid and cable cost for your hydro is a major part of your overall cost then you should use the appropriate **ME version** at up to 250 V DC with a Maximum Power Point Tracking (MPPT) function regulator to alter the voltage and harvest optimum power (while charging your battery at 12, 24 or 48 V DC). In countries that have 120 ELV laws the ME 75/100/120 turbine can be installed by the owner. ME 140 and ME 250 need to be installed by a registered electrician.
- If you are living on the grid/network you **may** use the **ME version** where the maximum input voltage of the inverter does not exceed 100/120/140 or 250 V DC depending on ME version. Most clients will use the **GE 400 version** that is designed for grid-tied situations via inverters that commonly operate at up to 400 V DC. The GE 400 must be installed by a registered electrician.

Each PowerSpout also has a High Power (HP) version which can generate up to 25% more than the regular turbines. Hence if the calculator suggests more than one ‘regular’ turbine, it could also be worth trying the HP version. In some cases using HP turbines can reduce the number of turbines required, hence reducing total cost. There is no advantage to a HP turbine if you do not have a site that needs more that one normal turbine.

Table 1. Choice of PowerSpout version

Version	Description	Cable length (m) approx.	Applications
BE	Battery Enabled	0 - 250	12/24/48 VDC battery systems where the cable voltage is nominally the same as the battery voltage.
ME 75 (coming soon)	MPPT Enabled	50 - 500	Lower power sites, countries with ELV75 laws* and for those wanting to use the Morningstar SS-MPPT-15L 400W MPPT regulator.
ME 100	MPPT Enabled	50 - 750	MPPT regulators that operate up to 100 VDC or Latronics grid tied inverter (made in Australia)
ME 120	MPPT Enabled	50 - 1000	Countries that have 120 ELV laws*. Use with an MPPT regulator that can operate up to 120 VDC
ME 140	MPPT Enabled	50 - 1500	Countries without 120 ELV laws that want to operate at close to the 150 VDC limit of common MPPT regulators such as FlexMax 60/80, Xantrex XW SCC, Apollo Solar T80, TS-MPPT-45/60
ME 250	MPPT Enabled	50 - 2000	Long cable runs and those that want to operate at close to the 250 VDC limit of most large MPPT regulators such as the Midnite Classic 250
GE 400	Grid Enabled	0 - 2000	Used with common grid tied inverters that have an input voltage rating above 400 VDC
LH (coming soon)	Low head		New product designed for sites with low head (1.5 – 4 m) and flow of up to 50 l/s

* ELV (extra low voltage) laws in some countries allow home owners to install equipment up to a given voltage without regulatory control applying to them. For example ELV120 rules apply up to120 V DC in NZ and Australia, and ELV75 rules apply up to 75 V DC in parts of Europe (check your local regulations).

In the **Advanced Calculator** the type of PowerSpout alters the way the electrical calculations work according to how each version of the PowerSpout operates.

The type of Smart Drive (SD) stator/rotor used in your PowerSpout is important. The Advanced Calculator automatically selects the best options for your site data and PowerSpout type selected.

In most cases 3 or more options will be displayed in priority order. The first column score (Pref.) indicates preference with scores nearer to 1 being easier to produce. The SD codes have been developed by EcoInnovation to help differentiate between SD variations. The final column (Vo) indicates the output voltage.

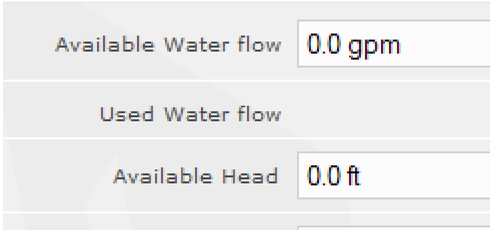
The following are SD type code options (These are copyright of EcoInnovation and are only provisional)
4 SD stator/rotor options found

Pref.	SDcode	Vo
1.5	100-14S1P-S	231.4
8.0	60-7S2P-D	264.9
20.0	60dc-4S3P-D-HP	220.2
32.0	60dc-5S2P-D-HP	214.9

This SD data is displayed in the electrical section of the calculator for your information. The primary objective is to help EcoInnovation identify the most suitable rotor/stator and hence ensure you can get the best from your site.

2.2. Essential data

You need to enter values for the available water flow and head before other entries are possible.



Enter the amount of water you have available to use. Enter the vertical fall (available head) for your stream.

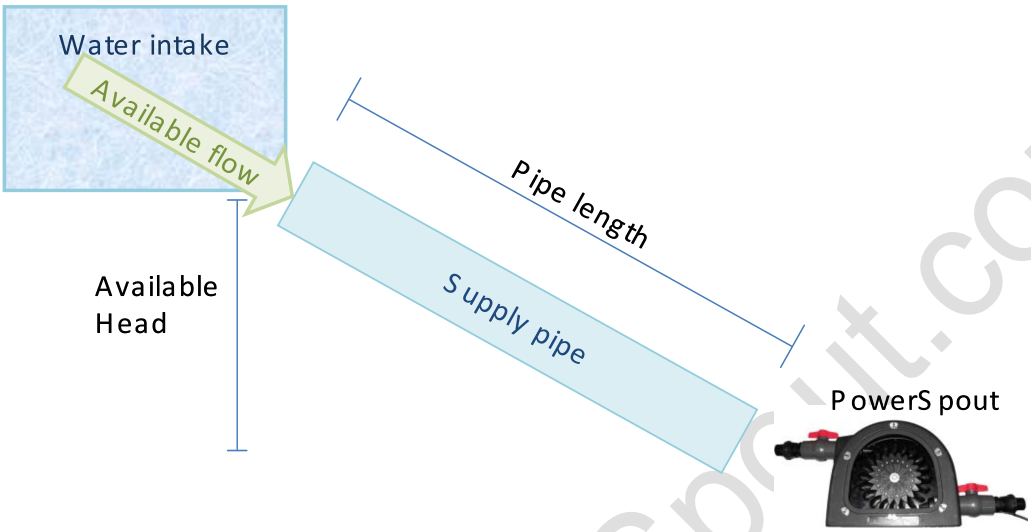
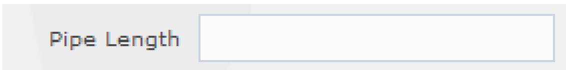


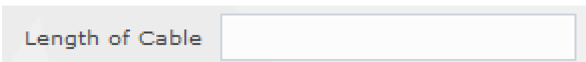
Figure 1. Water supply system

Once this data have been entered, the program completed the other data fields with random data to fill in the blanks in order to get an answer. **You must edit** this information so it is correct for your site.

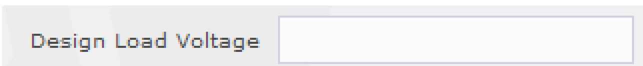
The pipe length relates to the distance between the intake and generator.



The cable length is the distance from generator to the batteries (or load).



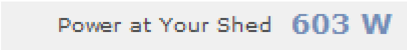
The Design Load Voltage is calculated by the **Advanced Calculator** if you are using an ME or GE PowerSpout, the correct number will be entered automatically.



If you are using a BE PowerSpout then enter the nominal float voltage for your battery bank.

- Typically a 48V lead acid battery bank will have a nominal float voltage of 56V
- Typically a 24V lead acid battery bank will have a nominal float voltage of 28V
- Typically a 12V lead acid battery bank will have a nominal float voltage of 14V

2.3. Improving your design



Once initial data have been entered you will see an output figure at the bottom of the page. The “Power at Your Shed” is given in Watts and represents the capacity of your system.

The **Advanced Calculator** always tries to maximise the electrical power for a given hydro resource. The **Advanced Calculator** will recommend as many PowerSpout turbines as necessary to harness all the available water.

Improvements generally satisfy one or both of two main objectives:

- Reducing system costs
- Increasing power generation

Other improvements may enhance the safety of the system or ensure the design will comply with warranty conditions. Notes will appear on the left side of the screen to guide you through most of these issues (see below).

You can type your values into any entry box. A few moments after you stop typing the **Advanced Calculator** will recalculate all values, causing other values to change as a result. Whenever you make a design change, check the ‘*Power at Your Shed’* result. More power is almost always better.

2.3.1. Reducing system costs

If the design provides ample power for your needs and you wish to minimize your build costs then you can try reducing one or more of the following:

- The number of PowerSpout generators
- Pipe diameter (inside diameter. The calculator assumes a smooth walled plastic pipe)
- Cable sizes

You can test the impact of each of the above in turn or in combination, while checking there will still be enough generation for your needs.

