Portable Remote Power system, Canada Olympic Park, Alberta. While not all systems are this portable, you can take your system with you when you move. (Photo courtesy of Nor'wester Energy Systems Ltd.)

Estimating Peak Power Requirements

To ensure you have the right size of wind energy system, you need to know more than just annual electrical energy consumption. Many appliances, such as refrigerators, do not run constantly, but cycle on and off. Similarly, lighting is not in constant use, nor is an electric iron, electric space heater or many other pieces of equipment.

To properly size your system, you must estimate peak power consumption. Even though it is unlikely all your equipment and appliances will be turned on at once, a peak power estimate should be an extreme example.

Consider, for example, that you might be watching television with the lights on while you do a few minutes of ironing and that your water pump and high efficiency refrigerator also turn on automatically. This could be your peak load. An example of this scenario is given in the table on the previous page.

Check *Appendix A, Typical Power Ratings of Appliances and Equipment,* at the end of this guide to note the most power hungry appliances which may be operating simultaneously. Add up the wattage to obtain the peak load.

Step 3: Size a Wind Turbine and Tower

You should now have an estimate of the wind energy available at your site, and an estimate of how much energy you need. Sizing the turbine is a matter of trying to match the two.

Helpful Hints

To obtain smooth airflow, the tower should position the turbine of a mini or a small system at 100 metres horizontally from the nearest obstacle at turbine height (such as larger trees or buildings), and 10 metres above any obstructions which are closer.

Look at the manufacturer's specifications for turbines to get an idea of approximately how much energy will be available given your site's average annual wind speed. A more precise estimate will depend on the variability of the wind speed over time.

This is also the time to think about towers. A higher tower will be more expensive, but could give your turbine access to greater wind energy. A shorter tower will require a larger turbine to generate the same amount of energy as a higher tower with a smaller, less expensive turbine.

The type of tower you need will depend on your site. Is there room for the tower guy wire anchors? Is a stand-alone tower a more viable option? Does the tower height allow the turbine to operate 10 metres above nearby obstructions?

Step 4: Select Balance of System (BOS) Equipment

BOS equipment depends entirely on the answer to the earlier question, "What is it you want to run?" Will it require power every day, on demand? Will it require AC power? Is the power absolutely required 24 hours per day, every day, all year? Let us look at each of these questions in turn:

Do you need power every day on demand?

If "yes," you will require batteries. You will need to know what size of battery best fits your system. You should have an experienced wind equipment dealer help you calculate the amount of battery storage you need because the estimate is based on several factors.

For example, what is the longest period you can expect to be without adequate wind? You will need enough battery capacity to run your appliances during this period. An example of this calculation is shown in the box on the next page.

Remember also that when the wind is blowing, your wind energy system must not only run your appliance and equipment, it must generate enough excess power to recharge your batteries.

You also should determine how much time you want to spend maintaining the batteries. If maintenance will be regular, flooded cell batteries are appropriate. If not, a maintenance-free battery would be a better choice.

If the answer to the question is "no," your BOS requirements will be minor because the turbine will provide the required power.

Will AC power be required?

Any home, business or factory hooked to the electrical grid needs AC power. However, DC appliances, equipment and lighting are readily available, designed for use in cottages, recreational vehicles, and boats. Cottages, for example, could have both AC and DC power, with DC running the lights and a small water pump. In these cases, the system

Calculating Battery Storage Capacity

Battery capacity is measured in amp hours. Here is how you calculate how many amp hours of battery capacity you will need.

From your earlier calculations on electrical requirements, you should have an estimate, likely in watt hours, of how much energy you require each day. Let us say it is 1,300 watt hours (1.3 kWh). Assume three days is the maximum amount of time without adequate wind. You will require (1,300 watt hours x 3) 3,900 watt hours.

A typical battery supply would provide 24 volts. The battery specifications tell you that this battery supply will allow for a 50 percent depth of discharge (DOD). That means only one-half the total capacity is available without draining the battery too far.

To find the number of amp hours needed, simply divide the watt hours by the voltage. In this case, 3,900 watt-hours divided by 24 volts gives us 162.5 amp hours.

But remember, your battery capacity has to be twice this because you do not want to draw more than 50% of the total capacity (i.e. the DOD is 50%).

Therefore, you need a battery supply rated at a minimum of 325 amp hours (162.5 x 2) capacity. In fact, it is best to round this number up, say to 400 amp hours.

Is power absolutely required

If the answer is "no," the combi-

8. Other **Issues** to consider

- **You may have your own reasons for choosing renewable wind energy, and these are just as important to consider as cost**

Chances are you had several good reasons to consider wind energy that had nothing to do with economics. There are also other considerations to think about that have nothing to do with technical issues. Most of these are difficult to quantify, but this does not mean that they do not have technical or economic implications, or that they are less important than those which can be costed out.

There are also other issues which cannot be quantified, but which might impact your wind energy system.

The chart below lists a number of issues to consider when deciding if wind energy is right for your situation.

Environment. Wind energy is non polluting, reduces the demand on the grid, and reduces the use of fossil fuels, the construction of hydroelectric dams or nuclear generators. Buyers of wind energy equipment need to decide whether and how to put a price on the environmental advantages of wind power use, and what role the environment should play in the decision-making process.

Safety. In cold regions, ice can accumulate on wind turbine blades. This can cause severe vibrations; the ice may be thrown great distances. Hydrogen venting from batteries is another potential safety issue. Climbing of towers by the owner or maintenance persons is a potential liability. Special safety precautions are required if children have access to the system.

Extreme weather. In some parts of the country, the environment is very hard on equipment and can cause operational and durability problems for the wind energy system and batteries.

Neighbours. The proximity of a wind turbine to a neighbour's property should be discussed with the neighbour before proceeding with a wind energy system purchase. Neighbours could be concerned about the size of the system and the noise a system's generator might make.

Aesthetics. The wind energy system can affect a view, or that of your neighbours', and it might block or change an historic landscape.

Noise. With a hybrid system, generator noise may be a problem. It would be a good idea to listen to the generator to see how much noise it makes when operating. The turbines themselves are relatively quiet.

Corrosion. Corrosion of system parts at locations close to the ocean can be a problem.

Zoning restrictions and other potential legal obstacles. Local municipal offices should have information about restrictions on elements such as noise and permissible tower height.

Local bird life. Birds can be injured or killed if they collide with the blades or the tower; and their breeding, nesting and feeding habits could be disturbed. To minimize these potential problems, avoid siting a wind energy system on a migration route or where many birds nest and feed. The system should be designed to reduce perching and nesting opportunities. This is typically not a problem with smaller systems.

Electromagnetic interference. Systems sometimes produce electromagnetic interference that can affect television or radio reception. The interference can usually be traced to the generator, alternator, or metal blades. This problem can be avoided if the parts are shielded, filtered or made of wood, plastic or fibreglass.

Technical know-how. Some small wind energy system can be maintained by the owner. This may require basic technical skills. It will save money, but will require time and the inclination to do what is necessary.

Access. The existence of an access road for remote systems will simplify construction, maintenance and fuel delivery, and will likely bring with it associated cost benefits.

Insurance, construction standards, private property deed restrictions should also be considered.

Wind Speed Measures

Description	Effect	m/s	km/hr	knots	Beaufort	
Calm	Smoke rises vertically	0 - 1	0 - 4	0 - 2	Force 0	Insufficient Wind for Generation
Light air	Smoke drifts with air, weather vanes inactive	1 - 2	4 - 6	2 - 4	Force 1	
Light breeze	Weather vanes active, wind felt on face, leaves rustle	2 - 4	6 - 13	4 - 7	Force 2	
Gentle breeze	Leaves & small twigs move, light flags extend	4 - 6	13 - 21	7 - 12	Force 3	Generation Occuring
Moderate breeze	Small branches sway, dust & loose paper blows about	6 - 8	21 - 30	12 - 17	Force 4	
Fresh breeze	Small trees sway, waves break on inland waters	8 - 11	30 - 40	17 - 22	Force 5	
Strong Breeze	Large branches sway, umbrellas difficult to use	11 - 14	40 - 51	22 - 28	Force 6	
Moderate gale	Whole trees sway, difficult to walk against wind	14 - 17	51 - 62	28 - 35	Force 7	
Fresh gale	Twigs broken off trees, walking against wind very difficult	17 - 21	62 - 75	35 - 42	Force 8	
Strong gale	Slight damage to buildings, shingles blown off roof	21 - 24	75 - 88	42 - 49	Force 9	
Storm	Trees uprooted, damage to buildings	24 - 30	88 - 109	49 - 60	Force 10	Too Much Wind for Generation
Violent Storm	Widespread damage, very rare occurrence	30 - 32	109 - 117	60 - 65	Force 11	
Hurricane	Violent destruction	32 -	117 -	65 -	Force 12	

SUMMARY CLIMATE INFORMATION FOR SELECTED NEW ZEALAND LOCATIONS

Data are mean annual values for the 1971-2000 period, for locations having at least 5 complete years of data

Extreme temperatures are for the full historical record

Station details for each location are available in separate table

Monthly temperature and rainfall data for each location are recorded in separate tables

