Guide to

Best Energy Practices

For

Remote Facilities

Produced by

Arctic Energy Alliance

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1. Introduction

Is this guide for me?

The purpose of this guide is to outline the best practices available for outfitting remote facilities which produce their own energy on-site. The goal is to assist remote facilities to reduce fuel use, and therefore operating costs and pollution. It is written for owners and operators of small to medium sized remote facilities (lodges, exploration camps, and traditional camps with up to 50 people on site at one time). We have tried to provide an overview of all the major energy systems found at remote sites, and for each one describe how to use energy as efficiently as possible. The topics range from energy efficiency measures to electricity production (generators and renewable sources) to heating and water and vehicle usage.

Arctic Energy Alliance (AEA)

The Arctic Energy Alliance (AEA) is a not-for-profit society established in 1997. Our mission is: "To promote and facilitate the adoption of efficient, renewable and carbon neutral energy practices by all members of NWT society". From our offices in Yellowknife, Inuvik, Norman Wells and Fort Simpson we work to serve all the communities of the NWT. We offer support and advice on energy efficiency, renewable energy and sustainable energy practices for individuals, businesses, communities, and other interested groups.

If you have more questions, please call the Arctic Energy Alliance (867-920-3333), where an energy advisor can talk to you about your camp's energy issues and provide free advice.

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2. General Overview

Facilities such as Remote lodges and exploration camps can be very expensive to operate. Because there is usually no road access with which to deliver fuel, fuel drums are flown to the site and staff time is required to transfer fuel to the generator. The end result is very expensive energy. This makes remote sites very attractive for investments in energy efficiency improvements and renewable energy systems. And, to maximize the return on your investments, a specific order of investment planning should be followed to optimize your energy systems:

Energy Optimization Sequence

1- **Track Energy Use** – You can't control something unless you are keeping track of it
2- **Energy Conservation** – Only use energy when needed
3- **Energy Efficiency** – Use energy in the most efficient way possible
4- **Generator Optimization** – Match the generator to the load and operate it efficiently
5- **Electricity Storage (Batteries)** – By storing electricity in batteries, the generator can be shut off during low load times, and run at its most efficient speed during peak demand times and to charge the batteries
6- **Renewable Energy systems** – Solar panels, Wind turbines and Hydro generators can be used to supplement the generator, or even eliminate the need to operate the generator if battery storage is added.

The tendency is to short circuit this investment sequence and start by buying solar panels or a wind generator, when the best initial investment is energy efficiency measures or generator optimizing. For example, $100 spent on replacing incandescent lights with LED or fluorescent ones can save about the same amount of power as that produced by installing $10,000 in solar panels. So instead of spending $20,000 on solar panels, the optimized energy investment mix could easily be $10,000 on solar panels and $100 on lights bulbs to achieve the same reduction in fuel use. The best practice is to save money before spending money and by extension it is better to first reduce energy use as much as possible, and then install renewable energy systems to provide that energy.

Tracking Energy Use is something that is rarely done. Often people are aware of the high overall cost of energy, but are not usually keeping good records of where and how the energy is being used. The simplest method of tracking is by keeping logs of fuel consumption by the generator, heating equipment, vehicles etc. where staff record the date and quantity each time fuel is added. A more robust approach is to install a monitoring system that records the energy use in real time and graphs energy use so that trends can be seen and unusual events can be identified quickly. Understanding your energy use patterns is a very important first step in controlling and reducing your energy use. For more information see section 3.4.

Energy Conservation means only using energy when it is needed, and eliminating energy waste that does not provide any benefit. Some examples are leaving lights on when no one is present to need the light, or keeping spaces warmer than necessary when unoccupied. Automatic light switches with occupancy sensors, and automatic setback thermostats can be used to prevent this unnecessary energy use. For more information see Section 3.1.

Energy Efficiency means using as little energy as possible to achieve the desired result. It is estimated that for every $1 invested in energy efficiency, you save about $5 in operational costs. This includes both electrical efficiency and thermal efficiency.

Some examples of electrical energy efficiency measures are using LED or fluorescent lighting instead of incandescent, using Energy Star devices/appliances instead of units with higher energy consumption; and undertaking regular maintenance of equipment to keep it running efficiently over its lifetime.

Some examples of thermal energy efficiency measures are sealing the air leaks in the building envelope, adding insulation and installing a 90% efficient condensing propane water heater instead of an older 70% efficient unit. For more information see Section 3.1.

Generator Optimization refers to properly matching the generator(s) output to the load, and running the generator(s) in the most efficient manner. Many remote facilities have generators that are much larger than the load requires because buying a bigger generator is comparatively inexpensive. It is the increased fuel consumption of a larger generator that is the expensive part. A generator is much less efficient at low load than at full load. A larger generator will consume more fuel than a properly sized generator. Electricity demand is not constant; it has peaks that can be 3 times higher than the low demand times. There may be equipment that is only used for short periods, but the generator has to be big enough to meet that demand. Installing two generators allows one generator to be sized for the low load times, and one to handle the peaks. Many sites are reluctant to change generators to a more suitable size, or install multiple generators because of the “high costs” of new generators. These are economic fallacies because the fuel savings are much greater than the initial extra cost. For more information see Section 3.2.

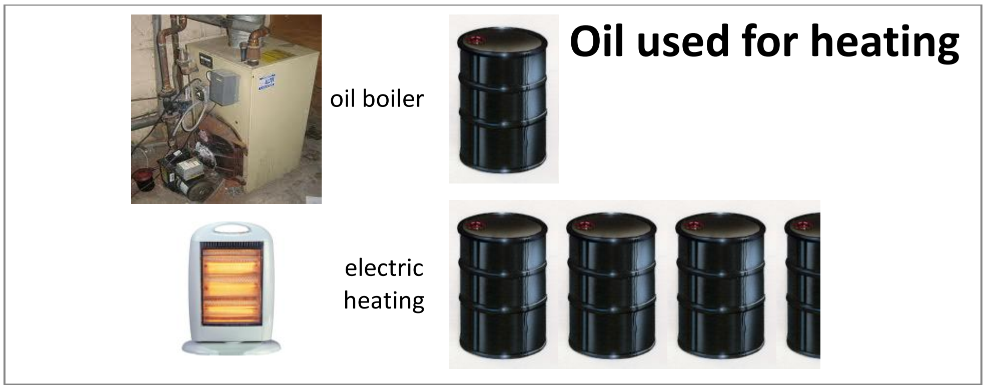
Batteries provide a way to operate the generator in a much more efficient manner. The generator can charge the batteries during low load times and electricity can be drawn out of the batteries during peak times. In this way a smaller generator can be used as it does not have to meet the peak demand alone. It might also be possible to shut the generator off at nights and use the batteries alone. Modern inverters can monitor the battery charge level and the electricity load and automatically start the generator to charge the batteries or meet a high demand. For more information see Section 3.3.

Renewable Energy Systems such as photovoltaic (PV) panels, wind generators, hydro generators, and solar water heaters can be used to meet your energy needs instead of burning fuel. Although the initial cost of these systems can seem high, they often pay for themselves in fuel savings very quickly. Before investing in renewable energy systems you must assess the available resource (wind, sun, etc) and your energy needs in order to get the best fit for your site. In some cases PV might be better than a wind generator, and in other cases a local river might provide a hydro resource that is a better investment than PV panels.

Equipment with a proven track record in remote facility operation and cold climates should be used as much as possible. There are many successful renewable energy systems in remote locations in the NWT. There are also research stations on Antarctica that are much more remote, and deal with harsher climatic conditions than found in the NWT, that have successfully used renewable energy systems for many years. Unfortunately, there are also many unsuccessful examples of systems that did not perform as promised; and, system failure has more often than not been attributable to poor design and operations, rather than with technical issues. For more information see Section 3.5.

Some other important topics

Heating with Electricity
Using electricity from a generator for space heating is just about the most inefficient method of heating possible. Small generators convert only 20% to 30% of the fuel energy into electricity. That same fuel could be used in a furnace or boiler with an efficiency of 85% or more. By using generator created electricity to heat your facility, three-quarters of the fuel is being wasted; or, to put it another way, 3 times the fuel needed to heat that space is being used. For more information see Section 4.



Heat Recovery from Generators
Small generators can waste over 70% of the fuel energy, and most of that waste is given off as unused heat. It is possible to capture that heat and use it to heat domestic water or provide space heating. There are two methods of heat recovery; one is from the cooling jacket of the generator, and the other is from the exhaust. Using both methods will provide the greatest heat recovery. For more information see Section 4.1.

District Heating
In general, having multiple low-efficiency heating appliances will burn far more fuel, and require far more maintenance than a centralized heating plant. A centralized plant can also allow heat recovered from generator to be used. Some thought needs to be put into the layout of the facility and the location of the heating plant and generator if heat recovery is to be used. For more information see Section 4.2.

Water Use Efficiency
Water is often overlooked, but it takes energy to move and heat water, so using less water will result in energy savings. Low flow showers, faucets and toilets can reduce water use by half or more. Ensuring you have a well maintained and efficient pumping system can reduce the energy you use on pumping by over 90%. For more information see Section 5.

Overall Design of Remote Facility Heating, Electrical and Water Delivery Systems
Trust experience. When working in remote sites there is little room for error, and working with experienced, established system designers, suppliers, and installers will save time, money and energy. Be very cautious of firms who claim to be skilled in this discipline but lack the practical hands-on experience. When dealing with remote and/or renewable energy systems it is possible to end up with an expensive piece of junk that does not provide the benefits that you were promised if you hire someone who doesn't know what they're doing.

3. Electricity

Electricity, which powers most of your equipment and lighting, is a major expense for remote camps. Most camps use diesel generators to supply electricity, but the costs to supply it are much higher than what businesses pay for electricity from an electrical grid. Because of this, energy efficiency is more important for camps and lodges than it is elsewhere.

This section deals first with energy efficiency, then generators, batteries and inverters, renewable energy systems, and finally, electricity monitoring.

For every $1 spent on efficiency, you save $5 in generation

3.1. Energy Efficiency

Remote facilities in general have very low standards for energy efficiency. Often equipment efficiency is less important than initial purchase price, so camps use equipment that is not the most efficient available. More and more camps are realising that paying more for efficient electrical equipment pays off, even in the short run. Because most camps are wasting lots of energy, it's not difficult to bring an inefficient site to a higher standard of energy efficiency. For new camps, it's even simpler to integrate efficiency practices from the start.

To keep electricity demand down, don't use electric heating. A diesel generator will convert about 30% of the usable energy in fuel into electricity. Using that 30% to produce heat as a final product is terribly inefficient. Modern fuel heaters operate up to 95% efficient, getting 3 times as much heat energy from that fuel.

3.1.1. Appliances

You may consider the electricity you use to run your appliances as a fixed overhead cost, or just the cost of doing business; but careful planning can reduce your electricity consumption significantly and save you money. Think carefully about what appliances should be run on electricity, which models to buy, and how they are operated and maintained.

Avoid electricity where possible

Avoid electric ovens, stoves, ranges and major kitchen appliances. Short-duration devices like toasters and microwaves are not as much of a concern. Avoid electric dryers, hot water heaters, and heaters - anything that produces heat as its primary goal and is in use for long periods of time.
Alternatives are generally easy to find; and the most common alternative to electric heating is a combustion-based source like propane or diesel. Propane is a convenient fuel which is easily dispatched and, because it's a gaseous fuel, it won't cause fuel spills. This could save you a lot of money because diesel or gasoline spills can be very expensive to clean up. Propane is commonly used for cooking, hot water and space heating. Diesel is also a common fuel for space heating and hot water. Diesel fuel has roughly twice the energy per volume of propane so storage and transport is generally less costly.
Machinery heaters are often electric. Propane and diesel pre-heaters are available, but are less common since they cost more. Operating costs vary according to your situation and location, and should be considered before deciding which to buy.

Buy an efficient appliance

There are several energy label agreements used in Canada: EnerGuide, Energy Star, and the appliance nameplate. They are important tools to help you decide which appliance to buy, but they don't tell you how much electricity the appliance will consume when you use it.

EnerGuide helps you compare the amount of energy used by appliances based on lab test results. It can tell you that washer 'A' uses less energy than washer 'B' in the test, but not that it will use 300kWh of electricity per year when you run it on your cycle of choice ten times a week for half the year. You should choose the appliance with the lowest EnerGuide energy rating that meets all your other requirements.

Energy Star is an international standard for energy efficient consumer products. It is a quick way to identify the most efficient appliances. Whenever possible you should buy EnergyStar appliances.

All electrical appliances sold in Canada must have a manufacturer's nameplate. It's usually located near the power cord. This shows brand, model, voltage, frequency and amps. The power consumption (amps) listed represents the maximum current draw possible and is generally much higher than the normal draw when using the product. This value should not be used to estimate the power consumption of the product.

Operation & Maintenance

People tend to ignore the role that operation and maintenance play in equipment efficiency because it means ongoing thought and work. How we operate and look after appliances plays a huge role in the amount of electricity they consume. For example: running the washing machine with one or two items results in it going through the same cycle as if you had filled it up. Opening the fridge door repeatedly for long periods of time may be convenient, but causes it to use more electricity.