You can check availability and costs of pipes and cables with your local suppliers to help determine the total costs and $/Watt cost of your system design options.

2.3.2. Increasing power generation

If the power available is very low, you should look at whether you can increase this by increasing:

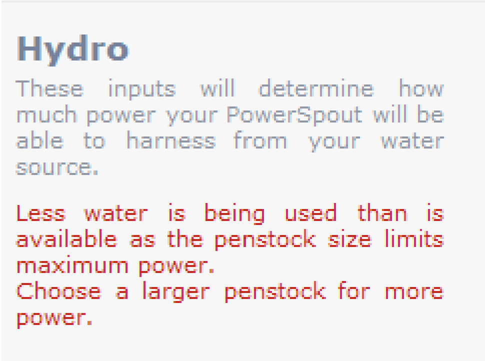
- The head (going further upstream) or
- Pipe diameter (inside diameter)

In some cases using a high power (HP) turbine is a cost effective way to boost your power production.

If generation is still very low you should investigate other generation options. For example, if you get only 20 W then in most cases there are cheaper and easier options. One solar PV panel is a good option for 20 W, unless there is no sunlight available.

2.3.3. Notes and hints

Please read the design notes in red on the left hand side of the screen. These notes are important as they enable you to understand ways to improve your design, or provide safety concerns and warrantee issues you may need to consider.



See Section 4 for more detailed explanations.

2.3.4. Interaction between entries

Some boxes do more than might seem obvious at first.

- If you enter a specific *'Pipe Diameter'* then the **Advanced Calculator** overrides the *'Target Pipe Efficiency'* you entered and automatically 'locks' the pipe size for you with *'Lock Pipe Diameter'*.

  If you then enter a new *'Target Pipe Efficiency'* then the pipe size will unlock and be adjusted for the *'Target Pipe Efficiency'* to be met.

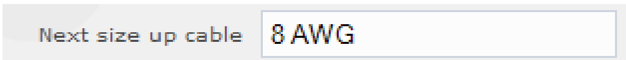
  The *'Actual Pipe Efficiency'* shows the efficiency of the displayed *'Pipe Diameter'*.

- If you enter a *'Cable size'* or *'Metric cross section'* then the *'Lock Cable Size'* will be ticked for you. This blocks the automatic calculation of the cable size based on the *'Target Cable Efficiency'*.

  Then entering a new *'Target Cable Efficiency'* will unlock the *'Lock Cable Size'* so the cable size will be calculated according to the new *'Target Cable Efficiency'* you have just entered.

- *'Cable size'* and *'Metric cross section'* are interactive. When you enter a *'Cable size'* in AWG then there is always a decimal number for the *'Metric cross section'* which is an accurate equivalent.

  Cables specified in *'Metric cross section'* are normally made to whole ½ square mm values. These do not have an AWG equivalent. So the Advanced Calculator rounds up to the next AWG size and displays this in the *'Cable size'* field and changes the title to *'Next size up cable'*.



2.3.5. Design improvement example: Hydro pipe losses

If you enter a very small diameter and/or long pipe then the pressure drop may be too great for the water to flow through it. The maximum water power through a given pipe size (assuming you have plenty of water available) occurs when the pressure drop is 33.3%.

To avoid excessive pipe losses the **Advanced Calculator** automatically reduces the water flow to obtain the maximum power for the pipe you have specified. A note will appear in red to alert you to the issue and advise you to specify a larger pipe.

For example, at a site with 40 m head and 2 lps available flow, a 20 mm pipe would restrict the flow used to 0.2 lps and hence significantly reduce generation potential. Increasing the pipe diameter to 45 mm will allow the full flow to be utilized and increase the generation capacity by an order of magnitude.

2.3.6. Design improvement example: Cable costs

Although it is possible to use a long small cable with a PowerSpout BE, it is likely to be very inefficient (high cable losses) and hence is rarely a cost effective option. Using a heavier cable or changing to another type of PowerSpout to operate at a higher voltage is the preferred solution.

For example, a 12 V battery located 1,000 m from a PowerSpout BE delivering 200 W at 90% efficiency requires a 430 mm^2 copper cable. Changing the design to use the PowerSpout ME and the *'Target Cable Efficiency'* to 95% will deliver the same energy but require a cable size of just 13.7 mm^2. Since the larger cable costs around $150/m and smaller pipe closer to $5/m, this is a huge reduction in cable costs.

The longer the cable run, and the lower the load voltage, the more likely it is you need an ME PowerSpout with a MPPT controller. Change to a GE or HE PowerSpout for even greater savings in cable costs, but be aware that only qualified electrical workers are allowed to do the installation.

2.3.7. Cable efficiency limit

With ME and GE PowerSpouts the maximum power transfer through the cable occurs when the 'Actual Load Voltage' is approximately half the 'PowerSpout Output Voltage'.

MPPT controllers and Grid tied inverters feature a wide input voltage range. The calculator knows this and alters the Design and Actual load voltages accordingly.

A cable with more loss will result in the 'PowerSpout Output Voltage' being higher, up to the limit for that type of PowerSpout. The **Advanced Calculator** then reduces the 'Used Water flow' to prevent exceeding the voltage limit of the PowerSpout.

2.4. Save & Share Results

Your turbine will be designed for the site data you supply, so it is very important to ensure the data are accurate. If you operate the turbine on a different site, or in very different conditions, the power output will differ. If you intend to run your turbine over a wide range of flow rates, you need to state this at the time of ordering, since a new generator core may be required to obtain the best results. A different generator core can be supplied for an additional charge.

Save & Share Results
If you wish to save your results above and share them with a dealer, please input your own email address, and select a dealer if desired. You will receive an email containing a summary of the results and a reference number.

You can save the data from the calculator for yourself, and/or share them with a dealer. All you need to do is to input your own email address, and select a dealer if desired. You will receive an email containing a summary of the results and a reference number. You should check all the data to ensure they are accurate. Once you are satisfied with the data **you need to follow up with your dealer to confirm your requirements and place your order**.

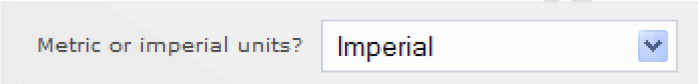
3. About making entries

3.1. Metric and Imperial units

Internally the **Advanced Calculator** does everything in metric units with full precision and results are displayed according to the selected unit system.

Please note that US Gallons are used not British Galloons in the calculations, Britain is metric.

If you change between imperial (US) and metric units then all values are redisplayed accordingly. The resultant output power may change a minor amount due to rounding differences between the input units.



You do not have to be in Metric to enter a metric value, and the units are **not case sensitive**. For example, you can enter “*10 lps*” or “*132 gpm*” (Litres per second, US Gallons per minute) for ‘*Available Water flow*’. The letters after the number tells the **Advanced Calculator** what units you are using. These will be converted for use and displayed in the preferred units after calculations are completed (Table 2).

Table 2. Units and conversion rates

Preferred unit	Entry units	Conversion factor
m	ft	0.3048
	in	0.0254
	cm	0.01
	m	1
	mm	0.001
	mile	1609.344
	kpa	0.102
	psi	0.703
	bar	10.197
	atm	10.33211
lps	lps	1
	lpm	60
	lph	3600
	gpm	0.06301
	cfs	28.31684659
	cfm	0.471947443
	cfh	0.007865791
	cfd	0.000327741
	cumecs	1000

All values are read from left to right as a number of digits with an optional decimal point followed by an optional string of characters giving the unit type. Furthermore:

- Only the first decimal point is considered.
- All spaces are ignored.
- Any unit that is mistyped or not recognized will be ignored and the unit displayed before typing is assumed.
- If no unit is given then the unit displayed before typing is assumed.

3.2. Each entry and result explained

3.2.1. Available water flow

This is the amount of water you can use, usually determined by measuring the flow in your stream(s). Valid units are litres per second (lps) and gallons per minute (gpm).

3.2.2. Used water flow

This is the water flow that will be used by the pipe. If you have a system design that limits the amount of electricity that can be produced then the calculator determines the amount of water that is required to produce this amount of electricity.

3.2.3. Available head

This is the vertical height from the pipe intake to the turbine (see Figure 1).

3.2.4. Pipe Length

This is the actual length of the pipe you intend to use (see Figure 1).The pipe that carries the water to the PowerSpout can be very long if you have gentle sloping land.

3.2.5. Target Pipe Efficiency

This is related to the losses in the pipe: water flowing quickly through a pipe causes friction and this reduces the water pressure available for the PowerSpout to convert into electricity. Generally 90% efficiency, or 10% power loss in the pipe, is a reasonable design point.

