Design Notes – Energy Project Facilities
Te Kura Toitu o Te Whaiti Nui-a-Toi

This document records some of the web research and other design research undertaken to establish equipment to support student learning about Energy at the Kura

Refer to webpage
http://www.kaitiakitanga.net/projects/1-3-1%20ponga%20whare-energy.htm
for details on this experiential learning and a lot of links to other resources

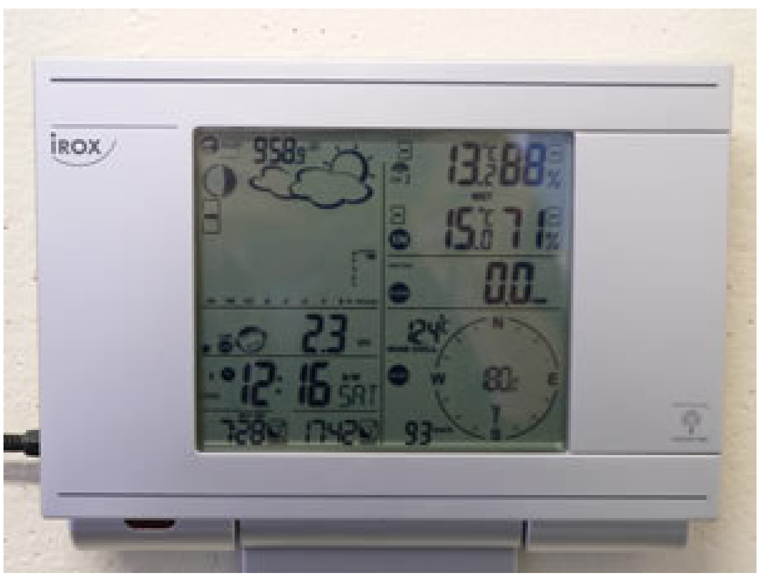
Contents:

1.0 Introduction:

This document contains design notes made for the installation of a weatherstation powered by solar and wind power to support learning projects around the Environment, Weather, Energy, Electricity and much more at Te Kura Toitu o Te Whaiti Nui-a-Toi, Whirinaki Rainforest, Te Urewera. A report on this is shared on the web at http://www.kaitiakitanga.net/projects/1-3-1%20ponga%20whare-energy.htm .

This installation was independently funded as part the community's Kaitiakitanga program (www.kaitiakitanga.net) by koha from a number of organizations who have benefited form the application of the Tipu Ake Organic Leadershp Model inspired by this school and shared on the web at (www.tipuake.org.nz)

2.0 Installing a Weather Station to support Learning at the Kura



The weather station chosen for this project is an iROX PRO-X It was purchased from Outside Inside NZ Ltd, PO Box 1109 Whangarei 0140, Ph 09 435 3133, email sunshine@weatherstation.co.nz

The total cost of this equipment including extra sensors was $672.20 including GST.

The full specification is available on their website at http://www.weatherstation.co.nz/02c42d97db0d12d0f/02c42d97db0e46814/02c42d97dc0ab3020.php

As well a being totally self contained with its own display and memory to store 3,000 dataset readings, it has a USB interface and "WeatherCapture" software which allows these readings to be automatically uploaded to a PC where they are displayable and stored in a file format where they can be directly read by Excel and processed very flexibly by any student or class on the school internet. The PC is able to transfer data to the Whirinaki website to make the current weather information and a webcam view of conditions in the valley available to everyone in the world.

Up to five extra wireless temperature/humidity sensors can be connected to the basic unit to include other readings in the dataset for monitoring other experiments around the school. We purchesd one each of sensor HTS33 for experiments and one HTC13 to measure ground temperature.