Location	Rainfall	Wet-days	Sunshine	Temperature			Ground frost	Wind	Gale days
				Mean	Very Highest	Very Lowest		mean speed	mean speed at least
	mm	>= 1.0 mm	hours	°C	°C	°C	days	km/h	63km/h
KAITAIA	1334	134	2070	15.7	30.2	0.9	1	15	2
WHANGAREI	1490	132	1973	15.5	30.8	-0.1	11	16	1
AUCKLAND	1240	137	2060	15.1	30.5	-2.5	10	17	2
TAURANGA	1198	111	2260	14.5	33.7	-5.3	42	16	5
HAMILTON	1190	129	2009	13.7	34.7	-9.9	63	12	2
ROTORUA	1401	117	2117	12.8	31.5	-5.2	57	13	1
GISBORNE	1051	110	2180	14.3	38.1	-5.3	33	15	2
TAUPO	1102	116	1965	11.9	33.0	-6.3	69	13	2
NEW PLYMOUTH	1432	138	2182	13.7	30.3	-2.4	15	20	5
NAPIER	803	91	2188	14.5	35.8	-3.9	29	14	3
WANGANUI	882	115	2043	14.0	32.3	-2.3	7	18	5
PALMERSTON NOR	967	121	1733	13.3	33.0	-6.0	38	17	3
MASTERTON	979	130	1915	12.7	35.2	-6.9	60	11	1
WELLINGTON	1249	123	2065	12.8	31.1	-1.9	10	22	22
NELSON	970	94	2405	12.6	36.3	-6.6	88	12	2
BLENHEIM	655	76	2409	12.9	36.0	-8.8	60	13	4
WESTPORT	2274	169	1838	12.6	28.6	-3.5	26	11	2
KAIKOURA	844	86	2090	12.4	33.3	-0.6	27	15	28
HOKITIKA	2875	171	1860	11.7	30.0	-3.4	54	11	2
CHRISTCHURCH	648	85	2100	12.1	41.6	-7.1	70	15	3
MT COOK	4293	161	1532	8.8	32.4	-12.8	140	10	5
LAKE TEKAPO	600	78	2180	8.8	33.3	-15.6	149	7	1
TIMARU	573	81	1826	11.2	37.2	-6.8	84	12	6
MILFORD SOUND	6749	186	1800*	10.3	28.3	-5.0	56	9	9
QUEENSTOWN	913	100	1921	10.7	34.1	-8.4	107	12	2
ALEXANDRA	360	66	2025	10.8	37.2	-11.7	148	6	3
MANAPOURI	1164	129	1700*	9.3	32.0	-8.1	not measured	10	not measured
DUNEDIN	812	124	1585	11.0	35.7	-8.0	58	15	8
INVERCARGILL	1112	158	1614	9.9	32.2	-9.0	94	18	18
CHATHAM ISLAND	855	133	1415	11.4	28.5	-2.3	4	25	16
SCOTT BASE	not measure	89**	not measure	-19.6	6.0	-57.0	365	21	27

* Estimated from mapped NZ sunshine hours

** Days with snow

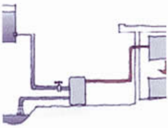
Micro-hydro Systems

Micro-hydro systems use flowing water to turn a water turbine that generates electricity in an alternator. They are viable as small-scale electricity generators that can provide electricity to a building or property separately from the mains electricity supply.

The main requirement is that the micro-hydro system location has sufficient water head and flow rate. They must have access to a regular water source (stream or spring) and are a more viable solution in rural or remote locations.

The efficiency of most micro-hydro generators ranges from 30 to 70%.

Micro-hydro system configuration



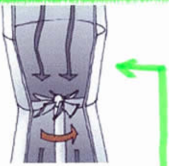
A micro-hydro system typically includes:

- a water source – a continuous flow of water (such as a creek, stream, waterfall, small dam or spring-fed dam), with a drop in level, that can be wholly or partially redirected through a micro-hydro system
- a turbine – which is turned by water acting on the blades of a runner or wheel
- a water intake or forebay – this is a catchment space to direct water into the turbine inlet pipe, while allowing sediment to settle and maintaining the water pressure head (examples include a dam, weir, bin, box, or channel race from a stream)
- a filter – a mesh to catch leaves, sticks, stones and debris and stop them entering the water intake pipe, where they may otherwise block the pipe, reduce water pressure, cause rapid pressure fluctuations or damage the turbine
- water inlet pipeline or penstock – the pipe transferring water from the water intake pipe to the turbine, which should at the inlet be fully submerged in water
- water outlet pipeline or tailrace or draft pipe – the pipe discharging water from the turbine and back to the stream or creek (a water outlet pipeline may not be included with an impulse turbine, as, in general, this type of turbine freely sprays out water)

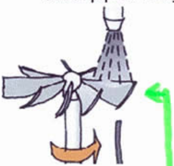
- alternator – alternating current electricity is generated by rotor windings connected to the shaft from the turbine turning inside the stator windings of the alternator body
- rectifier – is generally mounted on the micro-hydro unit (where required) to convert AC to DC for electricity that is being sent to a battery storage system. The generator initially produces AC, but is called a DC generator if the output electricity is immediately sent through the rectifier
- electricity cables – electrical cables transfer the electricity from the generator within the micro-hydro to the electricity supply or storage system
- a spill way or bypass so that excess water can flow past the system or allow the system to be shut down.

Turbine types

There are two main micro-hydro turbine types.



Reaction turbines have runners as their turbine blade unit. They are fully immersed in the water flow, and have a sealed case around the runner blade unit and a closed connection to the water inlet and water outlet pipes. They are typically installed in low water head applications.



Impulse turbines have wheels as their turbine blade unit. They run freely in air, with a water jet directed on to the wheel blades. They run in an open (i.e. not sealed) unit, and with an open-air connection to the water inlet pipe. An impulse turbine may or may not have a connection to a water outlet pipe. This type of turbine needs protection from water flooding. They are typically installed in higher water head applications, of up to 10 metres water pressure head, and are more common than reaction turbines for domestic applications.

Penstocks

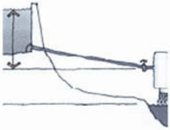
The penstock inlet should be located as low as possible in the water intake, to remain submerged when water levels are lower than average. However, it should not be so low that it is blocked by sediment building up in front of it. An air vent may be required near the intake to prevent damage that would occur if the intake is blocked and a vacuum formed.

Penstocks must always be sloped downwards, otherwise air locks can form and these can affect performance. A penstock should include a shut-off valve to stop water flow, and allow maintenance of the turbine. In addition, penstocks should strong enough to resist the design water pressures and be protected from:

- rapid starting or stopping of the water flow (which can cause damage)
- impact damage – for example, by burying them in the ground or covering them with a box structure
- exposure to the sun to prevent UV deterioration or polymeric pipes.

Micro-hydro system capacity

The electricity generation capacity of micro-hydro systems is directly proportional to the head of water and the water flow rate. The same power output can potentially be given by a generator with a low head and high water flow rate (for example, on flat terrain with a large water catchment) or a high head and low water flow rate (for example, on steeper terrain with less water catchment area).



The static head (or gross head) is the vertical distance (in metres) between the water level at the intake and the point at which the water is discharged.

Static head

The static head (or gross head) is the vertical distance (in metres) between the water level at the intake and the discharge point. Both these levels are where the water has contact with air. The water discharge level for an impulse turbine is where the water leaves the inlet pipe and enters the turbine. For a reaction turbine, the discharge level is where the water is discharged from the outlet pipe.

The static head increases as the water level at the intake increases. Minimum static head is where the water level aligns with the top of the inlet pipe – keeping in mind the inlet pipe entry needs to remain submerged.

The intake water level and static head will rise:

- when the main water flow rises, where there is no intake water storage system and only a part of the main water flow is temporarily diverted to the generator
- in an intake water storage system (for example dam holding all the water, bin holding a redirected part of the main water flow) when the water flow into storage is greater than the water flow through the generator.

The main water flow will typically vary during the year and between years and may be dependant on:

- seasonal rainfall
- snow and ice melt in the mountains
- cycles of flooding or drought
- blockages higher up the water source.

Micro-hydro generators work best where there is reasonably continuous water supply, giving a reasonably constant static head. It is important to determine what the average year-round water level is at the intake, as this will be used for the static head to determine the year-round power output.

The static head pressure has to be sufficient to overcome resistances in the turbine, so that it can spin and create electricity. In general the minimum static head for a domestic micro-hydro generator is about 10 m. Some can operate as low as 2 m, but this requires good design and installation of the pipework to reduce head losses.

Dynamic head

The dynamic head (in metres) is the static head (or gross head) less the losses in the pipework. The losses are summed and converted to a pressure head value in metres. The dynamic head is therefore the actual amount of water pressure head available to generate electricity.

Friction losses are lower in systems with shorter pipe lengths, larger pipe diameters, fewer pipe bends, higher-radius pipe bends, and a steeper gradient. Friction losses are also caused when the intake gets blocked.

Water flow rate

The water flow rate (in litres per second) is the amount of water moving through a pipe in a specific period of time. As the water flow rate increases, the turbine spins faster and more electricity is generated.

Any intake water storage system (e.g. dam, bin) with a reasonably constant water flow into it will maintain a consistent or equilibrium water level. When storage water levels are:

- higher, the generator flow rate increases until the level drops
- lower, the generator flow rate decreases until the level rises.