At 90% efficiency the pressure at the PowerSpout when it is operating will be 10% less than the pressure in the pipe when the PowerSpout is off (static pressure).

The minimum efficiency you can enter is 66% since this is the point that maximum power transfer will occur if there is unlimited water available. With limited water, more power is produced by reducing the pipe loses, which means a larger pipe.

3.2.6. Pipe Diameter

This is the internal diameter of the pipe carrying the water to the PowerSpout. Pipes are often sold by their external diameter, so be careful. A higher pressure pipe has a smaller inside diameter than a lower pressure pipe of the same specified outside diameter because it has a thicker wall.

For a high head site use lower pressure rated pipe for the top section in order to save on cost. Enter in the smallest internal diameter of all the pipe you will be using. The small pipe size will dominate the flow calculations.

3.2.7. Lock Pipe Diameter

A tick here tells the **Advanced Calculator** to use the given pipe diameter and ignores the Target Pipe Efficiency.

3.2.8. Number of PowerSpouts

The **Advanced Calculator** tries to maximise the power output for the water flow available and hence may use multiple PowerSpouts to achieve this. However, one less PowerSpout does not always reduce the output power that much since it may not have been fully employed, and you cannot have 1.2 PowerSpouts. It is worthwhile trying one less PowerSpout than the calculator advises.

3.2.9. Lock PowerSpouts

A tick in here tells the calculator to retain the current number of PowerSpouts rather than choose the number of PowerSpouts for maximum electricity.

3.2.10. 1 or 2 Jets per PowerSpout

Sometimes you might not want to use one jet even though 2 jeta are possible. In most cases a single jet is a bad design choice as it increases the loading on the turbine bearings.

One jet may be used in situations where for example:

- Output power is less than 400 Watts;
- There are much lower summer flows (2 jets used in winter, 1 in summer);
- You have a high head low power site and a single jet is larger so it is easier to make and less likely to become clogged with debris.

3.2.11. Jet diameter

This is the hole size for each jet. The size is calculated for 1 or 2 jets.

3.2.12. Actual Pipe Efficiency

This is the efficiency of the pipe size used. See section 3.2.5 aboveabove.

3.2.13. Rotor Speed

The Pelton wheel and generator speed is displayed so you can appreciate just how quickly it is going. Under no load conditions the rotor speed can almost double. The rotor has a maximum design speed of 2000 rpm with a 2.5:1 factor of safety. Both rotors are fully enclosed for your safety.

3.2.14. Output per PowerSpout

This is the electricty output in Watts measured at the PowerSpout.

3.2.15. Total PowerSpout output

This is the total electrical power from your PowerSpout(s) in Watts before the cable losses. This power then travels to your power shed via a cable which has losses.

3.2.16. PowerSpout output voltage

Power transfer through a cable results in a voltage drop across the cable. The PowerSpout output voltage is always higher than your load voltage so there can be electrical current flow. A quick look on the internet will explain Ohms law for you.

The calculator considers the voltage limit of the PowerSpout you have selected and will adjust the numbers accordingly to keep this voltage within limits:

- PowerSpout BE voltage can be upto 3-4 times higher that your battery nominal voltage if allowed to free spin disconnected from the battery. You must not free spin a Powerspout BE. Always ensure it is connected to the battery load.
- PowerSpout ME turbines are limited to the voltages given in Table 1. This is the clamping voltage of the internal circuit board to meet ELV rules for some countries as well as a safe operating voltage for many MPPT charge controllers.
- PowerSpout GE is limited to 380V. This is the clamping voltage of the internal circuit board to provide a safe operating voltage for many grid tied inverters.

3.2.17. Target Cable efficiency

Electricity flowing through a wire suffers from losses. Generally 90% efficiency, or 10% power loss in the cable, is a reasonable design point. At 90% efficiency there is a 10% voltage drop along the cable. The minimum efficiency you can enter is 50%. Please note that some regulations around the world limit the maxium cable loss to 3-5%, so check you local rules.

3.2.18. Length of Cable

This is the actual length of the cable from your PowerSpout to your batteries or load.

3.2.19. Design Load Voltage

This is the operating voltage of the equipment you will be connecting to your PowerSpout.

- If you are using PowerSpout BE then this will be the nominal float voltage of your battery bank (see section 2.2), which is typically 16% higher than the rated voltage. For eample, with a 48 V battery system you need to enter 56 V since this is the voltage to which a 48V lead acid battery is raised to achieve full charge.
- If you are using a PowerSpout ME 120 then the **Advance Calculator** will insert 105V. The PowerSpout ME clamps at 115V which allows for a 15% cable drop to your MPPT controller. You can enter a different voltage here if you want. Please refer to Actual Load Voltage below to see why there is little reason to adjust this number. The design load voltage for other versions of PowerSpout ME are ME 100: 90 V, ME 140: 125 V, and ME 250: 230 V.
- If you are using a PowerSpout GE 400 then the **Advance Calculator** will insert 350V here. The PowerSpout GE clamps at around 385V which allows for a 10% cable drop to your grid tied inverter. You can enter a different voltage here if you want. Please refer to Actual Load Voltage below to see why there is little reason to adjust this number.

3.2.20. Actual Load Voltage

This is the voltage at your power shed. If this is for a BE or HE PowerSpout then it will always be the design load voltage.

If you are using an ME or GE PowerSpout then the MPPT (Maximum Power Point Tracking) function in your charge controller or grid tied inverter will adjust the load voltage according to the losses in your cable. The MPPT function will never go below ½ the PowerSpout Output Voltage as this results in less electricity delivered to your power shed.

3.2.21. Cable Material

Copper is not the only material for electrical cables, and aluminium is often used. Aluminium has higher losses than copper on a cross sectional area basis but much lower losses on a weight basis. As wire is sold by the kg, aluminium cable is more cost efficient than copper cable. Copper cable is more efficient size for size only.

Most big power cables used for long distance power transmission in national grids around the world are made with a steel core for strength and with aluminium for conduction.

The availability of low cost steel fencing wire is an attractive option for standalone power systems particularly with PowerSpout GE. Very long suspended spans of up to 1 km (2/3 mile) can be made using high tensile strength steel wire and may be an ideal choice. (Please check local rules regarding suspended wires. They are very dangerous for aircraft!).

Steel is a variable conductor as there are many different steel grades. If you are considering this option you will need to confirm electrical losses with your supplier or to measure losses of a sample.

3.2.22. Metric cross section/Cable cross section

Metric cables are defined in square mm of cross section. This refers to the cross section of the cable for each direction. If you have a two-core 4 mm^2 cable, one conductor for positive and one for negative, then you enter 4 mm^2.

When you enter a new cable size the **Advanced Calculator** will tell you the next biggest AWG size for this metric size.When you enter a specific cable size then the Lock Cable Size will be ticked for you automaticlly.

3.2.23. Lock Cable Size

This locks the cable size and prevents the **Advanced Calculator** from using the Target Cable Efficiency to determine a new cable size.

3.2.24. Cable Size / Next size up cable

As for Metric cross section, the AWG (American Wire Gauge) size is the size of each wire required. This will update the Metric cross section with the exact mm^2 for the AWG wire size entered. When you enter a cable size then the Lock Cable Size will be ticked automaticlly.

3.2.25. Cable Current

This is the number of amps in the cable. It is useful to know this if you need to talk to a cable supplier about current handling and for fuse sizing.

3.2.26. Actual Cable Efficiency

This is the efficiency of your cable. If you have 90% efficiency then 10% of the electricty produced by your PowerSpout(s) is lost before it reaches your power shed.

These losses create heat in the cable. The loss calculation assumes your cable is lightly loaded and is operating at 20ºC (68ºF). As cables carry more current they heat up and their losses increase.

Cable manufactures specifiy their cable current carrying ability at the maximium temperature rise the insulation can safely operate at. Normally cables used for transmission at low voltages are oversized in terms of current rating in order to get the losses to acceptable levels.

3.2.27. Power at Your Shed

This is the most important figure of all i.e. the amount of power delivered to where you will be using it. When reviewing this number consider that it is providing power all day and night, 24 hours per day for every day of the year. This constant generation means a 500 W PowerSpout is equivalent to around 3,000 – 4,000 W of solar PV panels, depending on local weather patterns and time of year.

An average western house uses 25 to 30 kWhr per day. An energy efficient house with no electrical heating appliances can be less than 5 kWhr. A 500 W PowerSpout operating for 24 hours a day produces 12 kWhr per day.

If you are a conservative electricity user then
250 W of Power at Your Shed will run your home!