Some appliances draw power even when they are turned off! These are phantom loads which can add up to over 10% of your electricity consumption. A good example of this sort of appliance is a TV with remote control. For the remote control to work, the TV must always be listening for the remote, and this uses power. Other phantom load appliances include computers, VCR's, microwaves, battery chargers, computer power supplies and anything with a built in clock or remote control. To discover how much power these appliances use while they are turned off, you can use a meter such as a Kill-a-watt meter (about $40 and available from most large hardware stores). It shows you the instantaneous and cumulative power consumption. These appliances should be plugged into a power bar which is turned off when the devices are not in use.

Appliance location is important. Avoid locating the cooling appliances like fridges and freezers near sources of heat such as stoves, dryers and water heaters. Whenever possible locate fridges and freezers outside of the heated area to reduce the work they have to do.

Keeping your appliances in excellent working order reduces energy consumption and increases their lifespan. Cleaning filters for any air-moving devices is one of the simplest things to increase the efficiency of that unit. It's common to find rundown appliances still in use in remote sites. Issues like defective door seals or low coolant charge in fridges can result in near continual operation. Modern appliances often use a fraction of the energy of older units.

3.1.2. Lighting

Use energy efficient lighting and ensure lights are only on when needed.

Modern compact fluorescent lighting (CFL) and LED lighting present some very good options for replacing older lighting products. Be aware that quality counts. Don't buy the cheapest energy efficient lights you can find and expect them to perform as well as a higher quality product.

Old-style T12 fluorescent (1.5" diameter) lighting can be replaced with modern T8 (1" diameter) fixtures with electronic ballasts. Not only can they provide superior light quality, they use about one quarter less energy and start better in cold conditions.

By using simple devices such as daylight sensors, spring-wound timer switches, and occupancy sensors, or by using more elaborate computer-controlled lighting systems, lighting can be automated. Given the rapid turnover of people at many remote sites, it's not realistic to think that behavioural changes alone will have people "turning the lights off". It's simplest to automate the process.

3.2. Generators

For decades diesel generators have been used to provide electricity to remote sites. Diesel engines are a mature technology; we know how to keep them running. They are the most common, and one of the most expensive, types of remote power when full costs are accounted for (fuel, transportation, maintenance). Gasoline, natural gas and propane are also options for generators, typically for smaller electric loads. Propane and diesel generators offer the best levels of service for full time systems. Gasoline generators are generally cheaper to buy, but more expensive to operate.

Generators vary from around 1 kW for the smallest units to MW-scale units to run energy-intensive industrial applications. It's likely that a generator, typically diesel, will be a significant source of energy in your system. Renewable energy sources such as wind, solar and microhydro can work alongside a generator, but the system integration must be carefully planned. It's always much more expensive to retrofit after the case.

3.2.1. Generator Myths

There are many myths about diesel generators. They end up driving fuel costs up unnecessarily.

Myth # 1: It's better to have a large engine working at a lighter load than a small engine working harder.

Reality: A small engine working harder will use less fuel, and will burn it cleaner. Diesel generators are most efficient at 80% loading.

Myth # 2: Keep the generator loaded.

Reality: While it's true that the heavier a diesel generator is loaded, the better the Litre per kWh ratio is, you will end up burning more fuel by creating an artificial loading. It's best to have the right size generator.

Myth # 3: Generator capacity needs to be significantly oversized.

Reality: More attention to energy planning and load management will allow you to meet the peak demand without an oversized generator.

Myth # 4: Generators are expensive.

Reality: Generators are not that expensive compared to how much its costs to maintain and run them. Many generators will burn their value in fuel each year.

Myth # 5: Slow down the generator.

Reality: This lowers the power frequency, which can damage electronics and prevent some clocks from keeping accurate time. As the net energy required is still the same, there is no savings of fuel.

3.2.2. Generator Statistics

The statistics below apply to a typical generator in the sub 250 kW capacity range.

- Every Litre of diesel fuel burned will deliver approximately 3 kWh of electricity.
- Every Litre of diesel burned will waste approximately 7 kWh of thermal energy.
- Every Litre of diesel burned will emit approximately 2.68 KG of greenhouse gasses.
- 10% of the energy in fuel is used on the generator itself. Moving air, charging battery, water and oil movement to keep the engine cool and lubricated, as well as friction by mechanical parts.
- 60% of the energy in fuel is converted to waste heat, which is displaced primarily through the radiator, but also as radiated heat from the exhaust, muffler and the engine itself.
- This leaves the remaining 30% to do the work required, in this case, producing electricity.

These numbers represent an ideal situation with the generator load factor between 70 and 90%. As the load factor decreases, the ratio of waste heat to electricity produced further increases.

3.2.3. Diesel generator – capital cost versus operating cost

As a rule, generator operating costs are always much higher than their purchase price. Maintenance costs add more to this. Oil changes and air/fuel filter changes are also notable expenses. A typical generator will require oil and filter changes every 6 months or more often if the generator is used heavily or in a dusty environment. You must consider the capital costs of a generator and operating costs before deciding on the system you want to purchase.

> ***An example:***
> A 30 kW diesel generator may cost in the range of $20,000 + transportation and installation costs. At full loading, it can burn up to 200 litres of diesel per day. At an average loading of 40% to 50% (12kW to 15kW) it might burn around 100 litres per day. At a cost of $2 per litre delivered to the site, the generator will have burned its capital cost in fuel in about three months of continual operation.

3.2.4. Load Management

By employing two simple load management techniques you can save money on your generator in two ways. The first way to save money is to design your whole system to have a lower power demand so you can buy a smaller and cheaper generator. The second is to manage your power consumption so that you burn less fuel.

Power demand is the amount of electricity (kW) required by your system at any instantaneous point in time. It fluctuates as equipment is switched on and off. The peak load is the highest power demand you ever expect to have. You need to know what this is when you buy a generator because you need to buy a generator that can meet the peak load. It is also important when sizing a battery system because that system needs to meet the peak demand.

Many generator salespeople will advise you to add up what your peak load would be if everything were running all the time and then add some extra capacity to make sure you don't run into problems. This means you're stuck with an oversized generator that's running well below its capacity (and inefficiently) most of the time. A better approach is to prepare a power budget using the form at the back of this guide. Once you have an idea of what will be running on the system, you can manage your load by staging or scheduling equipment use. It will also give you an idea about what the big power consumers are and highlight places where you can reduce you energy consumption. Before filling out the blank power budget sheet, have a look at the example power budget to get an idea about how to fill it out.

3.2.5. Generator Efficiency

As discussed in the section on generator myths, generators run most efficiently when they're fully loaded. The table below shows how the number of litres of diesel required per kWh of electricity generated decreases as the % loading increases. At 10% loading 0.57 litres is required for every kWh but at 75% loading less than half of that, 0.26 litres per kWh is required. The first two lines show the fuel consumption with no loading. The dramatic difference between 1000 and 1800 RPM illustrates the load the cooling fan and oil pumps put on the engine.

Table 1 Fuel Consumption versus load chart

Load (%)	RPM	L/kWh
0	1000	N/A
0	1800	N/A
5	1800	0.93
10	1800	0.57
15	1800	0.44
25	1800	0.36
30	1800	0.33
40	1800	0.30
50	1800	0.28
75	1800	0.28
100	1800	0.26
Test performed on an Isuzu series 4HK1 tier 3, 2007 100kW machine		

3.2.6. Generator Sizing and Selection

Many people base their generator capacity solely on the recommendation of the generator salesperson. Remember that usually they want to sell you the largest generator possible for the profit and to avoid complaints that the generator can't handle extreme peaks in demand. The extra fuel cost that you will pay does not affect them.

A generator system needs to be sized such that it is large enough to meet the highest load – even if that load only runs for 1 minute per day. Before selecting a generator, reduce the size of your load using the load management techniques described above. Once you have reduced your electrical load as much as possible, there are ways to design your system so the peak load can be met without having to pay extra money for an over-sized generator. From an energy measurement perspective, it's ideal if the camp is already built, and you can simply measure the electricity demand (presuming all efficiency measures have been done first, so that you are using the best data possible). It's more difficult to design systems for a new camp with an unknown load. For new camps, consider renting a generator at first. This will allow you to power the site up and gather real-life energy use data which can then be used to inform the final system purchase.

The ways you control the power your generator produces can reduce the size of generator you need significantly. A few of the most common methods of generator control are: a load priority panel, parallel generators, and cycle charging.

Load priority panel

A priority load panel controls automated power down of optional loads. This allows a smaller generator to be used, and during the very infrequent times when generator capacity is reached, the system can automatically turn off optional loads (determined on a site-by-site basis) to allow the peak condition to pass.

Parallel generators

A parallel generator system is a system consisting of multiple generators which automatically come online and offline based on the site's loading. For example, a site with peak demands of 100 kW could have 20kW, 30kW and 50 kW generators. With the load under 20 kW, the 20 kW generator would be operating. As the load goes above 20 kW, the 30 kW generator can be brought online automatically to carry the load, and the 20 kW generator automatically shuts down.

Some notes about parallel generator systems:

- Parallel generator systems are best for larger sites, typically above 50 kW. This technology has been used for decades, but up until recently, has been cost prohibitive for anything other than MW class power plants. Modern parallel controllers for a 3-generator system can be in the $20,000 range;
- Parallel generator systems are best for sites with a relatively constant power loading. Take a situation where a site has a low load of 15 kW, peak load of 150 kW and an average loading of 40kW. This site would be ideally fitted with 20, 50 and 80 kW generators, allowing each generator to run at its most efficient point;
- Parallel generator systems are useful for camps that plan to expand since you don't need to buy a large generator to start with: buy a small one and add another when you need it. Additional generators can be tied into a parallel configuration to increase capacity or for redundancy. It's best to plan for the maximum number of generators at the start for easy future tie-in.

Cycle charging

Cycle charging is when a generator, battery storage and inverter system work together to supply the site electrical power. For example, if not much power is needed during the night, the generator can be shut down and the system operated on the battery bank.

Some notes about cycle charging:

- Cycle charging works best for sites which have highly fluctuating energy loads and significant periods of time at very low loads. A typical work camp is a good example of this, with an energy spike at mealtimes and shift changes, but when the camp is mostly sleeping, the energy needs are low;
- Cycle charging is generally suited to sites below 50 kW with notable periods of time which the load is under 5 kW;
- Cycle charging relies on batteries, which have a finite life and replacement must be budgeted for. With new battery technology on the near horizon, it may make sense to buy a lower-cost battery bank now, and re-evaluate technology when time for replacement comes;
- The inclusion of battery storage allows for easy integration of renewable energy technologies. A wind generator can be installed one year and PV the following year. Every kWh that is produced by renewable energy is a kWh not produced by the generator;

- Cycle charging systems have the capacity to synchronize generator power with inverter power to handle peak loading. This allows the generator to be smaller and harder working (more efficient).

3.3. Batteries, Inverters and other system components

3.3.1. Batteries

Batteries are used to store electricity until it is needed. Choosing the right type is important when designing a reliable energy system – unless your system has a generator available to pick up the full load all the time. Batteries can be used with generators to reduce generator run time and are almost essential for renewable energy systems where electricity production is inconsistent.

Batteries are made up of several cells - each one is normally about 2 volts. Battery cells are composed of a positive plate and a negative plate divided by a separator and immersed in an electrolyte solution. When you connect an electric load to the battery, molecules in the electrolyte bond to the plate, which releases electrons, which creates an electric current and supplies you with your electricity. When all of the electrolyte has turned to water, the batteries are considered to be discharged and an electric current needs to be applied in the opposite direction to reverse the process (charge the batteries).

Battery efficiency varies by battery type, operation conditions and maintenance, but 80% is a good rule of thumb: for every 1000 kWh that you put into a battery, you can only expect to get 800 kWh back out. Batteries are rated for a specific capacity in Ah (Amp hours). To convert Ah to kWh (kilowatt hours, which is used for measuring the power consumption of your appliances), multiply the battery's Ah rating by its voltage rating and divide by 1000. For example, your automotive battery might have about 100 Amp hours of storage capacity at 12 volts, so 12 volts times 100 amp hours equals 1200 watt-hours, or 1.2 kWh of energy storage. However, it is not a good idea to completely discharge a battery, as this will substantially shorten its lifespan. Discharging to 50% is a good rule of thumb for battery bank sizing, so in our example, the battery should only be drawn down 0.6 kWh before it is charged again.

Batteries are connected together to form battery banks, which store more energy than individual batteries. It is important to only connect batteries together that are the same type and age. If different types batteries are connected together, or old batteries are connected to new ones, they will not perform properly and the weaker batteries will draw down the stronger batteries.

Types of batteries

Many new battery technologies are being developed to produce smaller, lighter and cheaper batteries. Currently, the most cost effective batteries for remote camp applications are lead acid batteries. However, there are different types of lead acid batteries, and you should look at how the advantages and disadvantages of each type will affect your operation before deciding which one you want to buy. Avoid automotive batteries. They have thin plates and are not designed for repeated deep discharges, which will likely occur if your camp is running off the battery bank. If the battery has a CCA rating (Cold Cranking Amps), it is probably an automotive battery and should be avoided.