This equilibrium water level will be the design static head for the system. However it can be difficult to determine initially as it is related to the water flow rate through the generator and in the main water source. The water flow rate at a site is not simple to measure, and may require the temporary installation of a weir. The water flow rate through the generator can be determined by iterative design techniques for different water heads.

Turbine capacity

The micro-hydro generation capacity specific to the installed system depends on the effectiveness of converting the linear water pressure force into turbine rotary inertia and then electricity. This increases with:

- larger pipe diameter and turbine size – allowing a higher water flow rate
- appropriate turbine blade profile for the average water flow rate and pressure
- lower friction losses in the turbine shaft assembly.

Micro-hydro system installation

The micro-hydro system installation:

- will require a building consent and a resource consent
- should be installed as close as possible to the electricity supply or storage system, to reduce line power losses
- must withstand the water loads
- must have protection from impact, particularly for the less solid pipework
- generally requires little maintenance as it has few moving parts – the main issue is normally having to replace the alternator brushes and flushing the turbine
- may need regular cleaning of the filter, depending on the amount of debris in the water supply
- must incorporate a means of restricting the natural outward flow of water to build up reserve capacity
- must incorporate a bypass overflow in case of flooding of the reservoir.

For instance a 1 kW DC micro-hydro system may cost about $3,000 to install, while a 5 kW AC system may cost about $10,000. The cost of the dam construction, penstock and wiring depends on the location.

Electricity supply connection

Electrical power from the micro-hydro generator system can be available all times of the day at consistent output levels. The output AC can either be:

- transferred as AC to the building for immediate use, via a controller that gives a 240V AC at 50 Hz power supply
- converted by a rectifier to DC for storage in batteries.

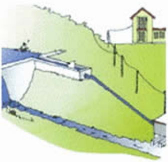
The choice between AC supply and DC storage is dependent on the reliability of electrical generation and the capacity of the generator to meet peak demand. It is best to:

- output all the AC directly to the building, where electrical generation is continuously guaranteed and generator capacity is greater than peak demand
- output some of the AC directly to the building, with the rest converted to DC storage, where peak demand is occasionally a little higher than generator capacity, or there is occasional reduced electrical generation
- convert all of the AC to DC storage, where electrical generation is inconsistent, or peak demand greatly exceeds generator capacity.

Micro-hydro system environmental impact

Micro-hydro generator systems have an impact on the water course. It may potentially affect:

- plant, and fish life in the water
- plant and animal life beside the water
- other users of the water further down stream
- the stability of the surrounding land thought the excavation for the reservoir.



Even small dams can have a significant impact both downstream and upstream as they are a break-point in the water system. It is therefore more usual, and more acceptable to the consenting authorities, to temporarily divert a portion of the main water flow into the micro-hydro generator. The water is returned downstream, and there is no block in movement up or down stream.

In general, the amount of water used for the micro-hydro system should be no more than 50% of the minimum seasonal flow rate of the water source.

Dams (even small ones) can have a significant impact both downstream and upstream as they are a break-point in the water system. It is therefore more usual (and more acceptable to the consenting authorities) to temporarily divert a portion of the main water flow into the micro-hydro generator. The water is returned downstream, and there is no block in movement up or down stream. In general, the amount of water used for the micro-hydro system should be no more than 50% of the minimum seasonal flow rate of the water source.

Second stage of general research

For the second stage of my general research, I have gone and found out some more in depth information on wind turbines, solar panels and hydro generators. I did this to try finding out which out of the three different methods of producing electricity from natural recourses would be most efficient and practical to be used to solve my client's issue.

Wind turbines

From my research I learned some basic information about wind theory and wind turbines:

~ The wind turns the blade of the wind turbine and the kinetic energy of the turning axle which is attached to the blade is transformed into electrical energy via a generator which can be used straight away or stored in a battery for use later.
~ The wind turbine consists of a tower, some form of generator, blades, electrical cable, batteries (if needed), regulator, transformer, yawing system and tail.
~ There are two main types of wind turbines, which are VAWT (vertical axis wind turbines) and HAWT (horizontal axis wind turbines).
~ The most efficient wind turbines that you can get are about 35%
~ The higher up the wind turbine is in the sky, the more efficient it will be as it will be closer to a constant flow of wind.
~ Wind turbines operate most efficiently in wide-open spaces or on hilltops because this is where the wind will be blowing most constantly.
~ A wind energy system needs an annual wind speed of at least 15 km/h to be practical.
~ The most frequent wind speed of an area is about 75% of its average annual wind speed.

Solar panels

From my research I learned some basic information about solar panels:

~ Solar panels turn sunlight into electricity using solar cells.

~ There are three main types of cells, which are monocrystalline or single cells, polycrystalline cells and amorphous cells. All three have varying costs and efficiencies.
~ The most efficient solar panels that you can get are about 16%
~ A single solar cell always produces a voltage of approximately 0.5 volts regardless of its size. To increase voltage, you have to connect cells in series. The bigger the cell the larger the amps and to increase amps, you have to connect cells in parallel.
~ You should keep the wiring between components as short as possible. (This is true for anything though)
~ About one square meter of solar panel can produce 130 watts.
~ Important variables to consider with solar panels are peak power of the panels, light intensity, number of hours of exposure to the sun and angle of exposure to the sun.
~ PV solar panels work better in cooler conditions.
~ And the most important thing that I found out about solar panels is that to get optimum performance out of them they should be facing the sunlight directly and the light rays should hit the panel at an angle of 90 degrees.

Hydro turbines

From my research I learned some basic information about hydro power systems:

~ Flowing or falling water is used to turn a turbine, which produces electricity.
~ The most efficient electricity producing method that there is.
~ The following things are what the whole system is made up of, filters, inlet and outlet pipelines, alternator, rectifier, electricity cables and the blade or propeller.
~ There are two types of hydro turbines, which are reaction turbines, these have an impeller inside an enclosed tube with a solid flow of water going through the impeller and no air. The other type is the impulse turbine, which has a propeller, exposed to the air and a single jet of water hits one side of the propeller.
~ The electricity generation capacity of micro hydro systems is directly proportional to the head of water and the water flow rate.
~ So a very precise location is needed in order to be able to produce a practical amount of electricity.

~ A good location to set up a hydro turbine would be one where there is a reasonable continuous water supply with a reasonably constant static head (explained in research page), a nice flat area where you could actually set the turbine up.

Decision of what electricity producing method to use and adding another specification

~ After reading through the research that I have produced, my client has come up with another specification for the device:

Specification number 3) I) the device, once set up, must collect energy throughout the day as automatically as possible.

~ With reference to my research and everything that I learned from it about wind turbines, hydro turbines and solar panels, I have decided to design a portable wind turbine to solve my clients issue. The reasons for this decision are stated below.

A hydro turbine system was not chosen because:

~ They have too many components making them very heavy and time consuming to set up. Not meeting specifications 3c and 3f.

~ Areas where you could set one up are not just every where that you go, they are very specific and the chance of finding a good area to set a hydro turbine in the bush are slim. This is because you first have to find a sufficient stream, which has all the right aspects, and then you have to find a nice flat area along the stream to set it up. This limits and restricts where you can go camping a lot.

~ Hydro turbines, to be efficient, need some sort of dam wall to create a reservoir of water. Building a dam wall is out of the question so you would have to find some sort of pool along the stream, which is narrowing your camping locations down, even further.

~ From my research, it seems that a hydro turbine is the most efficient electricity producing method out of the three that I have looked into by far but it is a system that you build into a stream permanently so to make a portable one would be extremely difficult and impractical.

~ Even though it is the best way to produce electricity out of the three methods that I researched, it is the worst for what my client wants and does not meet most of the design specifications which is why it will not be used.

<u>Solar panels where not chosen because</u>:

~ As they have a similar efficiency to wind turbines, the main reason that they were not chosen was because they really need to swivel or adjust to face the sun as the sun moves through the sky to get keep the light rays hitting the panel at 90 degrees all the time, to get maximum power output. This can be done manually but then it does not meet design specification number 3I, or it could be done using some sort of automatic system, which may be too difficult.

~ Solar panels only work during the day when the sun is up. As my device has to be able to charge a battery bank as quickly as possible, the device should be able to charge its own battery bank 24/7 and solar panels can't do this which means they do not meet design specification number 3h.

~ Solar panels are also very expensive and far out of my client's budget (design specification number 2)

<u>The device to charge the laptop will be a wind turbine because</u>:

~ They can produce electricity to the battery bank 24/7 (provided that the wind is blowing) because they can operate all night long.

~ Have potential to be made portable.

~ The places that my client goes camping have annual average wind speeds greater than the speed needed to make a wind turbine practical making a wind turbine an ideal power producing method.

~ I feel if it is designed correctly the wind turbine could be made to pack up very small which meets design specifications 3c and 3f.

~ Curtain blade designs can be very quiet which meets design specification number 3b

~ Industrial turbines today stay outside all the time which means there must be a very good method for making them wether proof, which meet design specification number 3d

~ If the wind turbine has a wind vain, it will always be facing into the wind and therefore operate automatically, which meets design specification number 3I.