4. Design comments

There are many reasons why a design may be flawed or not sensible. The **Advanced Calculator** advises the user of issues and what may be done about them. In some cases the design concern may not be a concern to that user. Below are the hints and warnings given (in ***bold italics***) and some further detail about each.

4.1. Hydro related hints and warnings

Less water is being used than is available as the pipe size limits maximum power. Choose a larger pipe for more power.

If you have a pipe that is too small you may not be able to use all the water available so will not get all the Watts from your water resource.

Less water is being used than is available as the maximum jet size is in use. Use 2 jets per PowerSpout or more PowerSpouts for more power.

The jet size is limited by the size of the buckets on the Pelton rotor. You need more jets for this volume of water. Use the second jet on the PowerSpout(s) to double the amount of water through each PowerSpout.

Less water is being used than is available as the maximum jet size is in use. Use more PowerSpouts for more power.

The jet size is limited by the size of the buckets on the Pelton rotor. You need more jets for this volume of water. More PowerSpouts are needed as they are already using both jets on each PowerSpout.

The PowerSpout can generate more power with the same size jet with more head, but some sites have less available water at more head. Depending on pipe costs, less water from further up the stream may be a cost effective way to get more power. Try appropriate combinations of head, flow and jet size to see what is best for you and your site.

Less water is being used than is available as the output is limited by the amount of water each PowerSpout can use at this operating head. Use more PowerSpouts for more power

For any given water pressure there is only so much energy that can be converted to electricity. You have reached the power to pressure ratio limit of the PowerSpout in your design.

No load speed is _ _ _ 'rpm!!! Damage from no load over speed is not covered by warrantee.
Please either: Select a ME or GE PowerSpout to limit no load speed to less than the required 2000 rpm, or ensure your site never operates without load.

When there is no electrical load the rotor in the PowerSpout increases in speed. On sites over 32 m (100 ft) the no load rotor speed is beyond its design speed. There is a risk of it coming apart! Often the rotor will survive over-speed as there is a design safety margin. If it does not survive the results will be obvious!

The GE and ME PowerSpouts have an internal clamp that maintains an electrical load which avoids this limitation.

Too much power for reliable, warrantable single jet operation. Note: All PowerSpouts are sold with 2 jets fitted!

Please select 2 jets per PowerSpout, or more PowerSpouts, or reduce water flow and/or head, or buy additional replacement bearings.

If only one jet is connected to your penstock there is a side load that causes increased bearing load. Please connect both jets, they are supplied for you to use.

In some low power, high head applications a single jet may help avoid a very small jet size. Please contact EcoInnovation if this is sensible in your situation.

Too much water pressure for reliable, warrantable operation. 100m (328ft) is the maximum operating head.

Use a smaller penstock size to reduce the operating head. Smaller pipe is also cheaper.

The use of too much water pressure will reduce the life of the PowerSpout. We do not recommend excessive operating pressure and we do not warrantee it either. We know the PowerSpout is a robust machine and will operate at well over the design pressure rating. The question is for how long… you are welcomed to try without warrantee!

4.2. Electrical related warnings

Operation of PowerSpout BE on this site with no load will result in _ _ _V at the terminals and risks internal unwarrantable damage.

Reducing cable loss may avoid this risk, or select either a ME, GE or HE PowerSpout, or ensure your site never operates without load.

When the load is removed from a PowerSpout BE the output voltage increases to 3-4 times the loaded voltage. If the rotor spins fast enough to generate a high voltage it can damage the internal insulation. If you, the operator, are always careful and make sure the PowerSpout never operates unloaded then this will not be a problem.

Your design has very high cable losses which makes your design more vulnerable to over voltage damage during no load. Use a heavier cable to reduce the PowerSpout BE operating voltage.

ME and GE PowerSpouts have internal voltage clamp circuitry to protect the electronics connected to the PowerSpout output. This also protects the PowerSpout.

Operation of PowerSpout BE on this site with no load will result in _ _ _V at the terminals and risks internal unwarrantable damage.

Please select another PowerSpout type, or ensure your site never operates without load.

This is very similar to the previous alarm but your cable losses are not so high. Either select a PowerSpout ME or GE or avoid no load operation.

Cable size is within 50% of likely current rating. Cable loss calculations are based on 20 deg C (68 deg F) conductor temperature. Please check with your cable supplier for suitability for current handling, temperature rise and loss at this current.

If you have selected a very small cable the calculator will always increase its size to avoid excessive heating in the cable. However, the maximum current a cable can carry depends on the cable and installation. Please check with the supplier of your cable to ensure this limit is not exceeded.

Water flow reduced to prevent continuous operation of over voltage protection circuitry. Either use a larger cable, or a shorter cable or accept less power.

There is only so much power that can be transferred through a cable that has losses. With a ME or GE PowerSpout excess power causes the over voltage protection circuit to operate. Although this does not damage it in any way it is not sensible to operate the protection circuitry continuously. To avoid this, the water flow rate has been reduced just enough to avoid operating this over voltage protection circuitry.

Less cable losses are required to prevent this, or to accept less power. Another option is to change to a higher operating voltage by using a PowerSpout ME 250 or GE 400, but this means a registered electrical worker will be required.

Water flow reduced to prevent over voltage damage to PowerSpout. Either use a larger cable, a shorter cable or accept less power.

This is the same as the previous but applies to PowerSpout BE. The operating voltage limit is the ability of the insulation inside the PowerSpout wires to not arc over. If this happens the results will be obvious quite quickly!

Steel wire is not all created equal and can have a wide range of loss. Calculations are based on common high tensile steel. Please check with your supplier for the actual resistance of your wire.

Steel wire, in particular high tensile fencing wire, can be a very cheap cable. However, steel has a relatively high electrical loss and is not well defined. This note is a reminder to check the resistance of the steel wire you intend to use.

4.3. Safety related warnings

Operation of PowerSpout BE on this site under load will result in _ _ _V at the terminals and exceeds the Extra Low Voltage limits for non electrical workers to maintain.

Please either select a ME PowerSpout, or increase cable size, or reduce cable length to reduce terminal voltage, or hire a registered electrical worker.

The PowerSpout BE is intended to operate at battery voltage and operate at ELV (extra low voltage) to avoid any electrical shock hazards. Under some conditions the operating voltage of the PowerSpout BE can exceed these safety limits when operating normally. Please make some/all of the changes required if ELV operation is required.

Operation of PowerSpout BE on this site with no load will result in _ _ _ V at the terminals and exceeds the Extra Low Voltage limits for non electrical workers to maintain.

Please select either a ME PowerSpout, or hire a registered electrical worker, or ensure your site never operates without load.

When the battery load is disconnected from the PowerSpout BE the voltage will be above ELV (extra low voltage) limits. If the water to the PowerSpout BE is stopped before disconnecting the battery load then there will not be any dangerous voltages.

If you cannot disable the water to the PowerSpout BE before disconnecting the battery load then a registered electrical worker will be required.

5. Examples using the Advanced Calculator

Please note that the advanced calculator is often updated, based on infield feedback, the numbers that you might get when following the examples below may vary, though they will be very similar.

The examples given here are intended to illustrate possible situations and the range of options available. Each situation utilises a different version of PowerSpout as follows:

Off-grid ELV system:	PowerSpout ME 120
Off-grid situation, long cable:	PowerSpout ME 250(HP)
Grid-connected situation:	PowerSpout GE 400
Small scale system:	PowerSpout BE

5.1. Off-grid ELV system

I have identified suitable sites for a water intake, generator and battery shed on my property. I have measured heights and distances and have collated the following site data:

Available Flow	5 l/s (minimum all year. 10 l/s in winter)
Head	70 m
Pipe length	400 m
Cable length	500 m

I go to www.powerspout.com and log in to the Advanced Calculator.

5.1.1. Preferences:

I prefer to work with metric units so I select this option.
My property is off grid and the generation site is not very close to my battery shed. I would like to install it myself and we have ELV regulations allowing me to work on systems up to 120 V, so my first choice will be the ME 120.

5.1.2. Hydro

I enter my measured values for Available water flow (5), Head (70) and Pipe length (400). Appropriate metric units are assigned if I do not enter them.

The calculator suggests that a pipe with an internal diameter of 75 mm can supply 2 PowerSpout units, each generating 801 W. The pressure rating for the pipe needs to be greater than 70m = 700 kPA = 0.7 MPA = 100 psi. PN9 pipe means that it is rated for 90m, 900kPa or 0.9 Bar so it stronger than needed.