Recreational or marine deep cycle batteries are a compromise between automotive batteries and true deep cycle batteries. They are cheaper than deep cycle batteries but don't last as long.

Deep cycle batteries have much thicker plates in them, which can withstand a greater discharge, so they can regularly go for longer periods without charging. There are two main types: wet cells and sealed cells.

Wet cells are cheaper, can tolerate higher charging voltages and are more common so they're better understood by more people. They also require regular maintenance and produce hydrogen gas during charging - this must be vented outside since it's hazardous. They also perform much better when used regularly, so they are not ideal for back-up or emergency systems.

Sealed cells perform better than wet cells when they haven't been in regular use, don't require as much regular maintenance and don't release hydrogen gas while charging. They are more expensive and require charge controllers to prevent damage to the batteries. The two common types of sealed cells are gel batteries and AGM (absorbed glass mat). AGM is less expensive but the gels tend to last a bit longer.

Lifespan

The lifespan depends on the type of battery you purchase and how well you maintain it. Generally the more you pay, the longer the lifespan. Some typical battery lifespans from the Solar Living Sourcebook:

- RV marine type – 1.5 to 2.5 years
- Golf cart type – 3 to 5 years
- Wet cell (L16) – 6 to 8 years
- Sealed cell (solar gel) – 5 to 10 years
- Sealed cell, gel (Industrial quality traction) - 15 to 25 years

Bank sizing

The size of your battery depends on your power source, the load on your system, and how long you want the system to be able to run solely on batteries (day or hours of autonomy). Filling out the table in the load management section of this guide will give you an idea of what your peak load will be. The battery system must be capable of meeting that peak load unless you plan to have a generator running when that peak load hits. For example, if you have a piece of equipment that has a very high load, but you know will only be run during the day, the battery system does not need to be able to cope with that load if the generator is running during the day. In that case, the battery should be sized for the night time load. The battery bank must also be able to supply the required kWh for the period of autonomy. Again, the table in the load management section will help you determine this.

A battery bank that is too small will have a short life and provide poor system performance because the batteries will cycle too deeply. A battery bank that is too large can make it difficult to maintain a full charge, which can also damage the batteries. It is best to build your bank with the fewest number of cells and batteries possible (use larger instead of more) because it cuts maintenance time and has fewer interconnections, which add complexity to the system.

The voltage of the system depends, amongst other things, on your energy requirements and the length of the connections between the generator and the load. Generally 12 volts works wells for systems under 2kWh/day, 24 volts for systems under 7 kWh/day, and 48 volts for larger systems.

Battery maintenance and Storage

For safety reasons, batteries should be in a sealed container that is vented to the outside. This is essential for wet cell batteries because they produce hydrogen gas when recharging. Your batteries must be stored where they won't freeze (battery performance is related to temperature). The charge should also be maintained since they will slowly lose their charge, usually less than 5% per month for well maintained batteries. Most batteries will sustain considerable damage if they are left unused in an unheated space.

Batteries need regular maintenance to keep them working well and to prevent permanent damage. Wet cell batteries need far more than sealed cell batteries. However, on-going maintenance and control of charging are important for all types of batteries. It is beyond the scope of this guide to go into detail of the maintenance required for the wide variety of batteries available on the market. Make sure you know what maintenance is required and can provide it before deciding which batteries to purchase.

When you batteries need replacement, you should replace the whole battery bank. You system only functions as well as the worst cell in it, so you're wasting your resources if you only replace half the batteries in an old system.

3.3.2. Inverters, Controllers, etc.

A number of pieces of electronic equipment are necessary for effective operation of your remote site electrical system, and there are additional devices that can be used to automate it and optimise operation. More and more of these components are being combined into units with multiple functions so you need to connect fewer of them. Ideally all of these pieces of equipment should be collected together at a control panel. Most control panels contain at a minimum an inverter, charge controller, DC disconnect and a bypass switch.

Inverters, along with batteries, are at the heart of your system. Direct current (DC) power stored in batteries is converted into alternating current (AC) power that is needed for most household appliances. The size of the inverter will determine how many appliances you can run at the same time. Some inverters can automate operation of a generator and have sophisticated computer controlled systems to allow you complete control of your system.

Charge controllers control the charge going into your battery and help keep it fully charged and prevent damage from over-charging or charging too quickly. Many new charge controllers have built in system monitors.

Other devices typically used in remote site camps or lodges using battery power include:

- A DC disconnect is required for code compliance and provides a convenient location for tying together DC wiring.

- A bypass switch allows you to bypass your inverter and run loads from the generator directly.

The more complicated your system gets, the more sophisticated your control system will have to be. Additional controllers and/or regulators may be required to manage your system.

3.3.3. Other Electrical System Components

You need to design the right size electrical service for your camp. Electrical codes are focused on the amount of peak energy a given site might require, and the size of an electrical service (e.g. 200 or 400 amps) is based on the square footage of a building. In a normal grid-connected building, the increased cost of a larger service is negligible, so it's normal to have dramatically oversized electrical services. In a remote site with generator power, everything is different: over-sizing the infrastructure (wiring, transformers and power plants) to service a theoretical load, causes the costs of operation to skyrocket. It's best to take some real-life measurements of actual demand and to size the power plant accordingly. This may not be possible for new sites, in which case it's best to consult with a renewable energy professional that has experience dealing with remote facilities.

Transformers

The purpose of a transformer is to step up or step down the system voltage, typically to save in wire costs or for longer distance transmissions. Transformers are very common items, but are often regarded as untouchable electrical infrastructure, designed and installed by those that know better. From the perspective of the engineer or installer, having a transformer that is oversized means they are less likely to have a customer calling and complaining about issues. However, the operational costs borne by the sites are tremendous. Each transformer has an idle load, typically in the range of 3-5% of the transformer capacity.

> For example, a 200 kW transformer will have an idle load of approximately 6-10 kW, 144-240 kWh per day. Since transformers are almost always energized 24x7x365, this adds up considerably: to 57 litres of diesel per day = 20,800 litres per year, in the example mentioned above.

Some transformer issues are simple. For example, if the site has a medium voltage distribution (480 or 600 VAC), ensure the prime generators output this voltage natively. Some sites have a low voltage generator which is then stepped up through a transformer immediately for distribution. This dramatically reduces the already low conversion efficiency from diesel to electric. Always minimize the number of transformers in the electrical design and size them for the actual load. If the load changes down the road, you can change the transformer for a fraction of its operating cost.

3.4. Monitoring

Knowing precisely how much energy is being consumed and when it's consumed is essential for efficiency. Most sites have no method to measure the amount of electricity used at any given time, let alone the amount of diesel they use to generate that electricity. The best practice is to ensure metering is a permanent part of your generator package from the start. There are many off-the-shelf products available, such as the Ion 6200 (designed in Victoria, BC). Monitoring power demand as a part of normal site operations allows site operators to learn the trends of power consumption, and to be able to flag anomalies.

3.4.1. Permanent monitoring

Permanent monitors help your system operators become familiar with system trends and help you keep track of what's happening on a day-to-day and year-to-year basis. The most important piece of information for this purpose is demand (kW). Many sites focus on measuring amps but this is not particularly helpful. Good quality meters compute the actual power being used many times per second, resulting in highly accurate data. The data can be viewed and recorded in a variety of ways. The best systems automatically upload data to a remote server, which protects against data loss. Data can also be stored on a memory key and manually collected. This monitoring can be one meter for the whole site, or can be broken up on a building-by-building, or even circuit-by-circuit basis. As energy efficiency is becoming a hot topic, more low cost, easy-to-use metering solutions are becoming available.

3.4.2. Portable Data logging

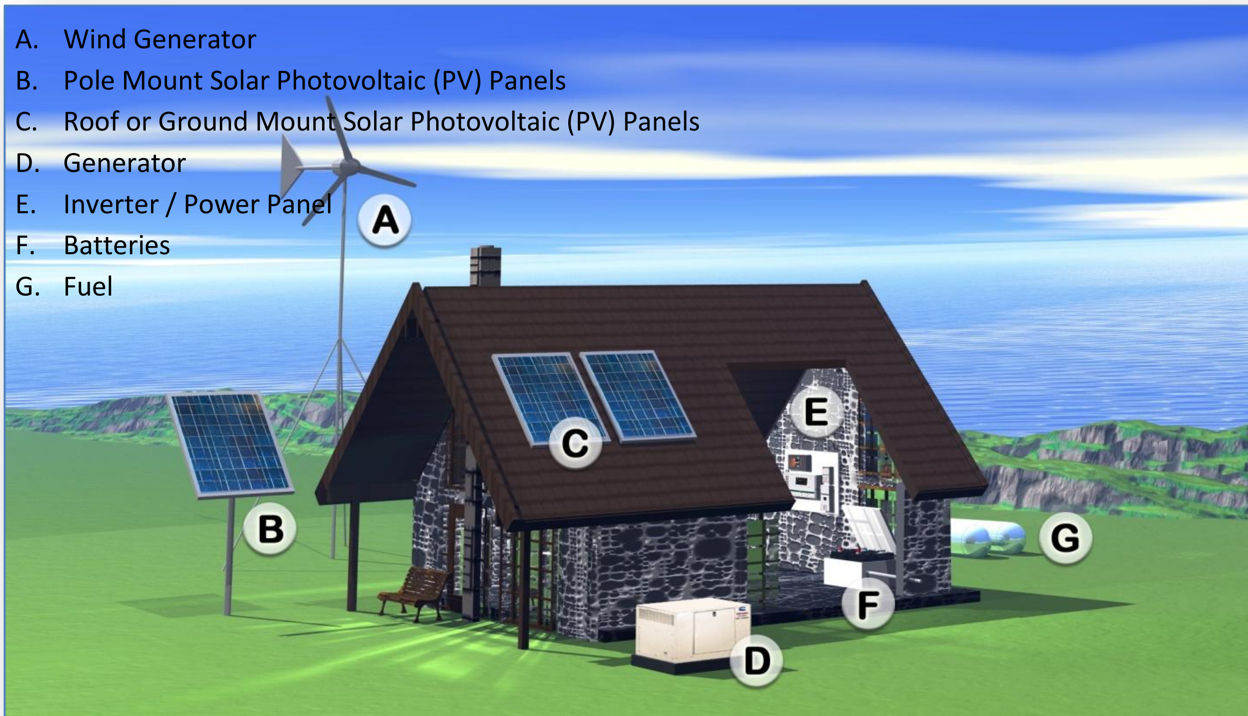
Portable devices allow temporary monitoring of power and are typically operated by energy auditors. Connection of these devices requires exposure to live electrical circuits and utmost care must be taken. Training is required to deploy portable metering. Portable devices typically include analysis software. The Hioki 3197 is one of the more affordable and easy to use tools for this purpose. There are several other products out there including Fluke. The Arctic Energy Alliance has a Fluke power analyzer that is available.

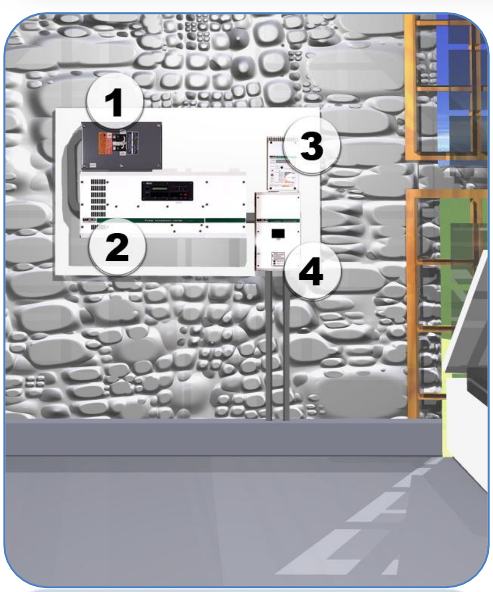
3.5. Renewable Energy (RE) Systems – Electricity

Renewable energy has been used for centuries to provide electrical and mechanical power. Some technologies, such as wind and hydro were in use long before electricity was commonplace. A properly planned, installed and maintained renewable energy system can save you money, increase your energy security and lower your environmental impact.

3.5.1. Some Renewable Energy system components

This illustration outlines some of the possible components of an off-grid renewable energy system.





1. Bypass switch
2. Inverter
3. Controller
4. DC Safety Disconnect

3.5.2. Tying it all together - Integration of renewable energy with fossil fuel generators

Generators supply firm, dispatchable power. This means that peak power is available whenever you need it – if you have a 50 kW diesel generator, you have 50 kW of firm peak power – or 1200 kWh per 24hrs of running. Renewable energy is different. Power is supplied based on the available wind or sun or other natural resource at that time. Microhydro systems offer power similar to that of a generator – it's constant and predictable power. Wind and solar systems on the other hand, are intermittent. Solar power is relatively easy to predict but varies dramatically by season. Wind is the most difficult natural resource to predict.

How your systems tie together will be the topic of planning sessions and the finer details of integration are beyond the scope of this document. It is a job for an experienced renewable energy designer. Be cautious with engineers who do not have successful projects completed. Look for firms with established track records and talk to their past customers before selecting one.