~ On its own, a micro wind turbine would probably be quite fragile so I would have to make a tough case for the turbine to be put in whilst transportation and then it will also meet design specification number 3a

The device that I design to solve my clients issue will be a wind turbine because from my research, wind turbines seem to be the electricity producing method that meets the most design specifications and the few that the wind turbine does not quite meet can taken care of when I design my clients portable wind turbine.

My client has read through the research that I have produced and read through my reasoning for choosing wind power as the method to solve his problem.

2^{nd} design brief

Brief ~ design and make a portable power generation system to charge a small battery bank

Specifications

~ The device must be **lightweight**. My client wants the device to be 10 kg or less in total.

~ The device must be **easy to set up and pack away**. My client wants the device to be as easy to set up as possible i.e. take no longer than a tent takes to set up. So I will set a goal of: any person must be able to set the device up into full operating mode in eight minutes or less.

~ The device must be designed and made for **under $120**

~ The device must be **safe**. My client wants the device to be as safe as possible to minimise unnecessary accidental injury. The device must be safe enough for anyone to use and be around with out getting harmed by it in any way.

~ The device must be **compactable**. My client wants the device to fold down into a container with measurements of one metre long. 30 cm high and 30 wide and the whole thing being a rectangular shape. This way, the whole thing can fit in his ute

~ The device must use power-generating systems that can charge up the battery bank as quickly as possible. It is understood by me and my client that you will not be able to charge everything all at once and expect the generating source to keep up. Research, my client will have a max power draw of about 150 –200 watts and so a battery bank of roughly 24 AH should be adequate. This means to be able to charge this battery bank, with the average climate conditions, it should be able to produce about 20 – 40 Watts.

~ The device must be **weather proof**. Which means that it must be able to permanently stay outdoors and not get damaged from rain and sun.

~ The device must be **durable,** i.e. it must be made strong so it is not all fragile and cant take a bit of bumping around. This I because were my client drives his car to go camping, they may not always be roads so it will not be a nice smooth drive to the set up destination and the way that the generator and container are designed and built must account for this possibility.

~ The device must be **easily maintained**. This means that the moving parts must not ware down over a short period of time and if the parts waring down can't be helped, they must be buyable, cheap and very easy to replace.

~ The device must be designed to produce the smallest amount of **noise** possible, it is likely that it will be used close to ware the user will be sleeping and because the device will most likely be operating throughout the night, it must be quiet enough so the user can get to sleep.

~ The **materials** used must be the most suitable materials to make it **light weight, durable and weather proof**.

~ The device, once set up, must collect energy throughout the day as **automatically** as possible.

2nd Specification list

1) Safety

2) Built/designed for under $120

3) a) Durability

b) Noise level

c) Easy to set up and pack away

d) Weather proof

e) Maintenance

f) Lightweight

g) Efficiency

h) Charge the laptop as quickly as possible i.e. use the most efficient and reliable type of generating means as the budget will allow

I) Operate automatically

<u>3a to 3i are all equally as important</u>

HAWT or VAWT

~ There are to main types of existing wind turbines, which are the horizontal axis wind turbine (HAWT) and the vertical axis wind turbine (VAWT). Both types of wind turbines have there advantages and disadvantages and I am know going to analyse both to try find out which type will suit my clients needs most affectively.

RESEARCH

HAWT advantages

- Blades are to the side of the turbine's center of gravity, helping stability.
- Ability to wing warp, which gives the turbine blades the best angle of attack. Allowing the angle of attack to be remotely adjusted gives greater control, so the turbine collects the maximum amount of wind energy for the time of day and season.
- Ability to pitch the rotor blades in a storm, to minimize damage.
- Tall tower allows access to stronger wind in sites with wind shear. In some wind shear sites, every ten meters up, the wind speed can increase by 20% and the power output by 34%.
- Blades can rotate faster than the wind increasing power output.
- Blades can be designed to start up in very low winds and have a large amount of touqu.
-

HAWT disadvantages

- HAWTs have difficulty operating in near ground, turbulent winds.
- The tall towers and long blades up to 90 meters long are difficult to transport on the sea and on land. Transportation can now cost 20% of equipment costs.
- Tall HAWTs are difficult to install, needing very tall and expensive cranes and skilled operators.
- The FAA has raised concerns about tall HAWTs effects on radar near Air Force bases.
- Their height can create local opposition based on impacts to viewsheds.
- Downwind variants suffer from fatigue and structural failure caused by turbulence.

VAWT advantages

- Can be easier to maintain if the moving parts are located near the ground.
- As the rotor blades are vertical, a yaw device is not needed, reducing cost.

- VAWTs have a higher airfoil pitch angle, giving improved aerodynamics while decreasing drag at low and high pressures.
- Straight bladed VAWT designs with a square or rectangular crossection have a larger swept area for a given diameter than the circular swept area of HAWTs.
- Mesas, hilltops, ridgelines and passes can have faster winds near the ground because the wind is forced up a slope or funnelled into a pass and into the path of VAWTs situated close to the ground.
- Low height useful where laws do not permit structures to be placed high.
- Does not need a free standing tower so is much less expensive and stronger in high winds that are close to the ground.
- Usually have a lower Tip-Speed ratio so less likely to break in high winds.
- Does not need to turn to face the wind if the wind direction changes making them ideal in turbulent wind conditions.
- They can potentially be built to a far larger size than HAWT's , for instance floating VAWT's hundreds of meters in diameter where the entire vessel rotates , can eliminate the need for a large and expensive bearing.
- There may be a height limitation to how tall a vertical wind turbine can be built and how much sweep area it can have. However, this can be overcome by connecting a multiple number of turbines together in a triangular pattern with bracing across the top of the structure . Thus reducing the need for such strong vertical support, and allowing the turbine blades to be made much longer.

VAWT disadvantages

- Most VAWTs produce energy at only 50% of the efficiency of HAWTs in large part because of the additional drag that they have as their blades rotate into the wind. This can be overcome by using structures to funnel more and align the wind into the rotor (e.g. "stators" on early Windstar turbines) or the "vortex" effect of placing straight bladed VAWTs closely together (e.g. Patent # 6784566).
- Most VAWTS need to be installed on a relatively flat piece of land and some sites could be too steep for them but are still usable by HAWTs.
- Most VAWTs have low starting torque, and may require energy to start the turning.
- A VAWT that uses guy wires to hold it in place puts stress on the bottom bearing as all the weight of the rotor is on the bearing. Guy wires attached to the top bearing increase downward thrust in wind gusts. Solving this problem requires a superstructure to hold a top bearing in place to eliminate the downward thrusts of gust events in guy wired models.
- While VAWTs' parts are located on the ground, they are also located under the weight of the structure above it, which can make changing out parts near impossible without dismantling the structure if not designed properly.

A HAWT will be used to solve my clients issue.

~ VAWT are less efficient than HAWT, which does not meet specification number 3g.
~ A VAWT operates near the ground which does not meet design specification number 1 as danger of someone walking into the system whilst in operation becomes a huge issue. (As the system is fairly large, from my research, they are generally not put up on tall poles.
~ To get the efficiency of the VAWT up, it would have to be made very large which does not meet design specification number 3f.
~ The main reason HAWT are going to be used is because most VAWT can't start on there own which does not meet specification number 3i. The HAWT can be designed to start in low wind speeds with a large amount of starting torque.

RESEARCH

More research to support my decision

Bill, Horizontal "axis" wind turbines (vertical blades) are the traditional conventional design. They consist of a rotor with one to twenty blades driving a generator or a pump either directly or through a gearbox, chain or belt system. A tail vane or fantail is required to direct the machine. These turbines are usually more efficient than vertical-axis units. Savonius and Darius are two designs of vertical-axis machines, and these types of units do not have to be directed into the wind. The Savonius windmill was the brainchild of Sigrid Savonius of Finland, racecar driver of the 1930s. The design produces a low-speed high-torque unit that can be used for pumping water through a gearing mechanism, generating electricity -- and the design also has the advantage of an aerodynamic effect called the "Magnus principle," whereby suction is formed by the air moving over the convex face of the rotor. The Darius windmill was named after its French inventor. It is also known as "catenary" because of its profile when operating. Darius units, also known as "egg beaters," will often not start to turn by themselves and need either an electric start or use a small Savonius unit attached to the top. As the blades revolve they lose some energy as they head into the wind, reducing the output. Some newer versions are coming on the market that can "self start" but they are not as widely commercialized. Southwest Windpower (AZ) and Bergey Windpower (OK) have tens of thousands of horizontal-axis wind turbines globally, and you can be sure they would have adopted vertical-axis designs if they were more viable. -- Scott *Scott Sklar is President of The Stella Group in Washington, DC, a distributed energy marketing and policy firm. Scott, co-author of "A Consumer Guide to Solar Energy," uses solar technologies for heating and power at his home in Virginia.*

Overview of the wind turbine

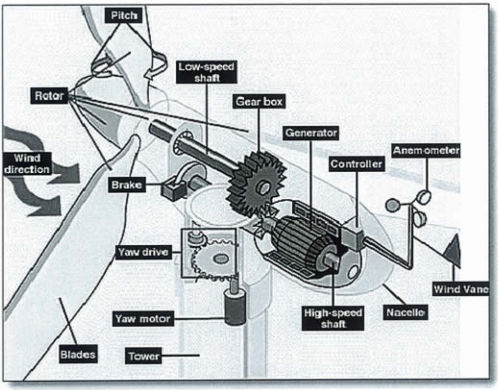
The Mechanics of Wind Turbines

Modern electric wind turbines come in a few different styles and many different sizes, depending on their use. The most common style, large or small, is the "horizontal axis design" (with the axis of the blades horizontal to the ground). On this turbine, two or three blades spin upwind of the tower that it sits on.