5.1.3. Electrical

I enter the Length of cable (500m) and the calculator suggests a design load voltage of 105 V. If I select aluminium cable, the calculator indicates I will need to use cable with a cross section of 39.2 mm^2. It will carry a current of 14.0 A, and with Actual cable efficiency of 90% it will deliver a total of 1443 W.

5.1.4. Refining the system

I need to obtain details from my local suppliers on suitable pipes and cables available.

I ask for costs and inside diameter of LDPE or MDPE pipes, which are most commonly used, rated for at least 70m of head. My local suppliers tell me they can supply the following pipes rated up to 90 m (900 kPa):

Pipe inside diameter	Pipe costs NZ$/m
79 mm	10.00
65 mm	7.00
55 mm	4.50
50 mm	3.00

I have 2-core aluminium cable with diameter of 25mm^2 at $3/m. For a larger cable I know I can run several parallel wires. 2 parallel cables equate to 50 mm^2 which is close to my target diameter, but I could try to increase efficiency still further with 3 cables.

The closest option to that suggested is to have a 79 mm diameter pipe and a cable with a cross section of 50 mm^2 (two parallel cables). This will produce 1511 W at the shed.

I can assess for each pipe diameter the impact of using 1, 2 or 3 parallel electrical cables. The most power is understandably generated with the biggest pipe and cable combination, but the extra size comes at a cost.

Figure 2 illustrates differences in output and cost per unit capacity, including 2 turbines and pipe and cable costs. Costs vary widely and hence must be considered as indicative only. In each case the columns are assigned two numbers referring to the pipe diameter and the cable size respectively. For example the first column is labelled 55, 25 which indicates 55 mm pipe diameter and 25 mm^2 cable size.

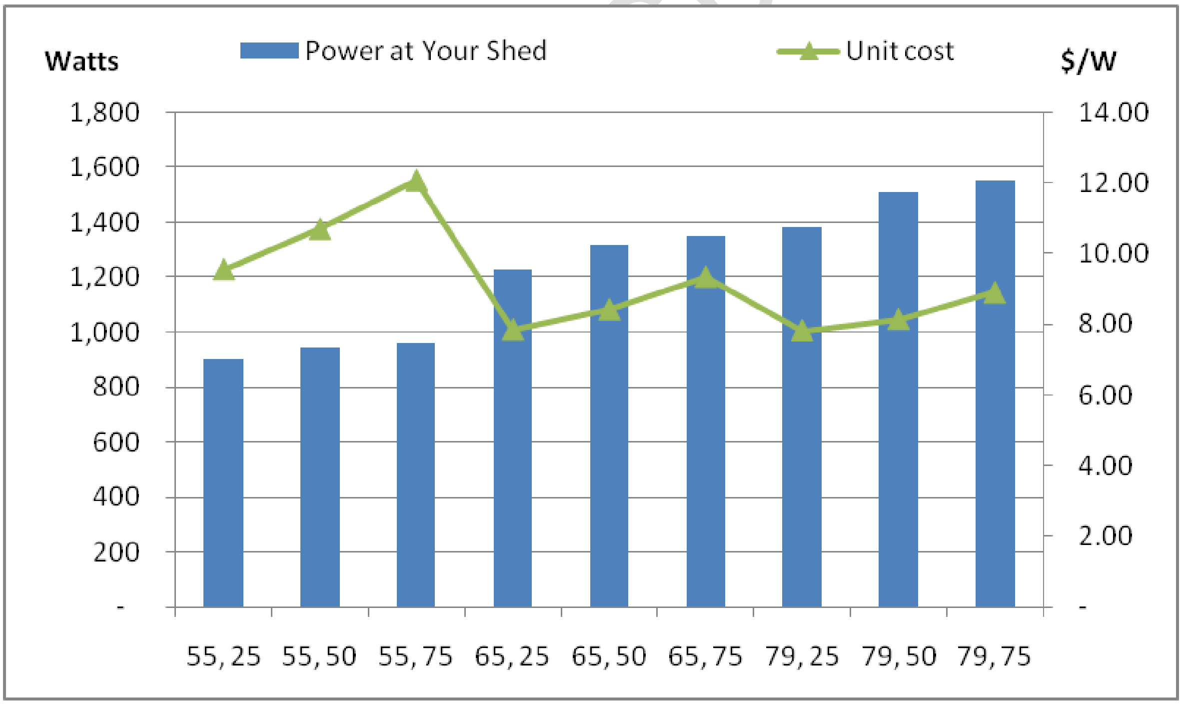


Figure 2. System output and costs (turbines, pipe and cable) with water flows of 5 l/sec

It is evident from this figure that the 79mm pipe diameter would maximize power production. Reducing the pipe diameter to 65 mm reduces the power output, and if I enter 55 mm I am warned this is too small to use the water available and hence will limit the power output.

My most cost-effective option in this scenario is a pipe diameter of 65 mm and a single length of 25 mm^2 2-core cable. If I decide that 1200 W is sufficient for my needs I could adopt this combination. Adopting the larger pipe could produce 25% more power, but would mean higher pipe costs.

I could also investigate other options that might exist, for example if I can gain 10m head by going 50m further upstream. I can change the head to 80 m and pipe length to 450 m and the calculator shows me I could increase generation with the 65mm pipe and 25mm^2 cable to 1379 W, and despite adding to overall costs I calculate I can slightly reduce the cost per Watt. I can also see that if the increased head means there is less flow (reduce to 4 l/s) then the power drops back to nearly 1200 W and hence I do not gain anything but extra expense.

When I evaluate winter flows of 10 l/sec (Figure 3) even the 65mm pipe is limiting the power output, although output will rise by around 10%. This pipe can use a maximum of 6.7 lps, and at this point it will operate at 66% efficiency. To produce more power I would need to increase the size of the pipe.

The 79mm pipe is sufficient to increase the number of PowerSpout units from 2 to 3 and generate almost 2000 W, but for comparison I will check the box in the calculator to keep the number of PowerSpouts at 2. Two units would not be sufficient to use all the water available at this site with 79 mm pipe, but the output would increase from these by around 25% and hence costs per W fall. The 55 mm pipe cannot use any of the extra flow available so the power and costs are the same as during lower summer flows.

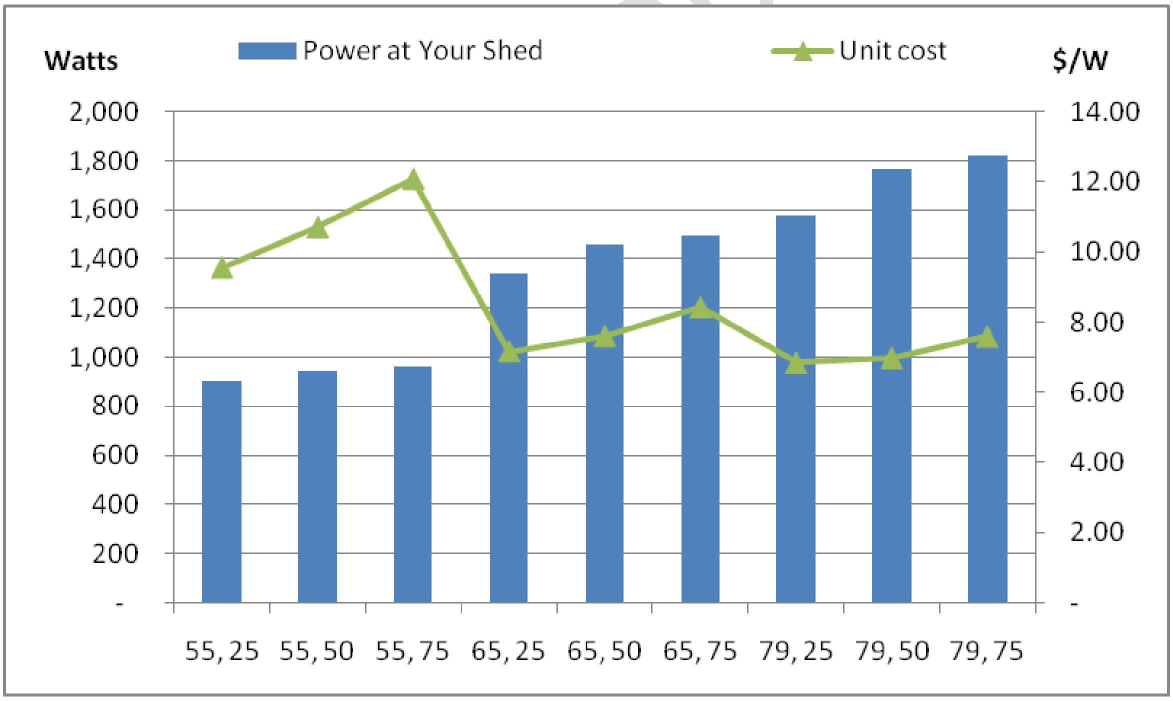


Figure 3. System output and costs (turbines, pipe and cable) with water flows of 10 l/sec