The data set is recorded hourly by the station and collected to a text file under the RECORDS folder in the weatherstation program folder

Year
Weekday
Month
Date
Hour
Minute
Internal Temperature (degC)
Internal Relative Humidity (%)
Ch1 sensor – External Temperature
– External Humidity
Ch2 sensor – Soil Temperature (uses a remote temperature sensor buried 300mm)
- empty
Ch3 sensor – slot reserved for another remote temperature sensor for experiments
- empty
Ch4 sensor – Experiment Temperature
- Experiment Relative Humidity
Ch5 sensor – spare slot temperature
- spare slot humidity
UV Radiation Level Index (UVI)
Barometric Pressure (hpa)
Weather
Windchill factor (degC)
Wind Gust (Km/hr)
Wind Direction (degrees)
Rainfall count
One hour rainfall
Rain last 24 hours
Rain Yesterday
Rain last week
Rain last month
UV Daily
UV Weekly

Installing the sensors is guided by the downloadable IROX manual. Downloadable from http://www.weatherstation.co.nz/02c42d97db0d12d0f/02c42d97db0e46814/02c42d97dc0ab3020.php

We installed a 9 metre spruce pole in a prominent position 10 meters away for the senior classroom in which the equipment was to be located. At the top of this are mounted the wind speed / direction sensor (required to be 30 feet above ground level for standard measurements) and the UV sensor (high to be above mist levels)

The outside temperature /humidity, (measured at standard height of 4 feet above ground) ground temperature (measured 1 foot below ground level) and rainfall sensors were mounted on a custom designed wooden unit approx 1.8 metres high

The pole pivots on tanalised support posts to allow it to be easily and safely lowered to gain maintenance access to the sensors and the 10 watt solar cell and wind turbines that will be developed to power all, including a small electronics laboratory facility.

Detail/ photos

/www.kaitiakitanga.net/projects/1-3-1%20ponga%20whare-energy.htm

3.0 Building a Solar and Wind Powered facility for Electronics / Physics study

The Weatherstation and associated laptop will be powered by a 10 watt Solar Panel and some future wind generation on the pole erected at the Kura.

The Solar control unit mounted in the senior classroom includes a 7.5 Amp Hour sealed lead acid battery, with a charge controller, an 7.5 volt supply for the Weatherstation display, a 12 to 19 volt adapter to power the associated laptop, a Ni-cad recharging facility for the batteries fitted in the weather station remote sensors.

In addition it includes a 150 watt Invertor that can provide a limited 230 volt mains supply (limited to 50 watts) for short periods and also an adjustable 0-12 volt DC bench supply that can power small science experiments. A small digital multimeter is fitted on the front face of it for experimental and monitoring purposes.

The total material cost of this facility including the solar panel pole cabling, ducting and other hardware was around $700.

Maintenance and Operational requirements

Little maintenance is required except for regularly monitoring that the battery is being charged. Its voltage should be between 12 volts (flat) and 14 volts (fully charged) It is useful to have on hand some 10 amp minature slow blow fuses in case accidental shorts cause these to blow

Design Notes

It is all mounted in a single 222 x 146 x 55 Polycarbonate enclosure (Jaycar Cat HB 6220 $ 29.90) where all internal voltages low and safe.

Source input circuits

The inputs provided are all diode decoupled so none can reverse drain on each other. This involves an additional diode drop of 0.6 volts for each input – a small price to pay to make it impossible for input short circuits to drain the battery:

All the following inputs are brought out to screw terminals on the front panel black (-ve) and two reds (+ve) that allow the connection between them to be broken so that the source current can be measured (read using the 10 amp DC input connections on the front panel meter)

Solar 1 -

Wind 1
Wind 2
Wind 3
Wind 4

A further input on the LV side panel allows a mains power supply adaptor with a nominally 18 volt DC output to be plugged in to charge the battery from mains if required)

Solar Charge Controller:

This is solar charging to the battery is controlled by a 1.5 amp controller (Jaycar Cat AA0258 $ 27.90), which ensures that excessive solar or wind generation does not overcharge the battery. All inputs from each solar or wind source are diode protected so that shorting external wiring cannot short the battery and also to decouple any sources that are not generating cannot drain power generated by others (eg solar panels dragging Wind energy at night)