DC subsystem

If your electrical system has a DC subsystem, such as a hybrid battery/inverter system, renewable energy sources can be tied in at the DC level, augmenting battery charging from the diesel generator and allowing the generator to work less. It is more efficient to run DC appliances off a DC system than convert the power to AC and use AC appliances.

AC coupled mini-grid

For larger systems and systems in which the distances between the generator and the loads are long, an AC coupled mini-grid may make sense. In these situations, it is presumed that a diesel generator is running constantly (ideally in a parallel configuration). Using off-the-shelf grid-intertie inverters, you can use the same hardware that allows individuals connected to a utility grid to sell power back to the utility. These systems feed power back into your mini-grid. Any kWh of energy produced by renewables is a kWh not produced by a generator.

3.5.3. Solar Power, Photovoltaics or PV

Solar Electric (solar power, photovoltaic or PV) products convert the sun's energy into electricity. Solar energy is a variable resource which can produce electricity for a somewhat predictable time of the year. In remote camps the electricity produced is normally stored in batteries for future use. It can also be used to power an appliance such as a water pump directly, or fed into the power distribution grid if you have a mini-grid. PV systems are modular, allowing you to start with a small system. As your power requirements grow, you can add more modules.

Electricity Production

PV modules produce electricity in proportion to the amount of sunlight falling on them. In full overhead or "peak" sun (1000 Watts/m2) they produce their rated power. Reduced sunlight caused by clouds, pollution, precipitation, dust, shading, etc. will diminish the amount of electricity generated. Seasonal output variations are significant, especially in the north, due to the change in the number of daylight hours throughout the year.

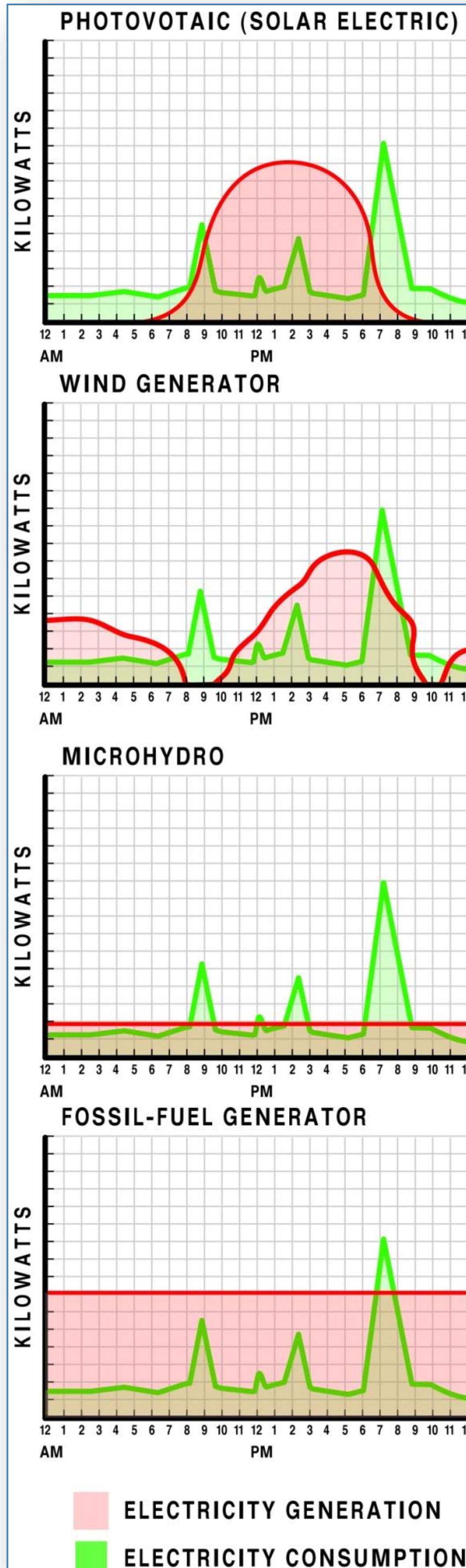
It is a common misconception that heat is required for PV modules to produce electricity. High temperatures actually decrease the power output. Warmer climates require PV modules with a higher maximum voltage than those used in cold climates. Cold temperatures decrease resistance and increase voltage. Modules with a lower voltage rating are ideal in colder climates such as Canada.

Types of solar cells

There are different types of PV cells: single silicon crystal (mono-crystaline), multi silicon crystal (poly-crystaline), and amorphous silicon (a-Si). They have varying levels of efficiency and cost. The cost per watt of output doesn't change very much, but more efficient panels will be smaller. Amorphous panels are the least efficient but the most robust.

Location and orientation

Proper location of solar panels is critical to get the best value from your investment. Solar panels should be located in an area with the best sun exposure while keeping the solar panel as cool as possible. Shading (such as from trees or other buildings) on even one cell of a module will reduce the output of the entire module. Solar panels must be angled to capture the most energy from the sun. A general rule for this is your latitude - 15° for summer and +15°for winter, e.g. in Yellowknife at 62° latitude, solar panels should be mounted at 47° from horizontal for summer optimization, or at 77° for winter optimization. Seasonal adjustment of



solar panels can make a significant improvement to output. The further you are from the equator, the more pronounced this is. However in the NWT, the number of sunlight hours in the winter is so low that most system operators leave their panels at an angle equal to the latitude to optimise spring and fall collection. If you have a high electrical demand in the summer, it would be worth adjusting the panels to latitude - 15° for the summer.

All PV mounting structures must have good air circulation around the modules. Air circulation provides natural cooling of the modules and increases efficiency by allowing them to operate at lower temperatures. If the site where your PV array will be mounted receives high winds you must ensure the back of the modules are not exposed. High winds and northerly winds during the winter can create uplifting forces strong enough to seriously damage your PV array. Spacing your modules a few inches apart decreases the likelihood your array will be damaged by the wind. Snow loading is another consideration. The panels must be installed at a height and angle that allows them to shed snow easily.

Roof mounts are the most popular choice for small residential systems. The modules are located on the roof above most objects that would cause shading problems and the large roof surface makes it easy to attach the mounting structure. A roof mount also locates the modules out of sight, reducing the possibility of vandalism or theft. If your roof is facing in the wrong direction or the roof pitch causes problems then modules can be installed on a south facing wall using the same mounting structure.

Pole mounts, an option which involves installing the panels on a pole dug into the ground, are easy to install and allow the array angle to be adjusted after installation. The mounting frame fits on a length of schedule 40 pipe set securely in a concrete form in the ground.

A significant increase in electricity production can be achieved by installing a solar tracking system. These systems keep the modules oriented towards the sun as it moves across the sky during the course of the day. However, they are expensive, introduce a mechanical component and add complexity to the system. They are not recommended for remote applications in the NWT.

Maintenance

Mechanically PV is the simplest form of alternative energy. There are no moving parts in PV modules, little maintenance is required and there are no consumable items. It is a mature and proven technology. It was developed in the 1950’s, primarily to serve the needs of space exploration. The original panel was invented in 1954 and still works. Product reliability is excellent; modules typically have 25-year power production warranties on them. PV is extremely low maintenance: typically limited to keeping the panels clean and periodic inspection of electrical connections.

3.5.4. Wind Generators

A wind generator converts the power of the wind into electrical energy. Wind energy has been used for centuries for grinding grain, pumping water and generating electricity. Small wind turbines were an important source of electricity for rural families in North America in the 1920s and 1930s. Wind energy faded into the background with the rural electrification efforts of the 1940s and the development of reliable small engine generators. Today, wind is gaining tremendous popularity and is generating significant amounts of power both off-grid and as a source of energy for large utilities.

The most important factor in assessing the potential for wind generation at your site is the local wind speed. The power produced from a wind generator is not a linear relationship with wind speed, the power produced goes up with the cube of the wind speed.

For example, a doubling in wind speed produces an 8-times increase in power output. A wind generator will produce about 8 times as much power in a 30km/h wind as it will in a 15 km/h wind. Even a 25% increase in wind speed will produce about twice as much power from your wind generator.

This is why knowing what the wind regime is at your location is extremely important.

Electricity Production

Wind power output depends on the quirks of nature, and is one of the most unpredictable renewable resources. Wind turns the blades of the turbine, which spins a shaft within the turbine structure. The shaft drives a generator to produce electricity. The electricity is either used directly (such as an AC coupled system or water pumping) or stored in batteries. The established way of working with a variable resource like this is using a hybrid system, such as solar PV, and storage for surplus and backup power.

Types of wind turbines/equipment specifications

Horizontal axis wind generators are by far the most common type and are what most people think of when they hear about wind turbines. They require a tower on which they can be installed securely. There are two main types of towers – guyed and monopole. Guyed towers are significantly lower in cost and easier to maintain, as they can be winched down to the ground for any service needs, however they take up more land area. Monopoles are typically located when space or aesthetic issues are a priority - installation and maintenance are more expensive.

Vertical axis wind turbines, which manufacturers claim operate at low wind speeds and are more versatile and easier to install than horizontal axis wind turbines are starting to make their way into the marketplace, but are still largely untested in Northern locations. If you are considering this technology, you should demand independently verified performance data and a guarantee that it will work as claimed at your particular site.

Turbine selection is critical. Ensure the model you choose has good performance at the wind speeds at your location and has a proven track record of operating well in Northern climates.

Location and orientation

Your site requires good wind in order for a wind generator to be effective. Wind energy is generally unpredictable and varies tremendously site-to-site. Proper location and turbine selection are required for successful projects. Monitoring the wind speed before making the decision on where to put the turbine and which one to buy can prevent you from wasting your investment. Do not rely only on your feeling that there is always a good, strong wind because we generally only notice the wind when we feel it – not when we don't feel it. Most small wind turbines have a cut in speed (the wind speed they need in order to start electricity production) of about 4 m/s or about 14 km/h. But at this low wind speed the wind turbine produces only a tiny fraction of its rated output. Depending on the height of your tower, you may need approval from Transport Canada. Very large wind turbines may require other permits.

Maintenance
Wind turbines require regular maintenance with the degree of maintenance varying depending on the turbine selected. Ensure you have a plan in place for maintaining the turbines (regular and emergency maintenance) once they have been installed. This includes getting access to the turbine, which may be the most difficult part of the maintenance.

3.5.5. Microhydro
Microhydro power is predictable, constant and can be an excellent investment IF a suitable source can be found nearby. Since water flows day and night, a microhydro system requires far less battery storage than other technologies. Seasonal streams may be used when a hybrid water and solar system is designed. Unfortunately, most remote facilities in the NWT are not near a water source that's suitable for easy use with today's microhydro technology.

Electricity production
Flowing water can produce between 10 to 10,000 times more power than sun or wind for the same capital investment. It all depends on the amount of water, how far it drops and how close you are to it. Every microhydro system is unique because every water source is different. Proper planning and design is required to optimise a system for your needs. Advanced skill microhydro designs are required to allow a microhydro plant to continue to operate during freezing.

Types of Microhydro
The type of turbine selected will depend on the type of application. For example, is the power coming from a large amount of water falling a small distance, a small amount of water falling a large distance, water flowing through a stream bed, etc?

DC and AC microhydro generators are available. Generally speaking, DC is used for smaller systems, typically under 5 kW, and where the turbine is located within 500 meters of the power system. This power would generally feed into a battery-based hybrid power system. AC is used in larger installations and works just like a diesel generator, except water is providing the energy instead of diesel.

Location and orientation
To see whether microhydro would be suitable for you, the first step is to quantify the water resource available. This is done by determining the head (vertical drop), flow rate and pipe length, very accurate calculations can be made to determine the potential of this resource. Once the initial reports look good and you want to go ahead with the project, you will need to apply for permits. These can be quite diverse and lengthy so be sure to get this process going early.

Maintenance
The maintenance of microhydro turbines depends on the turbine and the water it's installed in. The turbine/generator needs to be maintained and the path to the turbine (penstock) needs to be kept free from debris, including ice and logs.

4. Heating

4.1. Efficiency

Heating is likely the largest energy user in your facility in cold weather. The easiest and most cost effective way of getting the most out of your heating system is by keeping the heat it produces inside your building. It doesn't matter how efficient your furnace is if the building leaks it all away. Fortunately, it is simple and inexpensive to keep that heat in.

This section looks at what you can do to prevent unnecessary heat loss from your building and then looks at how you can improve the efficiency of your furnace. – The same order that you should use when looking at reducing your heating bills.

4.1.1. Heat Loss

The building envelope is the shell of the building that separates the heated area from the outdoors and must control the flow of heat, air and moisture. It includes the walls, windows, doors, floor and ceiling or roof. Heat loss (& gain) through your building is linked to the level and quality of insulation in the ceilings, walls, floors, the losses with windows and doors; and, the sealing in the joints and holes in the building envelope. The most important things in minimizing your heating costs and fuel consumption are to ensure that you control your heat flow with enough insulation and control your air flow by making your building as airtight as possible.

Controlling heat flow

Heat moves from a warm spot to a colder one. Insulation wraps the house in a layer of material that slows the rate at which heat is lost to the outdoors. The higher the resistance value (RSI value or R-value), the slower the rate of heat transfer through the insulating material. One insulation may be thicker or thinner than another but if they both have the same RSI value, they will control heat flow equally well.