Small wind turbines are generally used for providing power off the grid, ranging from very small, 250-watt turbines designed for charging up batteries on a sailboat, to 50-kilowatt turbines that power dairy farms and remote villages. Like old farm windmills, these small wind turbines have tail fans that keep them oriented into the wind.

Large wind turbines, most often used by utilities to provide power to a grid, range from 250 kilowatts up to the enormous 3.5 to 5 MW machines that are being used offshore. Today, the average land-based wind turbines have a capacity of 1.5 MW.[7] Large turbines sit on towers that can be anywhere from 50 to 100 meters tall, and have blades that range from 30 to 50 meters long.[8] Utility-scale turbines are usually placed in groups or rows to take advantage of prime windy spots. Wind "farms" like these can consist of a few or hundreds of turbines, providing enough power for tens of thousands of homes.

From the outside, horizontal axis wind turbines consist of three big parts: the tower, the blades, and a box behind the blades, called the nacelle. Inside the nacelle is where most of the action takes place, where motion is turned into electricity. Large turbines don't have tail fans; instead they have hydraulic controls that orient the blades into the wind.

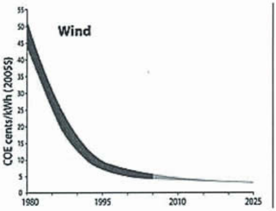


Source: NREL

In the most typical design, the blades are attached to an axle that runs into a gearbox. The gearbox, or transmission, steps up the speed of the rotation, from about 50 rpm up to 1,800 rpm. The faster spinning shaft spins inside the generator, producing AC electricity. Electricity must be produced at just the right frequency and voltage to be compatible with a utility grid. Since the wind speed varies, the speed of the generator could vary, producing fluctuations in the electricity. One solution to this problem is to have constant speed turbines, where the blades adjust, by turning slightly to the side, to slow down when wind speeds gust. Another solution is to use variable-speed turbines, where the blades and generator change speeds with the wind, and sophisticated power controls fix the fluctuations of the electrical output. A third approach is to use low-speed generators. Germany's Enercon turbines have a direct drive that skips the step-up gearbox.

An advantage that variable-speed turbines have over constant-speed turbines is that they can operate in a wider range of wind speeds. All turbines have upper and lower limits to the wind speed they can handle: if the wind is too slow, there's not enough power to turn the blades; if it's too fast, there's the danger of damage to the equipment. The "cut in" and "cut out" speeds of turbines can affect the amount of time the turbines operate and thus their power output.

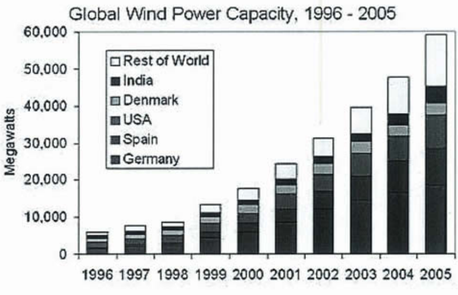
The Market for Wind



Source: NREL

The cost of electricity from the wind has dropped from about 25 cents/kWh in 1981 to as low as 4-6 cents/kWh in recent years. Though wind turbine prices have increased some since 2005 (see below for more information), in areas with the best resources, wind power is cost competitive with new generation from coal and natural gas plants. DOE projects that wind power costs will continue to fall over the next 10 to 15 years.

As wind power costs become more competitive, demand is growing exponentially all over the world. Global wind power capacity rose from just over 6,000 MW in 1996 to more than 59,000 MW by the end of 2005–almost a ten-fold increase.i[9] Growth has recently been most significant in Northern Europe, Spain, and India, but markets in Asia and the Pacific region are emerging as well.



Data Source: Wind Power Monthly

At the end of 2005, the U.S. wind power market reached more than 9,100 MW–providing enough power to serve the needs of 2.3 million homes.ii[10] The majority of this capacity is located in California, Texas, Iowa, and Minnesota, but there are wind power projects either in operation or under development in at least 36 states.

Once the long-time global leader in wind power development, the U.S. currently ranks third–well behind Germany. Inconsistent growth over the last ten years is mostly to blame, thanks in large part to the on again, off again status of the federal Production Tax Credit (PTC). The PTC provides a 1.9-cent/kWh tax credit during the first 10 years of a wind energy facility's operation.iii[11] Despite being one of the primary drivers of wind development, the federal government has allowed the PTC to expire on three separate occasions since 1999. These lapses in the PTC have lead to a boom-bust cycle that has drastically slowed the wind power industry for many months at a time.

For the first time, the PTC was extended prior to expiration as part of the Energy Policy Act of 2005, creating some short-term policy stability through 2007. Not surprisingly, the U.S. wind power market responded by installing 2,431 MW of wind power capacity in 2005, leading all countries and setting a new national record in the process.iv[12] Record growth is also projected for the U.S. market in both 2006 and 2007.

State-level renewable electricity standards–a requirement placed on electric utilities to gradually increase their use of renewable energy sources over time–are also working as a primary driver of U.S. wind development. Nearly half of all wind power capacity built from 2001-2005 was attributable to state standards, according to the DOE's Lawrence Berkeley National Laboratory.v[13] In addition to serving the near-term market, the 20 states (plus Washington, DC) with renewable electricity standards are also designed to stimulate significant new development for years to come. In addition to standards, other state level policies driving the U.S. wind power market include renewable electricity funds and various tax incentives.

Finally, voluntary green power markets and utility "green pricing" programs have resulted in a smaller, but quickly expanding market for wind development. The DOE reports that through 2004, more than 2,000 MW of wind capacity was serving voluntary markets, with an additional 365 MW in the development stages.vi[14]

The Future of Wind Power

With increasingly competitive prices, growing environmental concerns, and the call to reduce dependence on foreign energy sources, a strong future for wind power seems certain. The World Wind Energy Association projects global wind capacity will double in size to over 120,000 MW by 2010, with much of the growth happening in the United States, India, and China.vii[15] Turbines are getting larger and more sophisticated, with land-based turbines now commonly in the 1-2 MW range, and offshore turbines in the 3-5 MW range. The next frontiers for the wind industry are deep-water offshore, and land-based systems capable of operating at lower wind speeds. Both technological advances will provide large areas for new development.

As with any industry that experiences rapid growth, there will be occasional challenges along the way. For example, beginning in 2005, high demand, increased steel costs (the primary material used in turbine construction), increased profit margins, and certain warranty issues have lead to turbine shortages and higher prices.viii[16] There are also concerns about collisions with bird and bat species in a few locations. And the not-in-my-backyard (NIMBY) issue continues to slow development in some regions. But new manufacturing facilities, careful siting and management practices, and increased public understanding of the significant and diverse benefits of wind energy will help overcome these obstacles.

During a February 2006 speech at NREL, President Bush stated that wind energy could provide as much as 20 percent of America's electricity needs. In response, the American Wind Energy Association and the DOE have teamed up to launch an initiative to develop an action plan for achieving this goal. Getting to that level will require a determined national effort, but it will result in less dependence on fossil fuels, significant reductions in global warming emissions, and improved air and water quality for future generations. Wind energy is ready to meet the challenge.

The wind turbine that I am going to design, overview

~ Form my research into wind turbines and wind and just plain common sense, it is clear that the wind will not be blowing all day every day. For this reason, it will be very useful and practical to have a battery bank that the wind turbine can constantly charge (whilst the wind is blowing) for the two-day period. Then when needed, so long as the wind has blown a certain amount, the laptop or other small devices can be charged by it.

~ I thought that a car battery and alternator would be a good guideline for the wind turbine that I design as it has similar principles. E.g. the car has a battery bank and the alternator is constantly changing speeds and stoping and starting which is what the wind turbine is likely to be doing. And for the fact that you can charge lot of devices from the 12-volt car battery using the car charging lead for that device.

~ I then realised that most small appliances have car charging leads (including laptops) so if I use a 12 volt battery as the wind turbines battery bank (with the correct capacity to charge a laptop and some other small devices) and design the wind turbine to be able to fully charge the 12 volt battery bank as fast as possible i.e. using as lower wind speed as possible, then all I need is a cigarette lighter socket and my client will be able to charge his laptop and any other small device that has a car charge lead (eg lights, phones, gps ect but not all at the same time as this would require a huge capacity battery and longer than two days to charge it.) so the ideal battery to be used will have enough total capacity to charge the laptop fully and maybe one other device(this is just to keep the weight down for my clients prupose but it does not mean that a larger capacity 12v battery can't later be added if desired)

<u>Components that will be in the wind turbine</u>

<u>The following are the components that will be in the wind turbine and will need to be specifically researched</u>.

~ Battery

~ Generator

~ Blades

~ Collapsible tower

~ Stays/pegs

~ Tail unit

~ Horizontal swivel system.

~ Circuitry (includes, charge and input voltage controller)

~ Wind turbine container

~ Cigarette lighter socket

~ Overs speed breaking system

The Generator

Generator general research plan

~ I want to research and look around to try find out what types of motors/generators are actually used to produce power.