Input Overvoltage dump

This is a small circuit designed to clamp divert any input to a dump resistor when the battery is fully charged and the input voltage from wind generators etc raises to above 19 - 20 volts

This may also later include an undervoltage circuit to drop all loads when the battery voltage falls below 12 volts

Sealed Lead Acid Battery

Diamec 12 Volt 7.2 Ampere Hour zero maintenance sealed battery (Jaycar cat SB 2486 $35.9) This is protected by both a 10 amp quick blow fuse in the positive lead (for shorts) and a 5 amp thermal overload cutout. in the negative lead

A small centre biased analogue meter placed across a custom current shunt made of nichrome wire inside the box gioves an indication of charging or discharging into the battery (full scale is approximately 3 amps)

In addition two other linked red terminals can be used to measure total charging current and total load current.

(Note all the red switches should be left off when not being used as some of them involve a standby current that would otherwise waste battery power) .

7.5 volt power supply for Weather Station controller (display functions only)

This is a linear regulator made using a Versatile Regulated Voltage Adaptor (Jaycar kit cat KA 1797 $8.50). This drops the battery voltage to 9.0 volts, max 1.5 amps load but the weather station demand is minimal.

(Measurement on the nominally 7.5 volt mains adaptor supplied with the weatherstation central unit showed that at the low 20 mA consumption of the unit, the supply voltage was 10.5 volts. We have therefore uses the 9.0 volt regulated output to supply this).

12 volt DC Nicad recharger

This unit (similar to Jaycar cat MB 3549 $47.90) uses the 12 volt battery to charge Ni-cads (AA, AAA, or 9 volt) In it the Nicad AA batteries if used in the remote sensors can be recharged.

12 volt DC to laptop power converter

This is an 80 watt device (Jaycar cat MP 3463 $41.90) that takes the 12 volt battery and outputs it to the specific laptop and a selectable voltage of 15/16/18/19/20/22/24v DC.

This was tested by powering an ACER 4520 (with Athlon X2 CPU) Laptop which used the 19 volt connection, where the following consumptions form the 12 volt battery were measured:

Lowest CPU speed, Low LCD, graphics balanced, LAN on	= 1.65 amps (20 watts)
Max CPU, Max LCD optimum BGraphics, LAN on	= 2.8 amps (34 watts)
Sleep Mode	= 0.10 amps (1.2 watts)
Hybernated	= 0.06 amps (0.7 watts)
Laptop Unplugged (background converter idling load)	= 0.04 amps (0.5 watts)

Run down test - got down to 9.5 volts battery voltage and it was still supplying the laptop. (That is bad as lead acid battery should not be discharged below 12 volts – may need to put an undervoltage load in the battery lead)

For the Toshiba Laptop used at the Kura the 15 volt setting is used. No measurements of current were taken when this was installed.

NOTE For this configuration to work within the capacity of the 10 watt max solar panels (supported perhaps later by 1 watts wind power) it will be necessary to ensure that the laptop is always configured to go to sleep or hibernate when not being used. It may also be necessary to fit an electronic timer circuit to power say only intermittently thus disconnecting the laptop supply to avoid the standby (idling) drain the unit draws.

230 Volt Inverter Unit

A Powertech 150 Watt 12v DC to 230 Volt AC Convertor (Jaycar cat MI5121 $59.90) provides totally enclosed and double insulated floating AC power. It is limited by an external circuit breaker on the battery to 5 amps (approx 50 watts load) . The battery consumption was measured at:

Idling with no AC Load = 0.26 Amps (Battery volts 12.55)
Powering a 25 watt lamp = 2.4 Amps (Battery volts 12.14)
20 Watt ECO Fluorescent bulb 110watt equiv) = 1.8 Amps
18 Watt CE Fluorescent (unstable and flickered badly)
Electric Drill would not run - tripped at around 5 amps battery current

The unit drops off and locks itself out when the battery voltage drops to around 12 volts

The 7.2 Ampere hour battery would hold a 50 watt load (4.5 amps) for around 100 mins)

Adjustable Bench Power Supply 0-12 volts nominal (1.5 amps max)

This is a linear regulator made using a Versatile Regulated Voltage Adaptor (Jaycar kit cat KA 1797 $8.50). This provides an adjustable bench supply for doing electrical experiments at 3 - 12 volts . It is current limited to around 1.5 amps)

The front panel rotary switch provides the following options.