Heat is also wasted from hot water pipes. Insulate hot water pipes and minimize your hot water use by installing low flow showerheads and faucets, fixing leaky faucets and running washing machines with cold water.

Heating ducts running through unheated or cooler spaces should also be insulated.

Controlling airflow

Air leakage can represent 25 to 40 percent of the heat loss from an older building and can lead to other problems such as mould growth or damp patches on the walls and ceiling as well. Crawling and flying insects make their way into a building in the summer via many of the same routes as air leakage in the winter.

It is important to reduce the heat flow as much as possible. New buildings have a continuous air barrier to minimize air leakage but in older buildings this has usually been compromised by renovations - if it was there in the first place. Most air leakage occurs at the joints between materials and at openings, rather than through the materials themselves.   Reducing air leakage is one of the most cost-effective ways you can undertake in your buildings; the leakier the building, the greater the potential savings.

Ideally, an energy advisor would visit your facility and inspect your buildings and give you advice on how leaky your building is and which specific areas need attention. They can perform a 'blower door' test to measure the amount of air leakage, and to identify the main air leakage locations. However, if it is cost prohibitive to bring an advisor to your site, air sealing can be a do-it-yourself option. The first steps to consider are the following:

- Weather-strip and caulk windows and doors
- Upgrade or replace windows
- Seal all openings into the attic
- Seal the top of foundations
- Seal baseboards
- Seal electrical outlets
- Close up unused fireplaces
- Seal ducts

For more information on air sealing, consult NRCan's publications entitled "Air-Leakage Control", "Improving Window Energy Efficiency" and "Keeping the Heat In", and Canada Mortgage and Housing Corporation's "About Your House", and "Renovating for Energy Savings" fact sheets.

Buildings with very low air leakage may need provisions for ventilation air and air for combustion for stoves or furnaces. Older buildings typically have cracks and leaks in the building structure and leaky fans which provide ventilation, but it comes at a large cost as it is completely uncontrolled and causes major losses in heating. In a very well sealed building you will have to include alternative methods of ventilation, such as use of a heat recovery ventilator.

4.1.2. Controlling the heat

Insulation

As mentioned previously, it is important to insulate your hot water pipes and heating ducts. You want the water (or air in the case of a forced air system) to arrive at its destination hot. It is always important to insulate your pipes, but it is especially important if the pipes/ducts run outside or in an "unheated" crawlspace. If the crawlspace does not need to be heated, then you should have all pipes and ducts running through it well insulated to prevent heat loss.

Programmable thermostats

Programmable thermostats, along with proper programming of schedules provide an excellent way to fine-tune the temperature. You can use them to control different parts of the building and have it set at different temperatures for different times of the day.

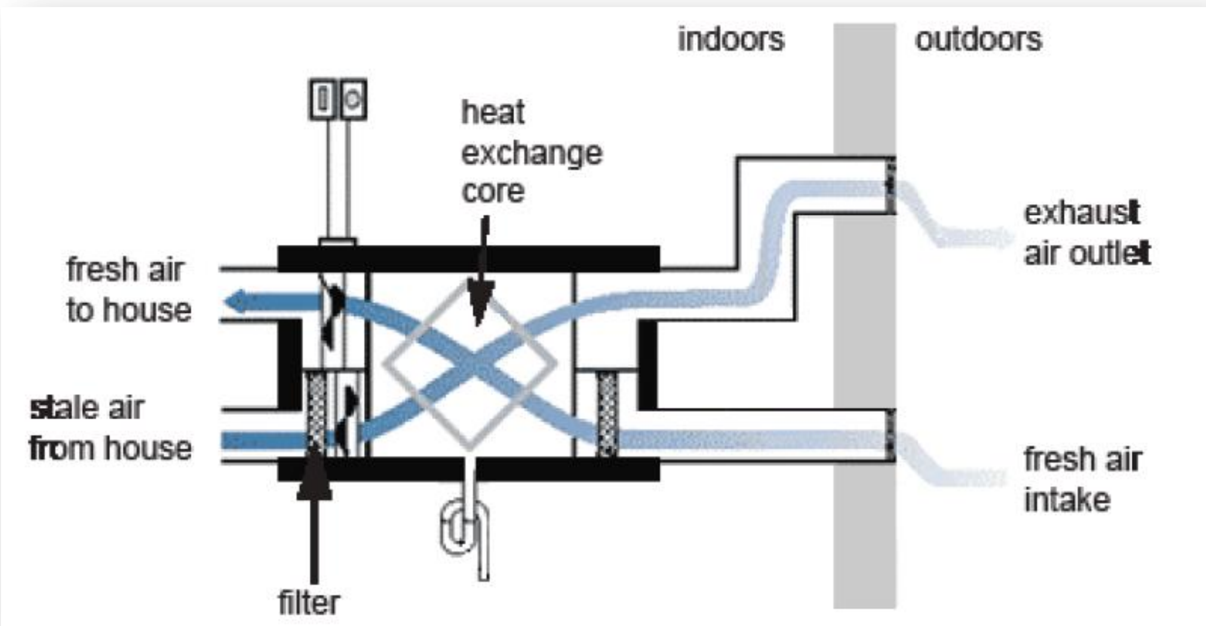
> For example, setting back the temperature to 16 degrees Celcius at night and when the building or section of the building is unoccupied can reduce your heating costs by up to 10%.

4.1.3. Heat recovery

Once your building has an energy efficient building envelope, proper insulation and air sealing, and an efficient heating system, you need to capture any other sources of heat available on site.

Heat recovery ventilator

Most energy-efficient buildings use a heat recovery ventilator (HRV). It works by passing stale, moist air from inside the building through an air-to-air heat exchanger in the HRV before exhausting it outdoors. At the same time, cold incoming fresh air is pulled through the HRV on the opposite side of the heat exchange core, transferring the heat from the warmer stale air to the colder incoming air, before distributing it in the central ventilation system or furnace air duct. A heat recovery ventilator (HRV) does 4 things: brings fresh air into your home, warms the air, circulates it, and gets rid of stale air.



Drain water heat recovery

Most hot water is only used for a few seconds before it goes down the drain, with most of the heat wasted. It is possible to extract the heat from your waste hot water using a simple drain water heat recovery device to pre-heat incoming water. This reduces the cost of heating the incoming cold water.. Properly planned, it's a very simple easy to install technology that yields excellent payback. The drain is wrapped with copper tubes which are connected to the incoming water of the hot water system, where it transfers a significant amount of waste heat into the incoming water. The higher the volume of hot water the better the benefits. This is especially effective in situations where there are many people staying on site and using running hot water for personal needs. It is not as effective if there's just one person who is already limiting their water use.

Generator heat recovery

A huge source of waste heat is from your generator. All generators emit a certain amount of heat during power generation; roughly 70% of the energy content in the fuel you burn in your generator is converted to waste heat. This heat can be captured to heat rooms or to preheat water.

Heat is usually removed from the body of the generator by a cooling jacket around it. The heat is usually taken from the coolant through a radiator, but it can be directed to a useful location instead. Also, you can capture the heat that's in the flue gases that normally just goes up into the air. This involves installing equipment in the exhaust stack to collect the heat. Of the two methods, heat recovery from the generator cooling system is easier because most of the heat recovery system is already there, and you don't have to deal with the corrosive elements in flue gases.

Old generators can be retrofitted to capture the heat, and some new generators come with heat recovery options. Before you buy a new generator you should consider how you can tie the waste heat into your heating system and look at the heat recovery options available. After all, do you really want most of the energy in the fuel you haul into your camp to be wasted?

4.2. Heating Systems

Electric heating with electricity created using a diesel generator is very inefficient. 70% of the fuel energy is wasted at the generator, making the electric system at best 30% efficient. If your camp has electric baseboard heaters, they should only be used in emergency situations.

4.2.1. Heating system configuration

There are three main types of heating system configurations you should consider for your camp. Space heaters, central heating, and a district heating system. Regardless of the type of heating you choose, shutting it down completely in the summer can avoid unnecessary fuel consumption.

Space heaters

Space heaters, such as wood stoves or freestanding diesel camp heaters can be used to heat each room or group of rooms on your site. Space heaters often don't require electricity to run and only heat the spaces in which they're located. For smaller camps with small buildings this works well.

Many older camps use passive, freestanding, non-electric drip type diesel camp heaters that rely on gravity-fed fuel source. These heaters are reliable, convenient and proven in the remote camps. They are a good option for sites with no electricity. However, they are terribly inefficient in design, easily consuming two to three times the fuel used by modern units. Poor overall combustion efficiency and the need for natural convection of exhaust gasses results in a lot of heat going up the chimney. More efficient electric assist heaters can be used at remote sites that have a source of electricity. Newer modern, electrically controlled units are even better with an efficiency of up to 90%. By using electronic ignition, and forced-air combustion, more usable heat can be extracted from the same input fuel.

Electronic ignition and thermostatic controls allow the unit to be turned down at appropriate times and to adapt automatically to changing outside temperatures.

Central heating systems

A central heating system can be used to heat each building on your site. This is similar to the residential model where one furnace or boiler produces heat which is distributed throughout the building through air ducts or hot water pipes (hydronic heating). If you have a medium to large size building with several rooms and/or floors, this is usually more efficient than having separate heaters for group of rooms. If the system is well designed, areas that are used for different purposes can be heated to different temperatures and on different schedules.

This type of system is easy to design because not much planning is required, no external piping is necessary and no thought needs to be given to other buildings on site. It is usually more costly to operate than a district heating system and the furnaces/boilers are often oversized.

District heating systems

Remote camps normally have a centralised generator and distributed heating. There is good reason why each structure doesn't have its own small generator to power itself – it's very inefficient; yet; this is exactly what most sites do for heating. Centralized heating needs more up front planning, but this investment pays for itself quickly in reduced operating and maintenance costs.

District heating systems are often overlooked, but work well for sites that have more than one building clustered together. This type of system uses one heating unit, usually a boiler, to heat a glycol solution that's piped between buildings and provides heating for all of the buildings, and often supplies the domestic hot water and process hot water too. This type of system can be very efficient and has the added benefit of only having one central heating plant to maintain. Zone valves can be used to control the temperature for different buildings and areas of buildings.

4.2.2. Sizing

It is important for you to size your heating system for the building(s) it will be heating. A system that is undersized will likely result in electric heating being used as a supplement in cold weather and this is a very expensive way to heat a building. A system that is over-sized will constantly fire up and shut down and will not run at its optimum efficiency, consuming more fuel than necessary.

4.2.3. Control systems

Installing programmable thermostats to control the temperature in different parts of the facility is a cheap way to reduce your heating costs while giving you better control over the temperatures of different spaces. More sophisticated computerised control systems are excellent for some remote sites, but you should take care to choose the least complicated system that meets your needs.

4.2.4. Fuel Choice
The best fuel for your site depends on fuel availability, storage and transportation costs amongst other things. You might end up using diesel for some applications and propane for others. Diesel fuel contains about 44% more energy than propane per litre, and is the most common fuel used for heating, mainly because of lower transportation costs. There are diesel cooking appliances, but most kitchen staff are more accustomed to working with gas cook stoves.

Propane is best used for appliances such as clothes dryers which are generally unavailable in diesel. High efficiency propane space heaters of similar design to the diesel stoves described above exist.

Wood products, such as cordwood and wood pellets are a viable option for space heating for most camps and lodges. Lodges in particular find that using a wood stove to supplement the primary space heating system adds to the ambiance. Wood pellet boilers that can supply the primary space heating needs are now available in the NWT, although, as with efficient diesel and propane systems, electricity is required to operate them.

4.3. Renewable Energy Systems - Heating

4.3.1. Wood and wood pellets
Wood, if it is harvested sustainably, is a renewable resource. When you're planning your building's energy systems don't forget that wood is an option for space heating and water heating. It might not sound as impressive as solar panels, but if the wood is available locally, then it's an option you should certainly look into. If you want a heating fuel that flows automatically like diesel, then wood pellets is an excellent choice. It has the added benefit of not causing environmental problems if it leaks – the pellets will just turn back into a heap of soggy sawdust when they get wet, and you can shovel them up or leave them to decompose. The availability of pellets and types of wood pellet appliances available in the NWT has increased rapidly over the past few years, and more and more businesses are getting into installing and maintaining them.

Wood and wood pellet stoves are a very good way to warm-up a space when you're in it. They're a great option if you need supplemental heating in a commonly-used room.

A wood pellet boiler heats your water for space heating and domestic hot water, just like your oil boiler, and also feeds automatically so you don't need to refuel it every few hours.

4.3.2. Solar heating
The sun's energy can be used to create heat. You feel this when you are wearing dark clothing in the sunshine. This phenomenon can be used to our advantage to lower the volume of heating fuel required to heat a building. The sun can be used to heat air, water or objects and is sometimes referred to as solar thermal.