Generator general research

RESEARCH

What sort of generator should I use?

Most small wind turbines are used for charging batteries, to provide a reliable stand-alone power source where grid power is not available. The obvious choice of generator for self-build is the car alternator. However this has major drawbacks. It must be driven at a high shaft speed (over 2000 rpm) to give full output, so you will need to gear it up or modify it in some way to drive it with rotor blades, which typically only manage a few hundred rpm. This reduces the efficiency. In low wind speeds there is very little power available in the wind, and you need a highly efficient generator to capture it. Most, if not all of the power in light winds will be used up energising the magnetic field in the alternator, so the results are disappointing. Nearly all small commercial wind turbines use purpose-built permanent magnet generators for this reason. The DIY enthusiast can make one too, but this is not simple to do. Or you can reuse a permanent magnet motor as a generator. The generator is the key to success or failure of the project, and by far the hardest part to get right.

"PM converted induction motors, DC generators, DC brushless PM motors, vehicle alternators, and induction motors are options" quote from http://www.otherpower.com/otherpower_wind_tips.html

What I learned?

From this first section of my motor/generator research I found out that the car alternator is the cheapest and easiest type of generator that a lot of people turn to but there are major issues with them as far as efficiency and fit for purpose ness goes. This is because they have an elector magnet which needs to be charged before any generating of electricity starts and also because they are generators designed for automobiles which typically run at very high rpm's (higher rpm's than a wind turbines blades turn). I also found out that permanent magnet motors seem to be the best thing to use for small-scale power generation.

The Generator comparison

The Generator comparison plan

~ I want to research into some specific types of generators and try find one that will best suit my clients needs

RESEARCH

Alternator and Generator Comparison for Wind Power

| Vehicle Alternators | Homemade PM Alternators | PM Converted Induction Motors |
DC Generators | DC Brushless PM Motors | Induction Motors |
Para Español, traducci□n de Julio Andrade.

Vehicle Alternators

- **Advantages:** cheap, easy to find, pre-assembled.
- **Disadvantages:** high rpms required, gears or pulleys needed, low power output, slip rings need maintenance.
- **Suitability for Wind Power:** POOR

The biggest problem with using car alternators for wind power is that they are designed to rotate at too high a speed to be practical in wind power applications without significant modifications. Even a small, seemingly fast windmill might do most of its work at 600 rpm, not nearly fast enough for a car or truck alternator. This means that gearing up with pulleys or other methods is needed, so lots of power is lost to friction--a big problem with wind or water power, but not a problem with a gasoline engine. Check out how useful car alternators can be for building a small gas-powered charger HERE.

A standard car or truck alternator is electromagnetic-- meaning that some of the electricity produced by the unit must be used internally and sent to the armature through brushes and slip rings to make the magnetic field. Alternators that use electricity to generate the field current are less efficient and more complicated. They are quite easy to regulate, however, since the magnetic flux inside can be changed by adjusting the field power. Also, the brushes and slip rings wear out, requiring more maintenance. Car and truck alternators can also be rewound to produce power at lower speeds. This is done by replacing the existing stator windings with more turns of smaller gauge wire. This project is not for the faint of heart, but check our

PRODUCTS page for the inexpensive booklet *Alternator Secrets* by Thomas Lindsay if you are interested. The booklet is invaluable for any alternator experimentor! Also, some alternator/electric motor shops may have the knowledge to do this for you.

Homemade Permanent Magnet Alternators

- **Advantages:** Low cost per watt of output, very efficient, huge power output possible, extremely sturdy construction
- **Disadvantages:** A time-consuming, somewhat complicated project, machining needed.
- **Suitability for Wind Power:** GOOD

Homemade Volvo Brake Disc PM alternator, 800 watts, $150!

Hugh Piggott in Scotland was the pioneer in building permanent magnet alternators from scratch. Much of our inspiration came from his designs. Thanks Hugh!

Our experiments have consistantly shown that homemade PM alternators are the most powerful and cost-effective solution for building a wind generator. Their low-rpm performance is excellent, and at high speeds they can really crank out the amps thanks to their efficiency. Our more recent PM alternators have been based on Volvo disc brake assemblies, which are very sturdy and have thrust bearings built into the unit. Our larger units are "Disc" or "Axial" designs...a flat plate of magnets rotating next to a flat plate of coils. Our smaller PM alternators are "Radial" designs, where the magnets are fastened to the outside radius of the armature. Since all alternators produce AC, the output must be converted to DC with bridge rectifiers for battery charging. Our designs to date have been single phase for ease of construction. Three-phase alternators have some advantages (they are somewhat more efficient, and make better use of available space), but they are somewhat more difficult to build.

With a 7 ft diameter prop, our Volvo brake designs can put more than 60 amps into a 12 volt battery in a 30-mph breeze--that's about 700 watts. We've seen the Volvo design peak at over 100 amps during high winds! This gives these homebrew designs a big advantage over similar-sized converted induction motors, which become inefficent quickly and top out at 20-25 amps output with a 7 ft. diameter prop.

Check out all of our PM alternator projects on our EXPERIMENTS page!

Induction Motor Conversion Alternators

- **Advantages:** cheap, easy to find, fairly easy to convert, good low-rpm performance.
- **Disadvantages:** power output limited by internal resistance, inefficient at higher speeds, machining needed.
- **Suitability for Wind Power:** OK

Armature converted with permanent magnets

A normal AC induction motor can be converted into a permanent magnet alternator at very low cost. Our experiments have shown that these conversions produce significant power at very low speeds, but become inefficient quickly at higher power levels.

An induction motor has a center core with no wires in it, just alternating plates of aluminum and steel (it will look smooth from the outside). If you rout a groove in this center core to accept permanent magnets, the unit becomes a permanent magnet alternator! We sell super-powerful neodymium magnets that are shaped and polarized perfectly for this application--check our products page.

In practice, our wind generators made with these do quite well until they reach 10-20 amps of output. At this point, they become inefficient quickly--it takes a large increase in windspeed to make only slightly more power, and the rest is wasted as heat inside the unit. The induction motors are wound with wire that's simply too thin for generating large amounts of power. In our tests, DanB's PM induction motor conversion windmill peaks at around 25 amps in 30 mph winds, with a 7-foot diameter prop. By comparison, a 7-foot prop on an efficient PM alternator made from scratch gives peaks of 50-60 amps in similar winds! Converted motors also have the tendancy to "cog" when starting...you can feel the resistance when you turn the shaft. This affects low-speed startup somewhat.

If the lesser output in high winds is acceptable to you, these units can make for a pretty easy wind generator project. Look for AC induction motors of the lowest rpm rating possible. 3-phase motors will perform better than single phase. Since alternators produce alternating current (AC), the power must be converted to DC with bridge rectifiers.

Tips and photos--converting an AC induction motor into a permanent magnet alternator.

DC Generators

- **Advantages:** Simple and pre-assembled, some are good at low rpm.
- **Disadvantages:** High maintenance, most are not good at low rpm, large sizes very hard to find, small ones have limited power output.
- **Suitability for Wind Power:** POOR to OK

Generators make DC current, and batteries need DC for charging. Generators were used in automobiles until around 1970, when alternators became more practical (due to the availability of cheap, small diodes). Even old car generators must spin too fast to be practical for wind power, but there have been many good plans for modifying them. Check out our PRODUCTS page for the *LeJay Manual* , which contains many useful, though involved, plans for doing this. Generators are fairly complex compared to alternators. They must have brushes, and complex commutators. Brushes require maintenance, and commutators can wear out. For most purposes, alternators are more practical today, although generators do have certain advantages at times. Certain low rpm DC motors can be purchased as surplus and work very well as 12 volt low rpm generators. These are from old mainframe computer tape drives, and are sometimes available in local and mail-order electronics stores, and on Ebay. Check out Our tape drive motor page HERE. They don't make a whole lot of power...you can expect only 100-200 watts of output...but these motors are almost a science project in a box! Slap on a frame and a 3-4 ft prop, and you have a small working wind generator.

Surplus tape drive motors can make a quick and easy generator for small windmills

Brushless AC PM Servo Motors

A brushless DC permanent magnet motor is really just a permanent magnet alternator! A special driver circuit provides AC power that is in phase with the rotation. If you are able to find a large one of these surplus, it's possible you might have an excellent start for a wind power project. They are used in robotics and precision control applications, and some use Nd-Fe-B magnets for high torque in a small space. As with surplus tape drive motors, we would not trust the bearings to stand up in a wind power application...add more bearings so you don't ruin the motor's original front bearing. We have not yet been able to locate any of these surplus for experimentation. If you have tried this, or have more information on sources, please Email us! However, we do have a small version...our Homemade anemometer uses a small surplus brushless DC PM motor, which is available for cheap on our Products pages.

The inside layout of our tiny Brushless PM DC Motor looks just like the Wood 103's alternator!

Induction Motors as Alternators

It's possible to make a 3-phase induction motor produce electricity, either 3-phase or single phase. This requires a controller and capacitor. The generator must run at a fairly constant speed. For this reason, this type of generator is more suitable for constant-speed hydro power installations than for wind, where speed varies--though it can be done. We have not experimented with this technique yet, since we don't have a suitable hydropower source. For more information, check out the book *Motors as Generators for Micro-Hydro Power* by Nigel Smith.