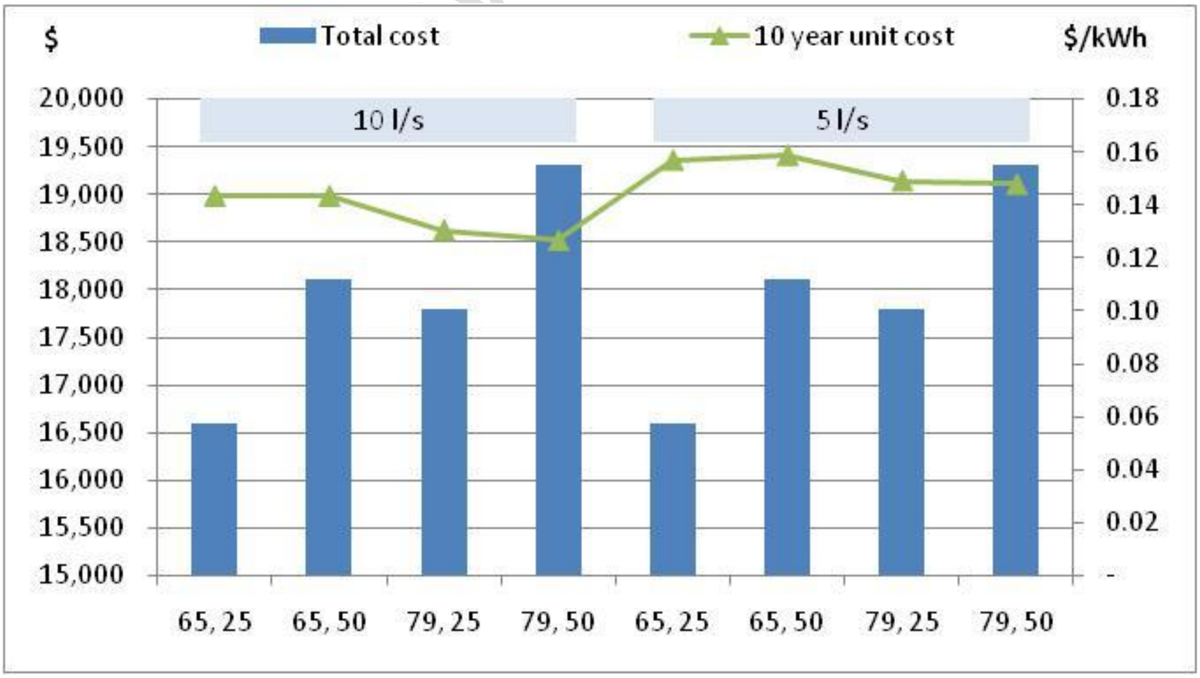
Although I do not need over 2000 W currently, it is useful to know that this larger pipe could supply 3 turbines during higher flows, and generate up to almost 2400 W. If I lock the calculator with 3 PowerSpouts and return the flow to 5 l/s I can immediately see there would be no increase in power output from having a third generator. In this situation I could turn off 1 turbine in summer, remembering to grease the bearings when doing so. Removing the turbine bearing block and generator and storing them in a dry warm place is wise if the turbine is not being used for an extended period.

To calculate total system costs I need to add costs for the other system components such as batteries, inverter, installation and other minor electrical items. These other costs combined could equal around $7,000.

The total costs are shown in Table 3, both in terms of cost per unit of installed capacity and the generation costs per kWh over 10 years of operation (360 days/yr).

Table 3. Indicative system options and total costs (2 PowerSpout ME120)

		Winter flow				Summer flow			
		65, 25	65, 50	79, 25	79, 50	65, 25	65, 50	79, 25	79, 50
Flow	l/s	10	10	10	10	5	5	5	5
Pipe diam	mm	65	65	79	79	65	65	79	79
Cable size	mm2	25	50	25	50	25	50	25	50
Power at Shed	W	1,340	1,460	1,580	1,765	1,224	1,319	1,382	1,511
Turbine(s) cost	$	5,300	5,300	5,300	5,300	5,300	5,300	5,300	5,300
Pipe cost	$	2,800	2,800	4,000	4,000	2,800	2,800	4,000	4,000
Cable cost	$	1,500	3,000	1,500	3,000	1,500	3,000	1,500	3,000
Other cost	$	7,000	7,000	7,000	7,000	7,000	7,000	7,000	7,000
Total cost	$	16,600	18,100	17,800	19,300	16,600	18,100	17,800	19,300
Unit cost	$/W	12.39	12.40	11.27	10.93	13.56	13.72	12.88	12.77
Annual power	kWh	11,578	12,614	13,651	15,250	10,575	11,396	11,940	13,055
10 year power	kWh	115,776	126,144	136,512	152,496	105,754	113,962	119,405	130,550
10 year cost	$/kWh	0.14	0.14	0.13	0.13	0.16	0.16	0.15	0.15



The final decision will be based on your needs for power and your economic situation. This is different for every customer and every hydro site. This is partly why you often struggle to get a get straight answer from a hydro supplier as there are an infinite number of possible solutions.

5.1.5. So what did we do?

Power consumption in the home will increase during winter as it is much colder and more time will be spent indoors. Also the solar hot water heater that will meet the home's needs in summer time will not in winter time. Generating more power in winter to help heat the hot water and drive the pumps needed for the wood fired central heating system would be of great benefit.

Hence the solution chosen:

- 2 turbines, upgradable to 3 if needed in the future
- 500m of $50mm^2$ cable
- 400m of 79mm ID pipe

As the labour cost to lay a pipe will be the same regardless of the pipe size, spending an extra $1200 on pipe seems like a very sensible option. This will allow the system to be upgraded to over 2000 W by the addition of a 3rd PowerSpout for winter time generation if needed.

When installed the output power was a little over 1500 Watts which was predicted in the **Advanced Calculator**.

2 x ME PowerSpout turbines doing 1520 Watts via a common aluminum cable into an Outback FM60 regulator

Input voltage 104 VDC, output 27.00 VDC and 1520 Watts.
The AUX relay is used to automatically turn on a water heater in the home, diverting surplus power not needed to hot water.

Battery Storage

5.2. Off-grid situation, long cable

We run a tourist hostel and chalets near a ski resort. We have minimized our consumption through efficient buildings and appliances as well as solar heating and sensible behavior. Solar PV panels are our principal source of power with a diesel generator for backup. We do not like the generator (noise, expense, fuel uncertainty, greenhouse gas emissions etc) but find it is increasingly in demand, particularly in winter.

We had not previously considered hydropower because we thought we are too far (about 2 km) from the spring and the stream running from it. It is a reliable spring and we use it for our drinking water via a 25mm pipe to our two 10,000l header tanks. A guest told me about the PowerSpout Advanced Calculator and I decided to investigate.

Our first decision was the location of the turbine: do we move the water to the house with a long pipe, or generate beside the stream? We thought moving the water to the house might help with drinking water supply, garden irrigation and possible water features, but soon realized it would require considerable effort and costs to return the surplus water to the stream. Hence we looked for sites with good access near the stream, and selected one with 50m head and available flow of 4 litres/second. It would require 300 m of pipe and 1,800 m of cable to the existing battery shed.

At such a distance it seems from the documents available online that the PowerSpout ME 250 could be the most appropriate. We do not have good electrical skills and wanted to engage an electrician to install the system to ensure compliance and safety for ourselves and our guests.

Entering this data in the Advanced Calculator suggested I need 2 turbines and a pipe diameter of 67mm. I change the pipe to 65mm which is the nearest size available to me. I also change the cable details to 50mm aluminium cable which my electrician says should be cost effective over long distances at this voltage.

With this data entered the system can generate 820 W at our battery shed. For interest I try using just 1 turbine and notice the alert indicating I am not using all the water available (only 3.6 l/s). However, I can still generate 784 W without the additional turbine cost. I know the HP versions have greater capacity and when I try this I see I can use all the water and generate 848 W.

The combined costs of turbines, pipe and cable contribute to a cost of over 22 $/W, or 26 c/kWh over a 10 year period, in my initial system design. Dropping to 1 turbine reduces power and costs to less than 20 $/W or 23 c/kWh, and using a single HP turbine reduces this further to less than 19 $/W or 22 c/kWh. Details can be seen in Table 4.