Passive solar design
All new buildings should be built with solar energy in mind. In order to take advantage of the heat coming from the sun to heat the building during the heating season, more and larger windows should be

on the South side of the building, and fewer on the North side, which receives the least amount of sunshine. Having a large thermal mass, such as a stone floor in the room the sun shines into can help trap the heat when the sun is shining and release it gradually, throughout the night. By using passive solar design principles, a portion of your heating can be offset. However, if the building is in use in the summer too, it's important to design it so that it doesn't overheat. The last thing you want is to run an air conditioning system on you generator! The overhang above your windows should be designed so that the window receives full winter sun, but is shaded from the sun in the summer. If it isn't possible to do this using the overhang, awnings can be installed. If the building is below the treeline, planting deciduous trees such as birch on the south side and letting them grow up can provide shade for the whole side of the building and sometimes the roof too. Orienting the building so that you have a roof slope facing South will make it easier to install solar panels on the roof.

When you select your windows, ensure you have some that can open to provide ventilation to reduce your reliance on mechanical ventilation systems in the summer. You should only buy windows rated for Energy Star zone D for the NWT.

Solar hot water

The sun's energy can be used to heat water for space heating or for use as domestic hot water. Think of the garden hose left outside in the sun and how hot the water in it gets. Solar hot water panels are more efficient at using the sun's energy than PV panels, however they produce useable energy in different forms. PV panels produce electricity, which offsets the fuel you use in your generator whereas solar hot water panels produce hot water, which reduces the fuel burned in your furnace or boiler. It is much more efficient to heat water directly from the sun than to use a solar panel to generate electricity to heat the water. Similar to PV panels, solar hot water panels need to have good solar exposure. Shading is not as important with thermal applications as with PV because the heating lost is only proportional to the area shaded, but you still want to get the most out of your investment by minimising shading. Why put money into buying solar panels and then put them in the shade so they don't do anything?

Solar hot water represents a mature and proven method of using renewable energy to heat water. These systems can easily be added to existing buildings or integrated into new construction. While there are many different solar thermal hot water systems, they all rely on the same basic operational principles. Energy from the sun is used to pre-heat water or a glycol solution which then travels through the conventional heater and is routed to a storage tank, ready for use. If the sun provides 70% of your heating needs, your conventional heater only has to supply 30%. Some of the most common types of solar hot water technology are listed below.

Flat Plate: these collectors consist of copper tubes with attached copper fins (to maximize the surface area) housed in a black insulated box. The glycol solution passes through the tubes and the heat from the fins and tubes is passed on to it as it travels through. Special low-reflectivity glass is used to keep the heat from escaping from the tubes. These units tend to be robust and glass that is shatter resistant can be ordered. Although their efficiency is lower than that of evacuated tube collectors in cold weather, they are more efficient in warm weather, and they're often a better choice for remote locations where robustness and ease of transport are important.

Evacuated heat tubes: these collectors consist of copper pipes with attached fins which are inside a glass cylinder that is commonly a vacuum tube. The glycol solution passes through a main pipe where it collects the heat. The vacuum tubes provide excellent insulation and prevent heat loss to the air better than flat plate collectors, so they're generally more efficient in cold weather. They are more expensive and more fragile than flat plate collectors.

Solar Air Heating

This technology uses the sun's energy to pre-heat incoming fresh air, resulting in the conventional furnace working less. It is a building integrated technology, and is suited to large structures such as gymnasiums, warehouses and factories with large ventilation systems. It consists of building cladding which is a perforated metal sheet installed with an air gap behind it. The sun warms up the metal and air, which passes in through holes at the bottom and in the cladding, is heated up and drawn into the building to replace stale air that is being exhausted by the building's ventilation system. While this technology can work for large or small buildings, it doesn't work in buildings without ventilation systems that take in fresh outdoor air.

5. Water

With the number of lakes in the NWT, and the seemingly endless supply of water, especially at remote sites, water use may seem almost free; but that is not true. In fact, there is a lot of energy and money spent on the transportation, treatment, disposal and heating of water. Energy is needed to pump that water to and from your site (water is very heavy), energy is used to treat and dispose of the water, and often the water needs to be heated. By using efficient and low-flow appliances, minimizing heat loss in your water, improving your pumping efficiency, using efficient water heating devices and setting up an intelligent water distribution system, you can save a lot of energy and money.

5.1. Efficiency

Conserving water by using efficient appliances is a very simple way to conserve water and in turn energy. You will find that most of the suggestions here have payback periods of less than a year.

5.1.1. Low flow devices

Toilet Flushing

Reducing water consumption from toilet flushing is a simple and effective way to reduce water use in your facility. Remove the old toilets in your facility if they use more than 6 liters of water per flush and replace them with certified low or dual-flush models. As a bare minimum you should look for models with a flush performance of 350grams or more and using 6 litres per flush or less.

Showers and Faucets

Low-flow showerheads and faucet aerators can reduce water consumption and hot water heating costs by up to 50%. Conventional showerheads use twice the water needed for a comfortable shower. These devices have built-in water-flow restrictions that reduce the flow without much difference in the way the shower feels. Look for models which use less than 9.4 litres of water per minute (LPM). Many facilities suffer from low quality hardware, and a broken showerhead is less satisfying for a shower and uses a lot more water and energy. Aerators can be easily installed on your faucets in the bathroom and kitchen. They reduce the flow of water while maintaining pressure. They're not generally recommended for laundry or utility sinks because they reduce the flow so it takes longer to fill up a bucket of water. They are most effective in locations where people leave the taps running while washing things. If water being left running for too long is a problem, it is also possible to get showers heads and faucets that turn off automatically after a period of time.

Dishwashers

Dishwashers consume most of their energy producing heat. The water must be heated by both the facility's water heater and the dishwasher's own booster heater and there is heat generated to dry the dishes. Dishwashers using less water have less water to heat. Air-drying the dishes instead of using the built-in drying function saves you even more energy.

Look for the following when buying an efficient dishwasher:

- Energy Star label
- Low annual kWh consumption

- Low gallons of water used / cycle
- High Energy Factor (reflects the number of cycles performed per kWh)

Washing machines

Front loading washing machines are generally more efficient than top-load washers because they use the less water, the least electricity and wring out the clothes better- so less drying is needed. By choosing the wrong washing machine, you could be forcing yourself to use 5 times more electricity than you need to wash a load of clothes. Washing in cold water and hanging items to dry reduce energy use.

Look for the following when buying an efficient washing machine:

- Energy Star label
- High modified energy factor (the number of cubic feet of laundry that can be washed and dried using 1kWh of electricity)
- Low water factor (the number of gallons required to wash 1 cubic foot of laundry)

5.2. Pumping and heating

5.2.1. Pumps and efficiency

Efficient water pumping provides a great opportunity for energy savings since modern efficient pumps can use a fraction of the power of a conventional water pump. Pumps such as the Grundfos SQFlex series can use 10-20% of the energy of a conventional submersible pumps. Pumps should be installed as close to the water source as practical. All leaks in the hoses should be repaired as soon as they are detected because leaks mean that the water you've just spent money on pumping out of the lake runs out onto the ground and is wasted, and the system operates at a lower pressure. Regular inspection and maintenance of water lines, with particular attention paid to joints is a cheap way to save energy on water pumping.

Solar-powered, wind-powered and water-powered pumps also exist and can be used either directly with DC motors or by using conventional AC-powered pumps and an inverter. DC powered pumps are more efficient than AC, especially when using a DC power supply – you don't lose efficiency in the conversion from DC to AC and AC to DC. Solar and wind-powered pumps can be used to pump water into a storage tank when the sun and wind are available and water can be drawn off the tank as needed, even when there is no sun or wind.

5.2.2. Heaters

Heating water electrically with a diesel/electric system is very inefficient. 70% of the fuel energy is wasted at the generator, making the electric system at best 30% efficient. Off-the-shelf propane or diesel hot water heaters can easily achieve upwards of 90% efficiency. Avoid using electric hot water heaters for your facility. There are three main types of water heaters you might consider for your camp: tank, instantaneous and boiler coil. Regardless of the type you choose, you should keep the pipe lengths as short as possible and insulate them.

Hot water tank

Hot water tanks are the most common type of hot water heater found in small buildings in the NWT. Electricity, diesel, propane, another fuel or even the sun (solar thermal) is used to heat water in a tank and keep it warm. Electric tanks should not be used in remote locations, for the reasons described above. Hot water tanks are usually the cheapest of the three options to purchase and install, but they're also the least efficient. You can find some energy savings with tanks by turning the set temperature down, this will require a bit of experimentation to determine how far you can turn it down while still keeping the water hot enough for all your applications.

Instantaneous water heater

Instantaneous (tankless) heaters are 15-30% more efficient than the best tank type heaters, more if you're using an older system. They work by quickly heating the incoming cold water instead of storing it and keeping it hot all the time. They serve hot water on demand, meaning that there is no running out of hot water (unless you run out of water or gas). Although instantaneous heaters will continue to produce hot water indefinitely, they do have a maximum flow rate so you need to estimate your water consumption to ensure you buy a unit that is capable of meeting your peak hot water demand. When heat recovery strategies are used, some systems end up being a combination of storage and instantaneous heaters. Instantaneous water heaters running on heating oil are available from Toyotomi. Numerous manufacturers make and sell propane instantaneous water heaters. Installing the heater as close as possible to the point of water use will optimise the savings.

Hot water coil from your boiler

If you have a boiler supplying your space heating needs, you can heat water for your domestic hot water or process needs using a coil inserted into the boiler. The hot water can be used directly or stored in a tank. This can increase efficiency because one appliance is providing all of the heat and isn't starting up and shutting down constantly and it means that you have fewer heating appliances t maintain. It does mean, however, that you can't shut the boiler down in the summer unless you have an alternative hot water heater.

6. Vehicles

Driving vehicles and machines around your site can be a large fuel user. By making the right choices when purchasing a vehicle and by driving and maintaining your vehicle with fuel efficiency in mind, you can realise fuel savings, reduced maintenance, and have a longer lasting vehicle.

6.1. Fuel Efficient Driving Tips

Avoid idling. When vehicles idle needlessly, an astonishing amount of fuel is wasted.

For example, a vehicle with a 5-litre engine, every 10 minutes of idling costs half of a litre of fuel. Idling for more than 10 seconds uses more fuel compared to restarting the engine.

Most Canadian fleet operators have implemented idling policies to reduce fuel costs- perhaps you could benefit from doing the same. By not idling you also reduce noise and enjoy better-quality air from reduced exhaust in the area.

Combine trips. By combining trips around the site (and to and from the site), you can save fuel, time and money. Don't drive with unnecessary loads. The added weight of heavy items will increase fuel consumption. Carry only what you require. This extends to choosing the most appropriate vehicle for the job. If driving a small car will allow you to get the job done safely, using a big truck is wasting fuel because you're carrying around extra weight and usually using an engine that is running inefficiently because it was intended for heavier loads. Maintain your vehicle. Inflate your tires properly and they will last longer and save fuel. Cold temperatures decrease the air pressure in tires. Read the owner's manual and follow the proper care instructions for the vehicle. Use a block heater to warm your engine before you start it. Block heaters can improve fuel economy and can be fuel-fired.

6.2. Vehicle selection

Fuel consumption varies greatly from one vehicle to the next. When purchasing a vehicle, consider the following for maximum fuel economy:

- Purchase the smallest, lightest vehicle practical for your needs. Normally the larger the vehicle, the heavier the vehicle and the more fuel it consumes
- If buying new, check the EnerGuide label for its fuel consumption rating or check the free *Fuel Consumption Guide* for all cars, vans and light-duty trucks sold in Canada
- Generally a manual transmission is more fuel-efficient than an automatic
- Many convenience power options increase fuel consumption
- Purchase a certified boat motor. California Air Resources Board (CARB) 3-star certified boat motors are energy efficient. Some 4-stroke motors and some direct injection 2-stroke motors are Carb 3-star certified
- Purchase 4-stroke snowmobiles. They're more efficient, don't burn oil and make less noise.

Appendix A – Load Calculation Chart

To calculate the size generator, batteries or renewable electricity system you need for your site, you must start with a load inventory – a list of the things that will be running off the electricity. The table below is designed to help you collect the information you need and make the necessary calculations.

AC Appliances

AC appliances are most common; they can be plugged in to standard grid power. These appliances usually have on the back a small tag with serial number and power consumption information. Usually, the tag will not have the watts (W) that the unit consumes and instead has the amperage (A). You can calculate the watts by multiplying the amperage by 120 Volts. If you use this tag, you should keep in mind that the watts calculated are usually much higher than would be used in any sort of normal operation.

Watts = Amps x Volts

DC Appliances

A DC appliance is anything that runs directly off the battery and does not go through the inverter. If you are just starting your renewable energy system you may not have any items that run on DC power. In that case just leave this portion of the table blank.

Usage

Hours/Day and Days/Week are the number of hours per day and days per week that the appliance is running.

It can be tough to find the information required from every appliance in your household, so there is a sample load inventory completed. You can use the values on that sheet if you cannot find the information elsewhere, but keep in mind that these are typical values, and not necessarily the same as what your numbers are.

Watt hrs (kWh) per week

To fill in the Watt hrs/week column, multiply the Watts that the appliance uses by the Hours/Day that you specified and the Days/Week.