What I learned?

~ From this research looking into some comparisons of different generator options, I found out many pros and cons about some types of generators. The first generator was the again the car alternator, although it is easy to regulate due to its electromagnetic properties, which you can manipulate, it requires too many rpm's to be suitable for my clients small scale wind turbine which is only likely to be operated in a medium to low wind speed areas **"Most wind gen pros will tell you that automotive alternators are not suitable for wind power" (quote from mhttp://eduhosting.org/windpics/altcomp.html).** I want to be using a low speed, high power output and efficient generator which is definitely not what a car alternator is. The second generator talked about in the above research is the homemade permanent magnet alternator. This is probably the best option according to my research as it gives the best and most efficient power out put at the lowest rpm's. But for my situation and what my client wants I do not feel it is suitable due to the fact that they are immensely heavy and take a lot of time to make. The third type of generator in the above research is the induction motor, these motors need to be converted into permanent magnet generators before they become of any use and even when they are converted, they do not preform that well especially when the rpm starts to get up. I feel this also does not suit what my client wants as for starters it would be expensive to buy neo magnets and also because an efficient as possible motor/generator is what should be used to make the power per kg of weight more so that the whole turbine is more convenient to take with. The next possible generator is the DC generator and from my research, I found that they definitely have potential for producing good voltage at low rpm's. They do have the added complexities of brushes and slip rings but they would be definitely worth looking further into. The final item in my research that can be used to produce electricity is the AC permanent magnet alternator, although permanent magnet alternators and generators do have the issue of the "cogging" affect, PM alternators seem to still have a large amount of potential due to the fact that there are so many different sizes and types that are readily available for small to no cost and they are also good efficient low speed electricity producers.

Generator/alternator trials and testing

Generator/alternator trials and testing plan

~ Throughout the generator research process, I have come across 7 main types of motors/generators that could possibly be used for my clients wind turbine.

1) Scooter alternator (flywheel and stator)
2) Car alternator.
3) Stepper motor.
4) Small plain DC motor.
5) Gentle Annie washing machine motor.
6) Smart drive Washing machine motor.

~ From previous research some of the above do not suit my clients purpose as well as others but there is no way to tell for shore which will best suet the purpose other that to actually get each type of electricity generator and run some tests on them.

~ The following pages shows research and trials on each type of motor/generator and wether or not they will be practical for my clients, wants and specifications.

Scooter alternator

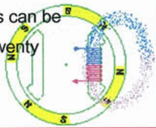
Research

RESEARCH

Typical set-up.

Inside the basic flywheel rotor are usually two main coils. One coil is fairly large and supplies about fifteen to thirty volts AC to the rectifier for the battery and lights. The other coil is a smaller, more finely wound coil to supply a

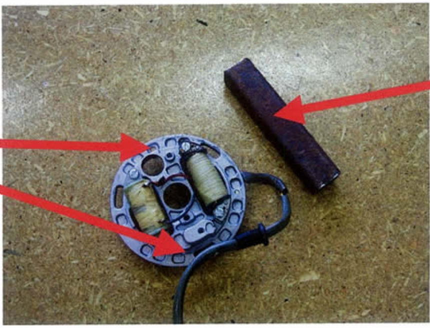
hundred or so volts to the CDI unit.
Outside, or sometimes inside is a small, finger tip sized pulser coil, which triggers the CDI at the correct time for the spark.
This picture shows a C90 rotor with the pulser interrupter as a piece of metal sticking out on the outer edge, which causes the timing pulse at the right place, and the pulser is the black lump between the rotor and stator. Lying flat is the stator plate with the pale lighting and dark CDI generator coils.
There are four or more magnets inside the rotor (it rotates), such that as they pass the stator (static) coils, they induce a changing north - south - north - south alternating magnetic field in the iron plates of the coils, thereby generating electricity in the copper coils of wire.
As can be seen, the four poles at the ends of the coils means that the magnets in the rotors are four, so the N-S-N-S field flows strongly through the iron cores. This is acceptable for a low power machine, but sometimes a little more electrical power is needed in such a small space, so six poles can be used, with six rotating magnets. My old Ducati V twin used about twenty permenanat magnets.



Testing

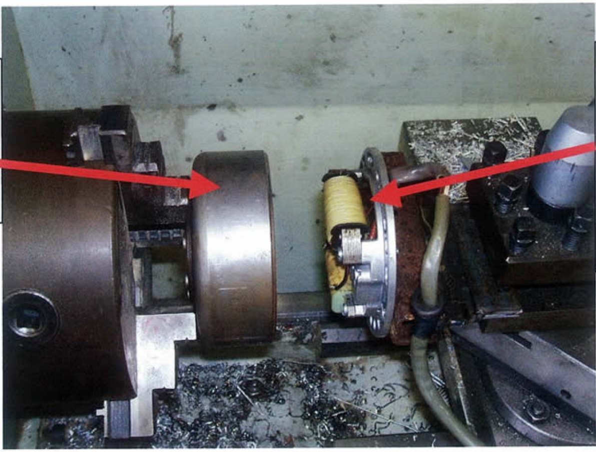
~ I completed the tests on the scooter alternator on the metal lathe. As the scooter alternator consisted of two separate parts, the stator and the flywheel, I had to mount the flywheel in the chuck and bolt the stator to a piece of steel and mount it in the tool clamp. I then had to move the tool clamp around until the stator was perfectly inside and centred with the flywheel.

Holes drilled in stator for bolts

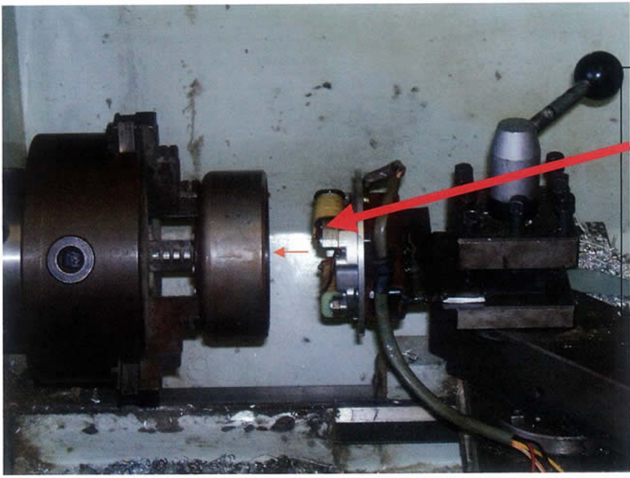


Steel bar that the stator gets bolted to.

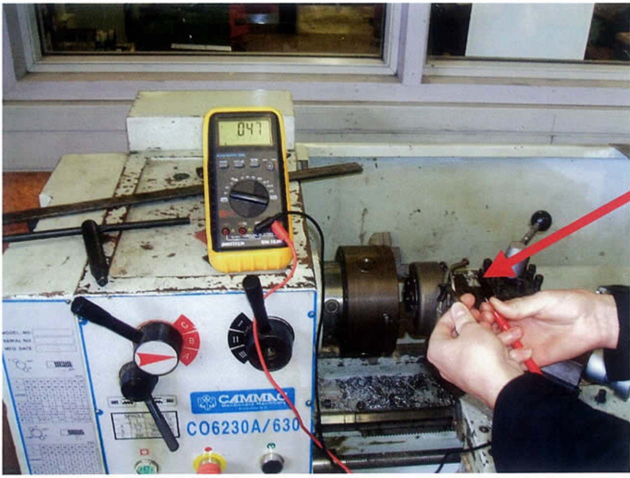
Flywheel mounted in lathe and spun at various speeds.



Stator mounted in tool clamp on metal lathe. And output wire connected t a voltmeter.



The stator i perfectly aligned to the flywhee and is ready to be move inside the flywheel.



Taking a voltage reading

Test Results

RPM	VOLTAGE (EMF)
200	9.5 V
220	10 V
270	12 V
360	16.4 V
600	27.3 V
800	35.2 V
1000	44.5 V
1400	58 V

What I learned?

~ From my research and tests, I have found that scooter alternators are small, quite heavy and require a huge amount of rpm's to produce the voltage that my client requires (wind turbines would typically spin at about 200 rmp) which is about 50 V at 100 rpm if it is going to charge a battery in any useful amount of time. So at this stage, scooter alternators are probably not going to suet my clients needs because of the weight and due to the fact that it requires nearly 1000 rpm to produce a useful battery charging voltage and small wind turbines will spin at a max of about 250 – 300 rpm.

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Options

The student explains how the complexities of the situation have been identified and explored.

Car Alternator

Research

Automotive alternators

RESEARCH

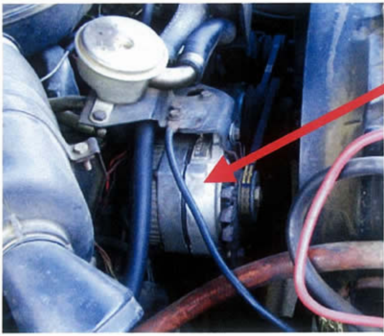
Alternators are used in automobiles to charge the battery and to power a car's electric system when its engine is running. Alternators have the great advantage over direct-current generators of not using a commutator, which makes them simpler, lighter, less costly, and more rugged than a DC generator. The stronger construction of automotive alternators allows them to use a smaller pulley so as to turn twice as fast as the engine, improving output when the engine is idling. The availability of low-cost solid-state diodes from about 1960 onward allowed car manufacturers to substitute alternators for DC generators. Automotive alternators use a set of rectifiers (diode bridge) to convert AC to DC. To provide direct current with low ripple, automotive alternators have a three-phase winding.