Table 4. Indicative system design and costs for PowerSpout ME250 (HP)

PowerSpout type		ME 250	ME 250	ME 250 HP
Head	m	50	50	50
Flow	l/s	4	4	4
Pipe length	m	300	300	300
Pipe diam	mm	65.0	65.0	65.0
Cable length	m	1,800	1,800	1,800
Cable size	mm2	50.0	50.0	50.0
Turbines	Nos.	2	1	1
Power at Your Shed	W	820	784	848
Turbine(s) cost	$	5,300	2,650	2,900
Pipe cost	$	2,100	2,100	2,100
Cable cost	$	10,800	10,800	10,800
Other cost	$	-	-	-
Total cost	$	18,200	15,550	15,800
Unit cost	$/W	22.20	19.83	18.63
Annual production	kWh	7,085	6,774	7,327
10 year production	kWh	70,848	67,738	73,267
10 year unit cost	$/kWh	0.26	0.23	0.22

5.3. Grid-connected situation

I pay an average NZ power price of 25c/kWhr giving me a power bill of $2400 per annum. I am considering installing a solar hot water system to reduce my power consumption, but my energy retailer has agreed to pay me 25c/kWh for every unit I supply into the grid if I generate power, provided I do not supply to the grid more than I use on an annual basis.

I want to stay on the grid and sell my surplus power into it. I have an existing water supply pipe that is used for irrigation in the summer for a few weeks, but not used the rest of the year. I want to know how much energy can be generated assuming 10 months of viable operation and at what cost. I am looking for a return on my investment (ROI) of 20% or more.

My site details are as follows:

Head:	120 m
Flow:	3 lps (summer)
Pipe:	400 m of 120 m rated pipe, 63 mm OD, 55 mm ID all the way
Cable length	30 m

I log in to the **Advanced calculator** and select metric units. I want to be grid-tied so I select the grid-enabled PowerSpout GE turbine.

I enter my data for flow (3 lps) and head (120 m), existing pipe length (400 m) and inside diameter (55 mm). At this point the **Advanced Calculator** indicates that 3 lps could supply 2 turbines and generate 822 W from each of them. I see a warning about the cable rating in the electrical section of the calculator, so I hope my data will rectify this. I enter the correct cable length (30 m) and 2.5 mm^2 copper wire which I know is widely available at around

$2/m. Not only does the warning disappear but I notice this cable can achieve 99% efficiency and produce 1636 W at the shed. Operating over 10 months at this rate would equate to almost 12,000 kWh.

I need to consider the output since my current consumption is just less than 10,000 kWh. I therefore need to reduce my production and/or increase my consumption, or renegotiate with my power company for any net surplus power I supply.

Although my static head (120m) is at the upper limit, I know from the **PowerSpout Installation Manual** that it is the operational (running) head that is important. I can estimate if I multiply the static head by the pipe efficiency (89%) giving 107 m. This is under the recommended operation head (120 m) covered by the standard warranty. As the flow rate increases the pipe efficiency falls, and rates above 4 l/s have efficiency lower than 83% and hence running head of less than 100m.

First of all I need to get some materials availability and cost data, then look at the system design options and their costs.

5.3.1. System costs

I want to look at the entire system costs and potential savings. I will examine two options for savings, the maximum saving is the value of potential power all sold at 25c/kWh, and the other applies a cap at the current cost of $2400. Hence in the latter case either I use more power, or I assume I will get no returns for any surplus supply.

Pipe diameter, rating and costs provided by my supplier are shown in Table 5, although I am keen to use my existing irrigation pipe at no cost:

Table 5. Pipes and costs

Pipe inside diameter	Pressure rating m	Pipe costs NZ$/m
65 mm	120	7.00
55 mm	120	4.50
50 mm	60	3.00
38 mm	60	2.50

Cable costs are insignificant since 2-core 2.5 mm^2 cable is widely used for house wiring and costs only NZ$2 per metre, hence 30m only adds $60 to the total costs.

The PowerSpout GE turbines cost NZ$ 2,650 each and fixed system costs could amount to NZ$ 4,000, including a suitable inverter (over NZ$ 3,000), meters and installation.

5.3.2. Flow rate

I know I have 3 lps in the summer when I use it for irrigation so I presume winter flows increase - but I haven't measured the rate. I do not want to reduce the pressure of water available since it suits my irrigation system.

By increasing the flow rate in the **Advanced Calculator** I discover I can use up to 5.8 lps with this pipe. At this rate I can use 3 turbines and generate 2,330 W, or 17,000 kWh over 10 months. I discover I can generate approximately the same from 2 turbines with a flow rate of 5.1 lps. Flow rates from 4 lps can generate over 2,000 W from 2 turbines, or nearly 15,000 kWh over 10 months.

5.3.3. Turbine version

There is no increase in output if 2 of the HP versions are used instead of the standard PowerSpout GE 400 turbine is used at up to 5.1 l/s and only a minor increase at 5.8 l/s. A single PowerSpout GE 400 HP turbine could generate over 1,500 W (11,000 kWh/yr) but would only use 2.7 l/s and hence there would be no increase if winter flows increased.

All these options generate more power than I consume, so I wonder if I can usefully increase consumption. I would enjoy adding some power tools to my workshop and a heat pump might be a good option for extra heat in winter or even cooling in summer.

5.3.4. Results

Figure 4 illustrates the performance and cost for each system, identifying each scenario by the flow rate and the number/type of turbines.

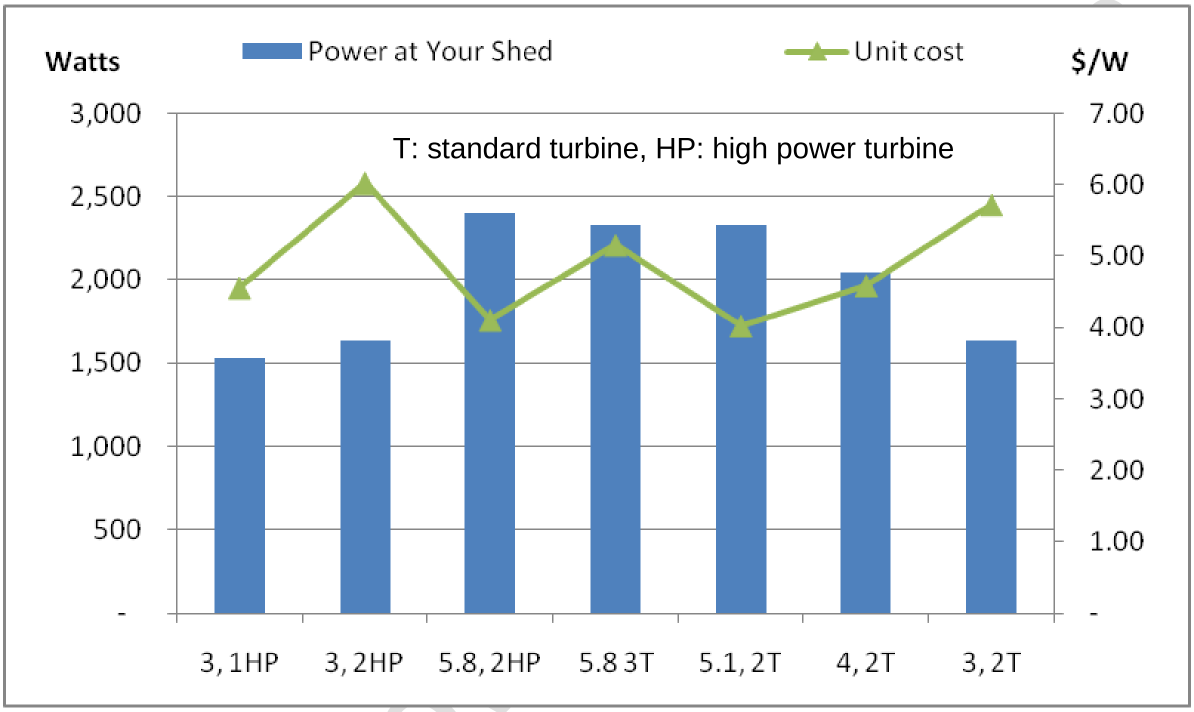


Figure 4. Costs of grid connected power options (flow, turbines)

The system features and all related costs are given in Table 6. The column on the right shows the initial data entered. The cost per Watt provides an indication of relative installed costs, and the cost per kWh is the overall cost of generation for 10 months of each year (360 days) over 10 years.