AC Appliances					
Appliances	Qty	Watts	Hours / Day	Days/ Week	Watt hrs/ week
RADIO	**1**	**15**	**8**	**5**	**600**
Battery Recharger		20			
Belt Sander 3"		1000			
Blender		1140			
Circular Saw 8 1/4"		1600			
Compact Flourescent Light					
Computer		60			
Computer Monitor		84			
Colour TV (Tube)		286			
Drill 1/2"		750			
DVD		400			
Hair Dryer		1100			
Jigsaw		300			
Laptop		1125			
Microwave Oven					
Power Tool		1350			
Refrigerator/Freezer (16 cu ft)		380			
Satellite TV		40			
Toaster Oven		1550			
Vacuum Cleaner		1025			
Well Pump 1/3 hp		850			

DC Appliances					
Appliances	Qty	Watts	Hours / Day	Days / Week	Watt hrs/ week
INVERTER STANDBY	**1**	**5**	**24**	**3**	**360**
Battery Charger		40			
Cell Phone		3			
Halogen		20			
Inverter Standby		5			
Motor		70			
Refrigerator/Freezer (SunFrost)		12			
Radio RX		4			
Radio TX		50			
Stereo		15			
TV 14" Colour		70			
VCR		16			
Water Pump		50			

Total AC Watt Hours per Week

Total DC Watt Hours per Week

AC Appliances

Appliances	Qty	Watts	Hours/ Day	Days/ Week	Watt hrs/ week

DC Appliances

Appliances	Qty	Watts	Hours/ Day	Days/ Week	Watt hrs/ week

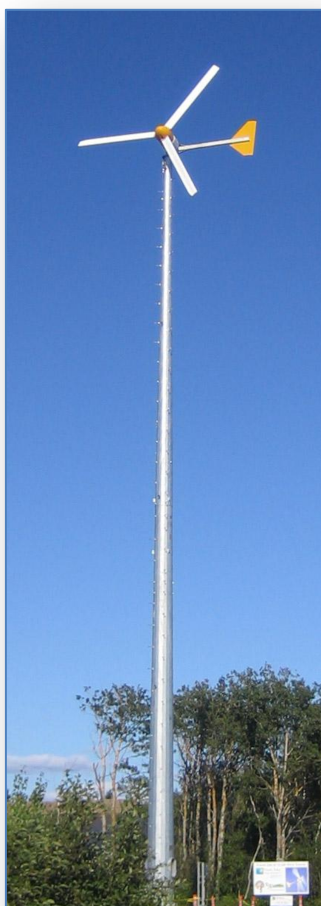
=

Total AC Watt Hours per Week ________

Total DC Watt Hours per Week ________

Appendix B – Pictures of Installations

7.5 kW Bergey wind generator on 100’ monopole tower



1 kW 48 VDC wind turbine on 60’ tilt-up tower.

Example of 7.5 kWp custom ground-mounted rack

2.1 kWp low-profile PV mount.

For locations with limited land space, or concerns such as animals, pole mounting is a good option. These are mounted on a 8” SCH40 steel pipe which is 1/3 below the ground encased in 30” of concrete.

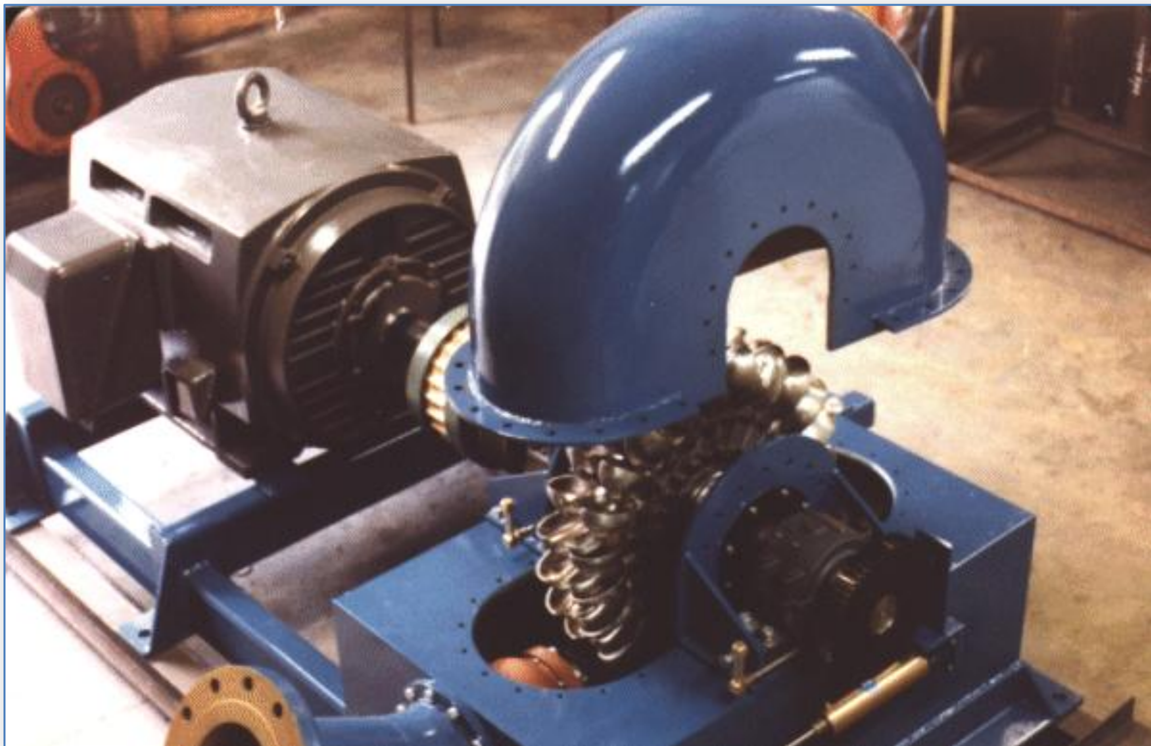
The modules on the left are on a tracking array, which follows the sun through the day.

The modules on the right are on a fixed array that is facing due south.

Drainback solar thermal installation. This system pre-heats hot water for 3 domestic hot water heaters + dumps surplus thermal energy into some colder rooms in the building. Racking is shared with solar Photovoltaic panels (bottom).

Microhydro Example – 48 VDC, 3 turbines, total 3 kW.

Microhydro Example – 500 kW Pelton wheel AC direct plant.



Appendix C – Case studies

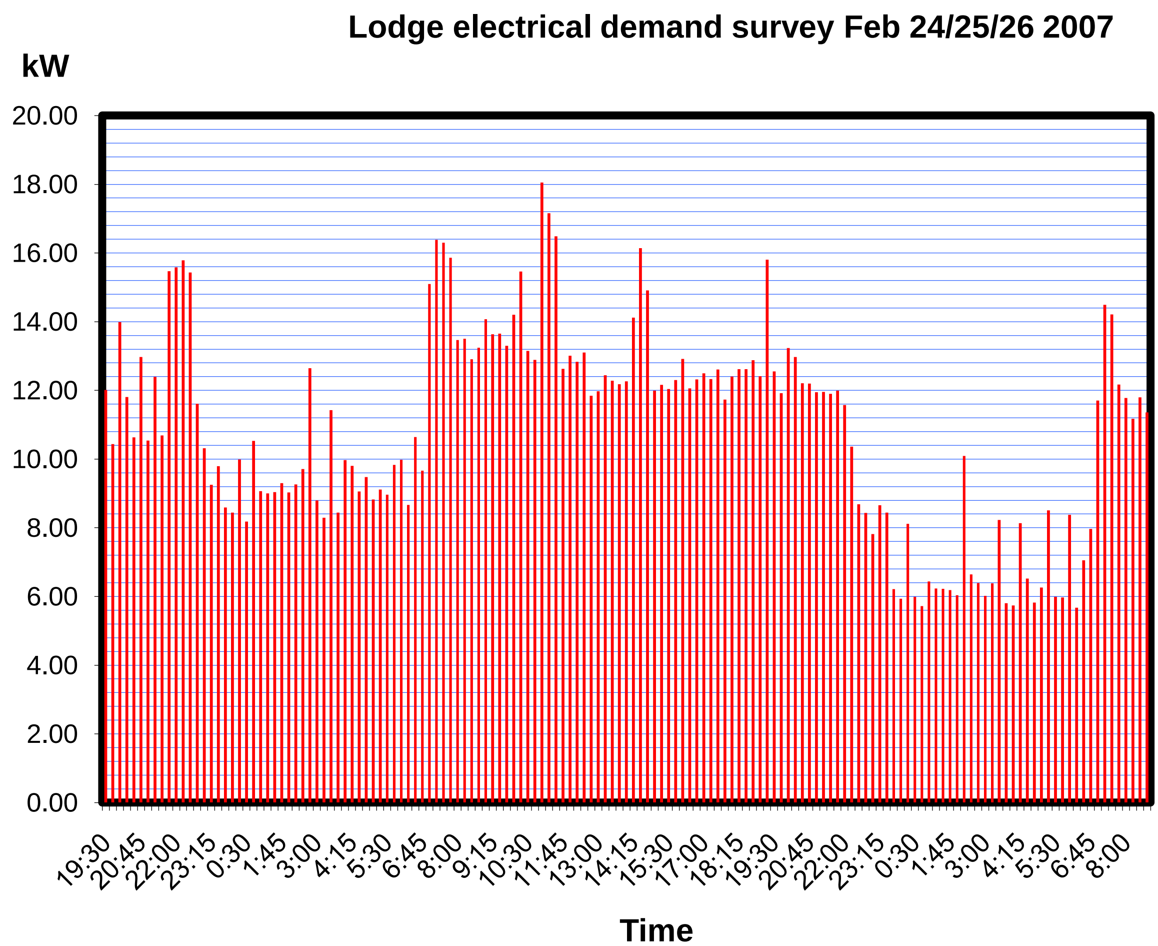
Remote Wilderness Lodge

Introduction

This case study is a remote wilderness lodge in Southern Canada. It accommodates 30 guests and staff. It had a 50 kW generator onsite at the beginning of the project. The generator was replaced with a hybrid generator/battery system to allow for cycle charging.

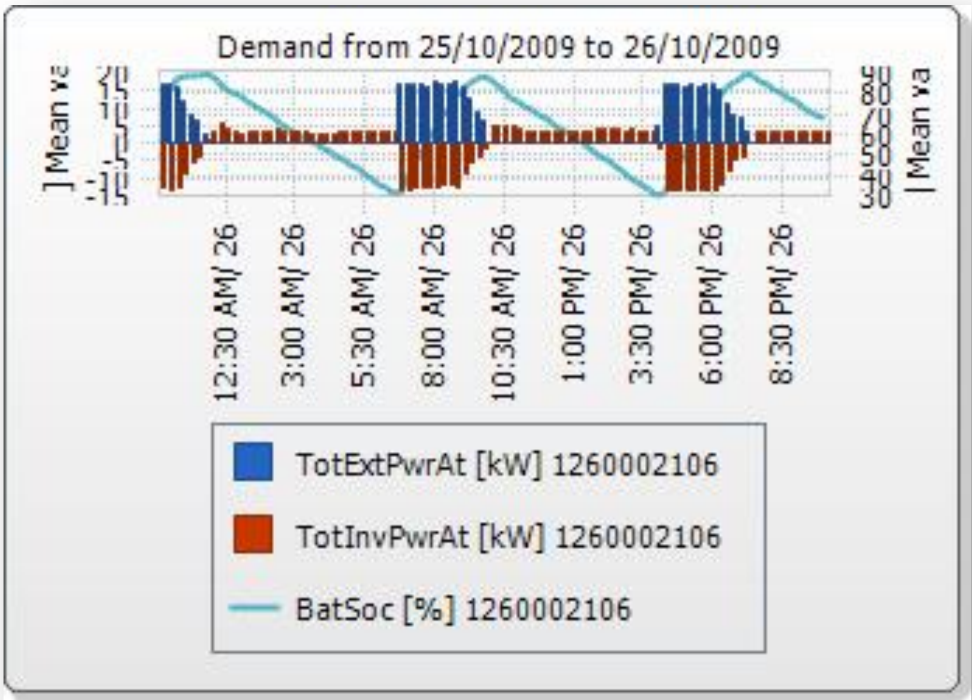
Initial Data Collection

This graph represents the actual electricity demand the lodge. The highest loads on the generator are under 40% of the generator's capacity, illustrating that the generator is significantly oversized.



Data Collection After Installation of Hybrid Generator/Battery System

This graph represents the real-time generator cycling from the same lodge after installation of a hybrid generator/battery system. The blue columns represent generator operation. The generator starts during breakfast load, then power switches to batteries, and then the generator runs again at dinner load and once through the night. This is a very efficient method of handling variable loads.



Results

The site reports a 60% savings in fuel after deployment of the hybrid system.