Position 1 Variable voltage set by the know below it
Position 2 1.5 volts nominal (lowest possible)
Position 3 3 Volts
Position 4 5 Volts
Position 5 6 Volts
Position 6 9 Volts
Position 7 12 volts (Nominally - dependent on battery voltage)

4.0 Lightning and Electrical Safety protection

All voltages within the unit are low, and under 32 volts so no electrical permit is required. The negative side of all low voltage wiring is connected to local mains earth to ensure that it is not livened by any accidental connections jointing it to mains voltage

All external wiring to solar panels, wind turbines etc on the pole and protected with GEMOV overvoltage protection devices at the input to the module to ensure that no induced voltage or static electricity can build up. This is discharged to building earth

As Te Whaiti is in a valley surrounded with large mountains there is no record of lightning strikes at floor level. Nevertheless, since the school sits in a predominant hill site as a precaution a lightning arrester rod on the top of the pole connected by a heavy 35mm2 (obtained by talking nicely to a metal recycling company who sold it to us at the copper rate) for rate earthing cable to buried cable and groundstakes have been installed to provide a safe path if a lightning strike did occur.

The total cost of materials to install the lightning diversion including the cable the earth stakes, ducting and terminations was a little over $200.

5.0 Wind Power experimental / learning equipment.

Experimental Generators:

Some small one pole brushless electric motors have been obtained from Surplustronics. (http://www.surplustronics.co.nz/shop/ at ($8.00 each) These will be converted to generators to get an understanding of different wind Turbine designs and how they respond to the type of wind conditions encountered at the Kura (being collected by the school weatherstation.)

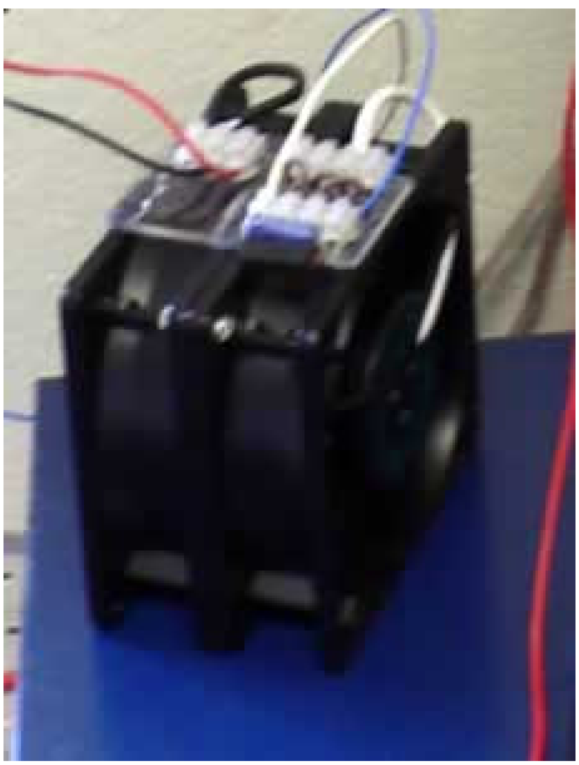
It is proposed to make up the following units over time to fit on the pole and monitor performance:

a. A horizontal generator - blade diameter 360mm
   (wind face approx 0.1 m2)
b. A Savonus vertical turbine – 200 diameter and 500 high
   (wind face 0.1 m2)
c. A Darrieus vertical turbine - 180 diameter and 600 high
   (wind face 0.1 m2)
d. Variation on these done by students to try to improve them.