Typical passenger vehicle and light truck alternators use Lundell or claw-pole field construction, where the field north and south poles are all energized by a single winding, with the poles looking rather like fingers of two hands interlocked with each other. Larger vehicles may have salient-pole alternators similar to larger machines. The automotive alternator is usually belt driven at 2-3 times the engine crankshaft speed.

Modern automotive alternators have a voltage regulator built into them. The voltage regulator operates by modulating the small field current in order to produce a constant voltage at the stator output. The field current is much smaller than the output current of the alternator; for example, a 70-amp alternator may need only 2 amps of field current. The field current is supplied to the rotor windings by slip rings and brushes. The low current and relatively smooth slip rings ensure greater reliability and longer life than that obtained by a DC generator with it's commutator and higher current being passed through its' brushes.

RESEARCH

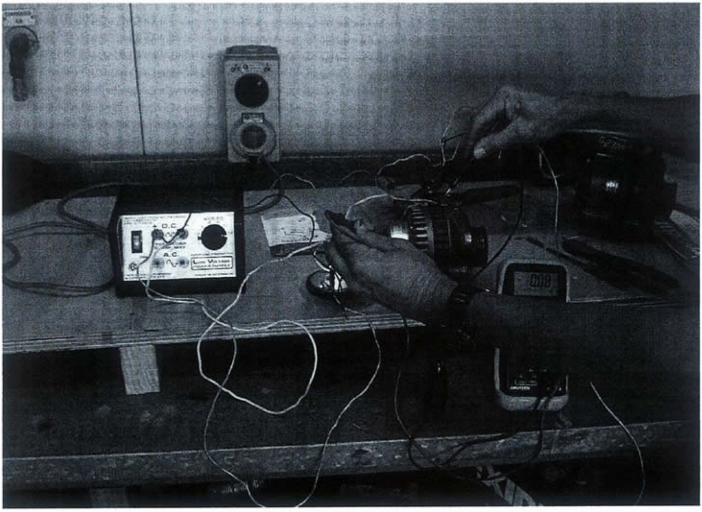
Efficiency of automotive alternators is limited by fan cooling loss, bearing loss, iron loss, copper loss, and the voltage drop in the diode bridges; at part load, efficiency is between 50-62% depending on the size of alternator, and varies with alternator speed.[7] In comparison, very small high-performance permanent magnet alternators, such as those used for bicycle lighting systems, achieve an efficiency of around only 60%. Larger permanent magnet alternators can achieve much higher efficiency.

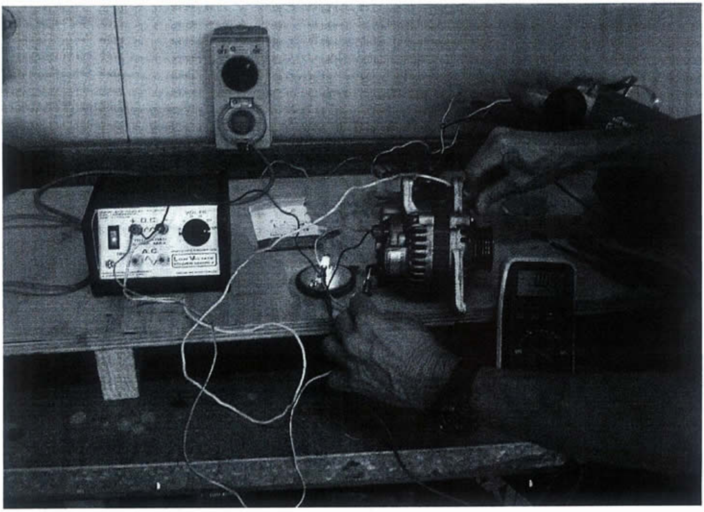


Testing

~ I tested the car alternator, and from my research I found out that car alternators need some power in order to make more power. They need a small amount of power from a battery to charge the electromagnets before they can begin charging the battery. Unsure on how to set this test up, I went and discussed it with the automotive teacher at school and he drew a sketch (below) showing me how to wire everything up.

These pictures show my mentor and I testing the car alternator output voltage





Test results

~ When I had set up the experiment correctly, I tested the car alternator by coiling a piece of wire around the pulley attached to the end of the shaft and pulled it first slowly and did it again and again speeding the pulling up each time. And the voltages (E.M.F) produced at even the fastest of speeds, which was far beyond a wind turbines average rpm, was only about 50 – 60 V.

What I learned?

~ From my research I have found that car alternators have far too smaller weight to power output value. They are also very inefficient. These alternators are designed to run at extremely high speeds, in excess of 1000 rpm before they become useful for charging batteries. A lot of energy is lost just to charging the electromagnets, which also makes them not ideal; permanent magnet alternators are probably going to be the best generator from what I have learned so far. So for these reasons, the car alternator will not be used as the generator for my clients wind turbine.

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Options

Critical reflection on information understandings and the practice of others, across a range of contexts that were used to inform the development of the technological outcome.

Stepper motor

Research

Generating Electricity with Stepper Motors

RESEARCH

All sorts of scrapped and second-hand devices can be used to generate your own electricity. Small permanent magnet motors such as radiator fan motors or cassette recorder motors are easy to use as they produce DC power directly without any external circuits like rectifiers or control boxes.

There is another type of electric motor worth considering - the small stepper motors used in old computer printers. They are quite small and aren't suitable for producing more than a few Watts, but there are good reasons for looking at them. For a start, the lunatic speed at which computer equipment goes obsolete means there are enormous numbers of them available free. Unlike small DC motors, steppers will generate power at very low rotation rates; typically only about 200 rpm for a good output which is ten or fifteen times slower than the rate for a DC motor. Small-scale generators to run things like computer games or flashlights can be made without mechanical complications like gearing. Because of their small size they're obviously not suitable for charging large batteries.

Better applications would be pocket sized generators to convert things like Walkmans and MP3 players to wind-up power, saving the waste and pollution of chemical batteries. Another possibility is small wind generators, as the low rpm needed means a propeller could be mounted directly on the motor shaft. (Actual gears in a wind generator are generally a disaster - the whining noise is amplified by the blades and spreads over a wide area because of the height). The present generation of printer motors are admittedly not large, and in fact are getting smaller as the old daisywheel and dot matrix printers are replaced by inkjets and smaller lasers. It is definitely worth experimenting with them though, as it is likely that the next generation of domestic appliances will be heavily computerised, and so full of nice big steppers. Anyone who has acquired experience on the small ones will be able to make these into some really nice generators.

Selecting Suitable Motors

Old Dot Matrix computer printers (the larger and older the better) contain at least two steppers. Usually one drives the roller and another moves the print head back and forth. Daisywheel printers will also have one to turn the daisywheel which can be a bit inaccessible but worth the effort. Tiny steppers were also sometimes used to wind the ribbon and in colour printers another minute one moved a striped ribbon up and down. Disc drives tend to be a bit disappointing - often the motors are built into the drive hub and contain some electronics so you can't get easy access to the coil connections. Really old 5.25" floppy drives contain a nice motor used to move the reading head back and forth - it's a lot more useful than the one for turning the disc which was sometimes a DC motor on older ones and tangled into the circuit board on later models. Very old hard drives (on 286 or 386 computers and less than 100M) use a small stepper to move the head array. Modern hard drives use an analogue galvanometer instead; it contains a pair of amazingly strong magnets - mind your fingers if you extract them! Physically large motors like the single ones which drive laser printers are obviously more powerful than small ones; anything less than an inch in diameter is probably only suitable for running a few LED's. They're OK for educational purposes or making illuminated things for playing with at chill-outs. (See the page on making Hub Disc Twirly Things)

Steppers come with different resolutions. Virtually all steppers are either 1.8° or 7.5° per step; (200 steps or 48 steps per revolution) the difference can be felt easily if you turn the spindle by hand. The 1.8° ones are obviously better for generating at really low revs, but also 'top out' lower. The coils in steppers have a relatively large inductance, and beyond a certain speed the output frequency gets so high that the impedance of the coils starts to become significant and limits the current. When making a stepper based generator, you need to keep the motor speed to around a couple of hundred revs per minute - something like the normal speed of a bicycle wheel.
Apart from printers, plenty of other things contain steppers. Scanners, shredders, faxes and photocopiers are also worth checking out. Be careful with things like copiers and laser printers not to get toner all over your workshop, especially if it doubles as your living room! Don't vacuum clean toner as the particles are so small they'll go through the bag into the air. Wash it off with water or clean it up with a damp cloth. Really large steppers are found in automated industrial equipment and the large tape drives used with old mainframe computers which you might still find at auctions. The next generation of highly automated washing machines and dishwashers, household robots etc. will contain some nice big steppers, and it won't be too long before they are superseded and start to turn up at the rubbish tips and car boot sales. There's already a nice example of this in New Zealand where Fisher and Paykel have been selling stepper-driven washing machines for some years, and scrapped