Remote Guest Ranch

Introduction

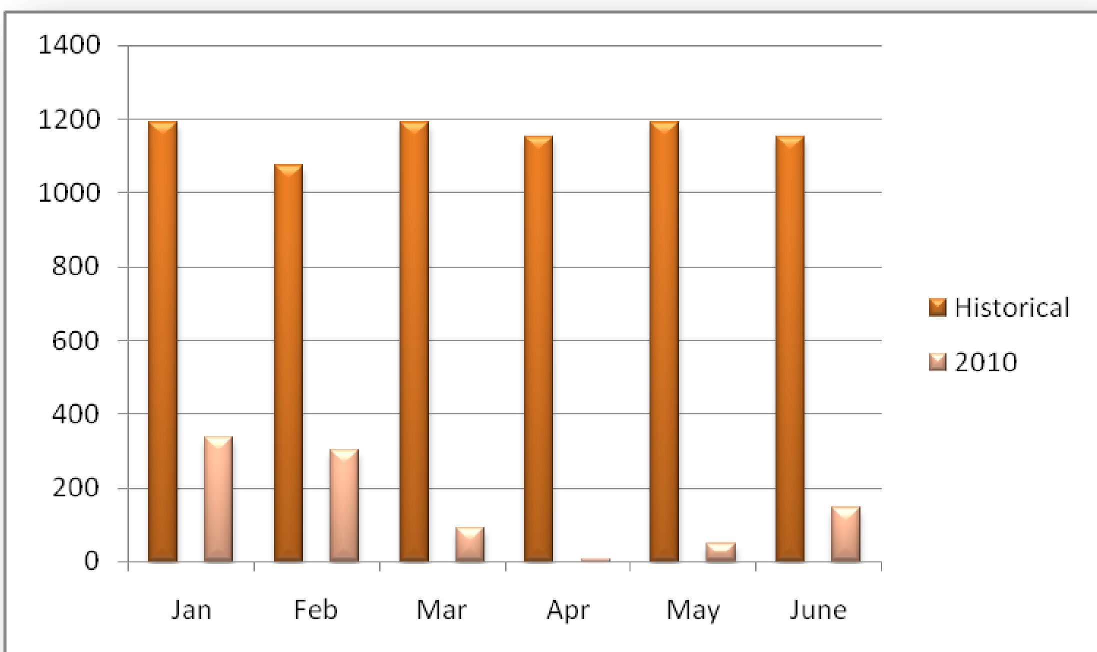
This site is a 160 Acre guest ranch. It houses a family of 4, a staff of 6 and up to 20 guests. This site had a small existing battery and solar system, but ended up running the generator 8hrs a day for an annual fuel consumption of 12,000L. A combination of energy efficiency upgrades (lighting and phantom load management) and operational and behavioural changes with the installation of a 4.5 kW solar photovoltaic array allowed this site to have a 90% reduction in fossil fuel consumption.

Data Collection

Part of the design of this system included comprehensive metering systems. Below is an excerpt from the first 6 months of system operation.

For example, at the ranch, we have been monitoring and measuring data on a daily basis for the newly installed technologies. In April and May, the weather was spectacular most days, and during this time frame we ran the generator for eleven hours total for those two months. In June, the weather was rainy and overcast for most of the month, and total generator time for that month was 30 hours. Compared to historical usage of eight hours average per day annually, this represents a 94%+ change (decrease in fossil fuel [diesel] consumption) over the three-month period.

The following graphs show total change over the past six months.



Fossil Fuel (diesel) Consumption (in litres)

Results

The ranch used 3,494 litres of diesel fuel for electricity generation in the period April 1st- June 30th, 2009. This past quarter, in 2010, they used only 197 litres. At a price of eighty-five cents per litre for farm diesel, the ranch saved $2,802.00 this quarter ($5,124.00 total savings for 2010 thus far).

By burning 3,297 fewer litres of diesel fuel from April 1st to June 30th, 2010, they reduced their greenhouse gas emissions by 8,800 kilograms during this quarter. Since January 1st, they have reduced greenhouse gases by 16,092 kilograms in total, which is the equivalent of taking 3 passenger vehicles off the road for one year.

Off-Grid Photovoltaics Case Study

Trout Rock Lodge

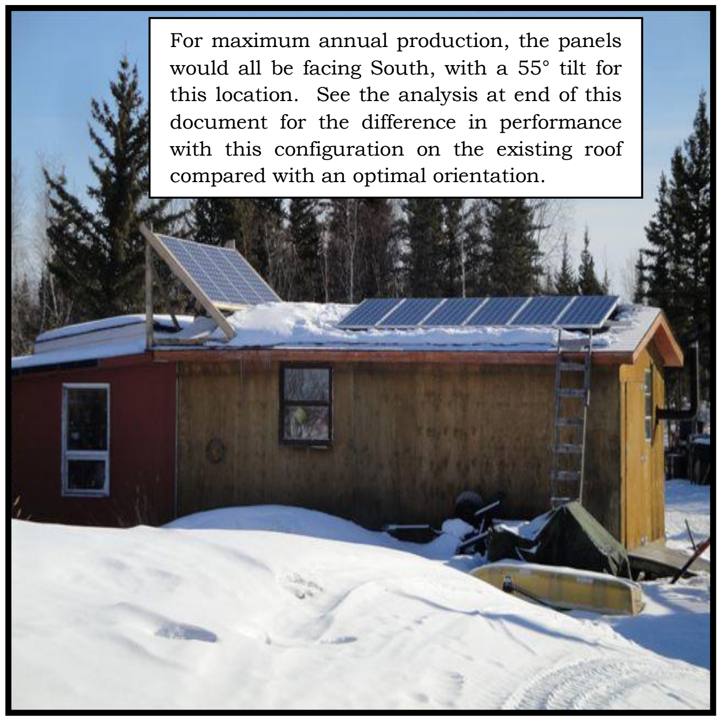
System Overview:

Solar photovoltaics (PV) were installed on the garage roof of the remote Trout Rock Lodge, located on the North Arm of Great Slave Lake. The owner, Ragnar Wesstrom, had the panels installed to reduce the diesel consumption of his generator and to save money.

The panels were installed in September 2009 and took 2 days to install. They are on the garage roof, with 4 of the panels facing Southeast at a 45° slope and 6 of the panels facing Southwest at a 15° slope. As they were installed on the existing garage, their orientation and slope are preventing maximum electricity production. The only difficulty they had during installation was in transporting the batteries to the lodge because of their weight.

The cost of this system, including installation, shipping and GST, was $46,500. The Trout Rock Lodge received a total of $41,200 in subsidies.

- $25,000 - *Industry, Tourism & Investment* - Tourism products diversification marketing program (this program is no longer available but others are)
- $16,200- *Environment & Natural Resources* -Alternative Energy Technologies Program.



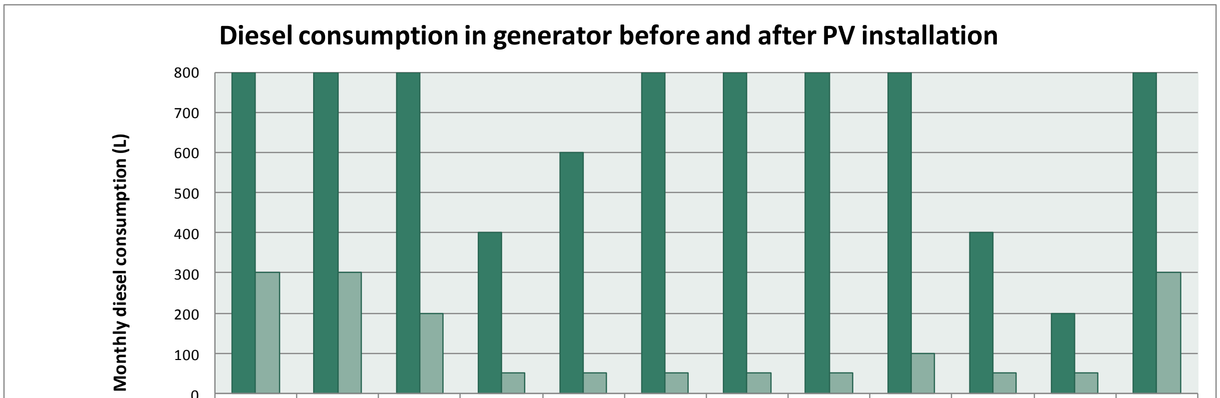
Ten 175W solar panels mounted at Trout Rock Lodge
Photo credits (All 3 this page): Ragnar Wesstrom

Two 3.6kW inverters in shed

Eight batteries in shed

Statistics	
Annual Liters of Diesel Saved (Estimated based on diesel flown in before and after the PV installation.	**6450 L** 80% reduction: 60% during occupied winter months 90% during occupied summer months
Annual $ Savings (Estimated based on fuel savings**)**	**$12,900 / year**
Annual Greenhouse Gas Emission Reduction (Estimated based on diesel savings)	**17.4 tonnes CO_{2e}**
Potential Yearly Production (Based on Retscreen analysis) Optimal- All panels facing South, 55° Current- Current panel configuration	**2575kWh/year** (optimal) **2172kWh/year** (current)

Performance Data:



	January	February	March	April	May	June	July	August	September	October	November	December
Typical year witthout PV	800	800	800	400	600	800	800	800	800	400	200	800
Typical year with PV	300	300	200	50	50	50	50	50	100	50	50	300

The diesel consumption was estimated by Trout Rock Lodge from their delivered fuel.

Technical Data:

Item		**Number installed (Total capacity)**
Solar panels	Sharp 175W	10 (1750 Wp)
Inverter	Outback power board inverter, including solar charge controller, battery capacity monitoring system, surge protection, battery bus protection, battery, inverter cables	2 (7200 W)
Batteries	Surrette batteries	8 (52 kWh, 72h rate)

Possible Improvements:

Mounting solar panels in the North comes with a particular set of challenges. For maximum annual production they should be mounted facing South, at an angle that is approximately the same as the latitude where they are located, unless trying to optimize for certain times of the year (e.g. summer use only).

The Trout Rock Lodge could have potentially produced 15% more power, had the panels been mounted differently. One solution would have been to use a pole-mounted or ground-mounted system (as shown in photo).

The Northwest Territories has great potential for PV, with between 900 and 1200 kWh annual production per kW installed, similar to the rest of Canada. PV also operates more efficiently at colder temperatures.

Pole mounted system in Behchoko.
Photo credit: Ventek Entreprises

Appendix D If you haven't had enough yet …

AEA has many resources available, some in hard copy, which we loan out, and others online:

http://www.aea.nt.ca/

Some other useful resources are:

Living off-grid in the Yukon – from the Yukon Energy Solutions Centre

http://www.energy.gov.yk.ca/pdf/living_offgrid09_web.pdf

Natural Resources Canada, Solar Water Heating Systems – A Buyer's Guide

http://canmetenergy-canmetenergie.nrcan-rncan.gc.ca/fichier.php/codectec/En/ISBN:0-662-28486-0/SOLAR-BuyersGuide-SolarWaterHeatingSystems_ENG.pdf

Natural Resources Canada, Photovoltaic Systems – A Buyer's Guide

http://canmetenergy-canmetenergie.nrcan-rncan.gc.ca/fichier.php/codectec/En/ISBN:%200-662-86306-2/Photovoltaic+Systems+-+Buyer%27s+Guide.pdf

Natural Resources Canada, Wind Energy Systems – A Buyer's Guide

http://canmetenergy-canmetenergie.nrcan-rncan.gc.ca/fichier.php/codectec/En/ISBN%200-662-37706-0/WindEnergy_buyersguide_ENG.pdf

Natural Resources Canada, Micro-hydro Power Systems – A Buyer's Guide

http://canmetenergy-canmetenergie.nrcan-rncan.gc.ca/fichier/79276/buyersguidehydroeng.pdf

Natural Resources Canada, transportation

http://oee.nrcan.gc.ca/transportation/personal/driving/autosmart-tips.cfm?attr=8

Appendix E Glossary

Amperage (Amp or "A" for short)

- Like water flowing through a pipe, electricity flows through a wire.

- An Amp is the amount of electricity flowing through a wire - this flow is called AMPERAGE or amps. Also known as current.

Voltage (Volt or "V" for short)

- Like water flowing through the hose pipe, if you lift one end, gravity pushes the water through.

- A Volt is the pressure with which the electricity is pushed through the wire.

Power or Wattage (Watt or "W" for short)

- A Watt is the actual power generated from the amount of electricity flowing through a wire (AMP) x the pressure with which it flows (VOLT).

- "A watt, is a watt, is a watt" as the saying goes.

- Watts = Amps X Volts.

Energy (Wh or kWh)

- Watt hours (Wh) and Kilowatt hours (kWh) are units of energy. Power = Energy / Time

- When people talk about how much energy an appliance consumes they use the unit kWh.

- This unit represents how much power something consumes in one hour of use - for example, if you used a 100-watt light bulb for 10 hours, you would have used 1000 Watt hours = 1 kWh.

- Amp/hour (Ah) is another way of measuring energy - kWh is a more universal measurement as Ah will vary according to the system voltage.

Alternating Current (AC)

- AC electricity is the most common type of electrical power used today.

- Most generators produce AC power.

- Most common household appliances operate on AC.

- AC electricity is typically at a higher voltage, which is easier to transmit longer distances.

- It is called Alternating Current as the current changes directions constantly.

Direct Current (DC)

- DC power can be stored in batteries - AC power cannot.

- DC power is converted to AC by the use of an inverter.

- Many appliances that have a wall cube plug-in unit are operating on DC power.

- DC offers significant benefits for efficiency - DC motors are more efficient than AC motors.

- Many renewable energy systems will have some DC loads.

- Water pumps and refrigeration are commonly DC.
- Solar panels produce DC power.
- Common voltages include 12, 24, 48 Volts.