Table 6. System costs and returns for grid connection

Scenario code		3, 1HP	3, 2HP	5.8, 2HP	5.8 3T	5.1, 2T	4, 2T	3, 2T
PowerSpout type		**GE 400 HP**	**GE 400 HP**	**GE 400 HP**	**GE 400**	**GE 400**	**GE 400**	**GE 400**
Head	m	120	120	120	120	120	120	120
Flow	**l/s**	**3.00**	**3.00**	**5.80**	**5.80**	**5.10**	**4.00**	**3.00**
Pipe length	m	400	400	400	400	400	400	400
Pipe diam	mm	55.0	55.0	55.0	55.0	55.0	55.0	55.0
Cable length	m	30	30	30	30	30	30	30
Cable size	mm2	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Turbines	**Nos.**	**1**	**2**	**2**	**3**	**2**	**2**	**2**
Power at Shed	W	1,528	1,636	2,403	2,330	2,328	2,041	1,636
Turbine(s) cost	$	2,900	5,800	5,800	7,950	5,300	5,300	5,300
Pipe cost	$	-	-	-	-	-	-	-
Cable cost	$	60	60	60	60	60	60	60
Other cost	$	4,000	4,000	4,000	4,000	4,000	4,000	4,000
Total cost	$	6,960	9,860	9,860	12,010	9,360	9,360	9,360
Unit cost	$/W	4.55	6.03	4.10	5.15	4.02	4.59	5.72
Annual power	kWh	11,002	11,779	17,302	16,776	16,762	14,695	11,779
10 year power	kWh	110,016	117,792	173,016	167,760	167,616	146,952	117,792
10 year cost	$/kWh	0.06	0.08	0.06	0.07	0.06	0.06	0.08
Financials (10 yrs)								
IRR (all)	%	65%	41%	78%	52%	81%	64%	44%
ROI (all)	%	186%	116%	218%	153%	224%	184%	128%
Payback (all)	years	3	4	3	3	3	3	4
IRR (cap)	%	51%	29%	29%	20%	32%	32%	32%
ROI (cap)	%	150%	76%	76%	45%	86%	86%	86%
Payback (cap)	years	3	5	5	6	4	4	4

The financial data are presented for both a situation in which all power generated is paid for and one where there is a cap under which payments are made only up to the quantity of power consumed (in this example 9,600 kWh/yr). All data are calculated over a period of 10 years. Given the indicative nature of costs and values, this data should also be considered as illustrative only.

The 2 standard turbines are appealing, particularly if the winter flows reach 5 l/s, but even at 4 l/s the simple annualised ROI is around 8.6% with the cap applied. However, a single HP turbine offers the best ROI under the cap due to the lower costs and least surplus power. An investment of around $7,000 will provide annual savings of $2,400 and hence a payback of 3 years.

The system may need a general overhaul at 10 years old, with some costs relating to the inverter and turbines, but the pipes and cable will last 25-50 years. If I spend some more money at year 10, then the system will continue to give us a great return into the future.

5.3.5. So what did we do?

The client was uncertain and keen to reduce risks, both the perceived “new technology risks” and the risk of borrowing money. This resulted in the decision to install 1-turbine and a smaller inverter and “see how it goes”. An upgrade is planned once sufficient money has been saved on power bills.

The turbine was installed using 2.7 lps. The turbine product was 1,500 W connected via a SMA Sunny Boy SB1100 inverter; the turbine could do more, be the inverter is limited to 1100 W.

PowerSpout GE running at 1100W

Grid connected SB1100 inverter

A recent upgrade of the inverter to an EnaSolar 1500 resulted in1500 Watts delivered into the grid

5.4. Small scale option

I have a bush lodge which is used by a range of friends and international hunters. It is very remote but has a small creek nearby that I would like to use to generate enough power for lighting and other minor loads, replacing the noisy generator I currently use. I am also considering using solar panels, particularly since the creek is little more than a trickle in summer sometimes.

I have a number of possible sites for an intake, depending how far I go up the stream. The simplest option is at a set of small waterfalls only 200m from the hut, but there is another intake site approximately 100m upstream which would increase the head from 20 m to 40m without noticeably reducing flow rates. The access to the second site is less convenient and part of the gulley is very hard to reach. The water pipe could be diverted away from the river to avoid this, which would considerably increase distance (total 500m from turbine).

I have a shed between the lodge and creek that would be suitable for the generator, only 20m from the lodge. This would require creating some sort of exit for exhaust water to return to the stream without causing erosion.

I have measured the stream flow frequently over the past year and it has ranged between 1 to 2 lps for most of the year, with a couple of floods and a short drought.

I decide to start with the easy option and conservative flows:

	Option 1 (min)	Option 2 (max)
Head:	20 m	40 m
Flow:	1 lps	2 lps
Pipe:	200 m	500 m
Cable length	20 m	20 m

Due to the short cable distance I select the PowerSpout BE, and choose to work in metric units.

As soon as I enter the head and flow I am greeted with voltage warnings, and changing the pipe length or diameter doesn't change this. I refer to the Calculator manual and I am reminded I need to enter the Design Load Voltage values for BE PowerSpout turbines. I do not know what to choose so I start by entering 14 V which is typical for a 12 V battery system. I can test other voltage options later.

I enter the voltage, correct cable length and select 2.5 mm^2 copper cable as used for house wiring. With 38 mm pipe this option will generate just 57 W for me, and increasing the pipe diameter to 50, 55 or 65 mm increases output to 73, 75 and 77 W respectively. The 38 mm pipe can only use 1.2 l/s and hence has little to gain with higher flows.

Based on the pipe prices in Table 5 I choose to use 50mm pipe for further analysis. I can test the different head options, and the impact of cable size. I know I can get 2.5 mm^2 cable for $2/m and use two or more parallel lengths to increase the size, or I can jump to 25mm^2 aluminium cable which I can obtain for $3/m. In each case I assume it will cost me approximately $4000 for inverter, batteries and installation. The results are shown in Table 7.

It is not surprising that I only need one turbine in each case, even if I can reach the higher flow rate of 2 lps and larger pipe diameter. To generate more than 100 W I need higher flows or head. The higher head and larger pipe returns warnings but these can be managed as I do not intend to run the turbine disconnected from the batteries. I have been advised to put up a sign in the shed that says "Attention, turn off hydro before working on this system", just in case I forget.

I am on a tight budget and the bush lodge is mainly used in summer when the flow is about 1 lps, I decide to go for 38 mm pipe at 40m head as this pipe costs less and I already have some. With this option, the pipe size restricts the usable water and hence there will be no noticeable increase in generation at higher winter flows.

Table 7. Low head and low flow design options

Flow l/s	Head m	Pipe diam	cable size	turbines	total cost	Power (W)	$/W	1 year kWh	$/kWh
1	20	38	2.5	1	6455	57	113.25	499	1.29
1	20	50	2.5	1	6555	73	89.79	639	1.03
1	20	55	2.5	1	6855	75	91.40	657	1.04
1	20	65	2.5	1	7355	77	95.52	675	1.09
1	20	79	2.5	1	7935	82	96.77	718	1.10
2	20	50	2.5	1	6555	119	55.08	1,042	0.63
2	20	55	2.5	1	6855	132	51.93	1,156	0.59
2	20	65	2.5	1	7355	144	51.08	1,261	0.58
1	40	38	2.5	1	7205	107	67.34	937	0.77
1	40	38	5	1	7245	114	63.55	999	0.73
1	40	38	25	1	7225	121	59.71	1,060	0.68
2	40	38	25	1	7225	122	59.22	1,069	0.68

In all cases the generation costs ($/kWh) over 10 years are higher than grid costs, but the grid is not an option. Our bush lodge has been running on a generator and some years ago we had installed a kWhr meter so we could charge visitors for the power (fuel) they used.

The fuel bill has been about $2000 per year for 900 kWhrs, a cost of $2.22/kWhr, not to mention the noise and effort of carrying in fuel.

Installing a hydro will reduce our energy costs by 70%, allowing us to put money aside for battery replacement every 10 years and maintenance as required. We hope to be able to market the bush lodge to both hunters and Eco clients. In the past some clients have not been impressed with the generator spoiling the tranquillity of the place. It is time for a change.

5.4.1. So what did we do?

A 38 mm pipe and 25 mm aluminum cable were used. A 12 V battery/inverter system and PowerSpout BE turbine was installed in the power shed. The site produced 120 Watts most of the time, dropping to 75 Watts during the last drought. The generator is rarely used these days with a fuel bill of less than $50/year.

PowerSpout BE

Small 12 volt system

Battery bank