Note: the wind energy available from an 0.1 m2 wind face with 40% extraction efficiency (the theoretical limit is 59%) would be:

5 m/sec (10 mph) gives 3 watts
10m/sec (25 mph) gives 25 watts

These turbines with the small generators used will probably not all generate enough voltage at low speed to help the solar cells charge the 12 volt battery system much. (They really need to be generators with more poles). These will however produce enough to monitor wind generator performance from the classroom. By measuring their Open Circuit voltage of the generator (no load) it will be able to determine speed of rotation (In Revolutions per second) By also measuring the current flowing into a Short Circuit on the generator output and knowing the winding / cable resistance (either in series or parallel we will be able to get an idea of the wind power converted in Watts.



One motor is physically connected to drive another one converted to a generator. This will make a motor – generator set driven by the bench supply above, to allow students find out how they work and understand the appropriate characteristics of an effective wind turbine generator.

This unit is technically a motor-alternator set as it generates Alternating Current (AC) that is converted to Direct current by the bridge rectifier on its output.

These 24 volt DV brushless motors are from axial computer fans. They are German made with good quality ball bearings and seals. They are not designed for outside use but since all electronics have been removed leaving only low voltage wiring they will probably rune for a year or so outside. Manufacturer ebn WG 107-AD03-85 24 volt (18-30 volt) 3.3 watts

The fan containing a strong permanent magnet rotates around a central fixed armature with two coils that are fixed to create a double pole magnet (North and South)

TO MODIFY THE MOTOR TO BECOME AN ALTERNATOR, carefully open the back exposing the green circuit board. Unsolder the three winding connections (entering through three existing slots) then carefully prise the PCB off its plastic standoffs (you may need to soften them with a soldering iron tip). Remove the board and cut off all its components. Look carefully to remember how the external cable entered the unit and was soldered to the pcb.

Now with the cable exit slot facing towards you, cut another slot to a soldering pad on the right, then snip the two left most winding ends if they are currently joined which may be joined the longest of these two wires will go to the new slot we have cut so both windings are totally separated. Now connect the four core cable to the PCB starting clockwise from the new slot.

Black wire to solder pin hole next to the new slot
White wire to the “c” hole in the PCB beside slot
Red wire to the “c” hole in the PCB beside slot
Blue wire to solder pin hole next to the new slot

Now clip the PCB back into place and then slide the winding ends back into their slots and solder them.

Both coils are in line and each has a winding resistance of 31 ohms. When modified to be AC permanent magnet generators both coils are brought out in the output wiring lead as follows: Winding A red and black, winding B white and blue (note The four core leadout cable has conductors with a resistance of around 0.1 ohms per metre)

The output of each winding of the the generator is an AC square wave (both in phase) with rounded corners

A bridge rectifier with smoothing capacitor is used one each winding and added at the DC output, or alternately the windings can be connected to a single bridge rectifier either in series (double voltage) or in parallel (double current) The following tests compare these options.

Connecting to the bridge rectifier AC side
(a) Series (for twice voltage output)

Use red and blue with black and white joined together

(b) Parallel (for twice current output)

Use red and blue joined together AND black and white joined

Motor tests

Running on 12 volt battery 0.065 Amps (65mA) = 0.78 Watts of power
Restricting fan to just run steady speed (max torque) 0.15 Amps = 1.8 Watt

Generator tests: (actually its an alternator with a bridge rectifier)

MOTOR			both		GENERATOR		
Vin	Iin	Power	Speed	Speed	Vout	I out	notes
(Volts)	(mAmp)	(Watts)	(Hertz)	RPM	(Open)	(Short)	
Test A. windings to separate bridges with DC outputs connected in series 3/5/08							
19	130	2.47	32.43	1945	25.04	-	Open circuit
			18.46	1108	-	125	Short circuit
11.16	80	.928	18	1080	15	-	Open circuit
11.08	150	1.77	12	720	-	70	Short circuit
9.5	70	.665	14.84	890	11.26	-	Open circuit
9.5	140	1.33	8.97	538	-	50	Short circuit
8.0	60	.42	11.83	709	850	-	Open circuit
8.0	110	.88	7.51	450	-	40	Short circuit
6.5	50	.325	8.67	520	8.37	-	Open circuit
6.5	80	.52	601	360	-	18	Short circuit
Conclusion ; this gives an indication of volts N (no load) per rpm (needs redoing) 3/5/08							
Test B. Comparing rectifier configurations 3/5/08							
11			175	1050	13	-	2 bridge - series
11			10.3	618	-	60	

11			17.45	1047	13.6	-	1 bridge - series
11			9.04	542		70	
11			17.87	1072	8.5	-	1 bridge - para
11			10.46	628	-	120	
19			31.3	1878	22.6	-	1 bridge - series
19			17.4	1044	-	140	
19			32.47	1948	14.10	-	1 bridge - para
19			18.74	1125	-	250	
24			40.8	2448	16.9	-	1 bridge para
24			21.54	1292	-	320	
Conclusion: as both winding have voltages in phase its best to join them before the bridge as it removes two diode voltage drops (0.6 volts x 2)							
Test C. - into a 12 volt battery via the isolation diode and charge controller 3/5/08							
19			27.64	1658	15.36	50	1 bridge series
24							
24					14.1	0	1 bridge para
Conclusion : With windings connected in series, at 1600 rpm would charge around 50 mA = 0.6 Watt into a 12 volt battery. It would be a struggle for most turbines to reach that speed For a vertical turbine with a generator providing bearings at each end , if both were connected in series this could produce a similar open circuit voltage at around 800 rpm. For turbines driving low voltage batteries eg 4 volts for LED lamps etc it could work perfectly well.							
MOTOR			both		GENERATOR		
Vin	Iin	Power	Speed	Speed	Vout	I out	notes
(Volts)	(mAmp)	(Watts)	(Hertz)	RPM	(Open)	(Short)	

TEST D Documented Generator test characteristics							
6.3							
6.5	50	0.32	8.62	517	8.44	-	
	110	0.75	4.9	274	-	30	
7.5	60	0.45	10.8	648	10.68	-	
	120	0.90	5.85	351	-	37.5	
8.5	70	0.45	12.75	765	11.83	-	
	140	1.20	6.79	407	-	45	
9.5	70	0.66	14.7	882	13.76	-	
	150	1.43	7.69	461	-	55	
10.5	80	840	16.6	996	15.42	-	
	170	2.10	8.67	520	-	65	
12.6	90	1.13	20.4	1224	25.5	-	
	200	2.52	10.47	628	-	80	
19 note 1			32	1920	27.57	-	
			17.35	1041	-	130	
24 note 2			39	2340	29.4		
			23.6	1416		180	
Note 1 an 2 this was not no load for these measurements							

Fisher and Paykel Dishdrawer Motors

We have two of these to experiment with. They are six pole units so bridge rectifying each of the tree phases and connecting the resultant DC in series they should generate enough voltage to carge a 12 volt batter at around 1/3 of the speed required for the above (eg around 500 rpm)

Fisher and Paykel Smart Drive washing machine motors

These are fourteen pole three phase motors and well suited to wind turbines where they can generate large currents at low speed. See application notes at http://www.yourgreendream.com/diy_fisher_paykel.php

Down the track after students have mastered the technology this could be used for a more commercially viable installation, including perhaps a water turbine on our Mangamate waterfall to power some camper facilities and lights there.

6.0 Equipment for Solar / Renewable Energy experiments.

In addition to the above some additional items of equipment have been obtained to support student learning including:

A Clip on Ammeter / multimeter - to allow monitoring of school power consumption (obtained from The Warehouse at around $15 each – very good value)
A Digital Multimeter - for electrical experiments ($10 each at Jaycar Electronics)
Misc electrical tools wire strippers etc
A polystyrene fish box and a power supply to enable solar energy / insulation tests
A small solar panel and shed light to do research on optimum solar cell orientation

Total cost around $150