

*Use of Wind Turbines  
As a Grid-Intertie Source on a Klickitat County Small Farm*





## A. Introduction

The purpose of this paper is to provide a small wind turbine solution for providing some or all of our energy needs. The plan recognizes the fact that the wind resource will not always be available. The plan also identifies rules and regulations that must be met and economic payback considerations.

### Energy Demand

The homestead includes a 28x54 foot house, attached 28x48 foot garage and shop building, and a 40x60 barn. All structures have 2x6 inch wood construction. Frequently occupied areas have the maximum possible attic, sidewall, and floor construction.

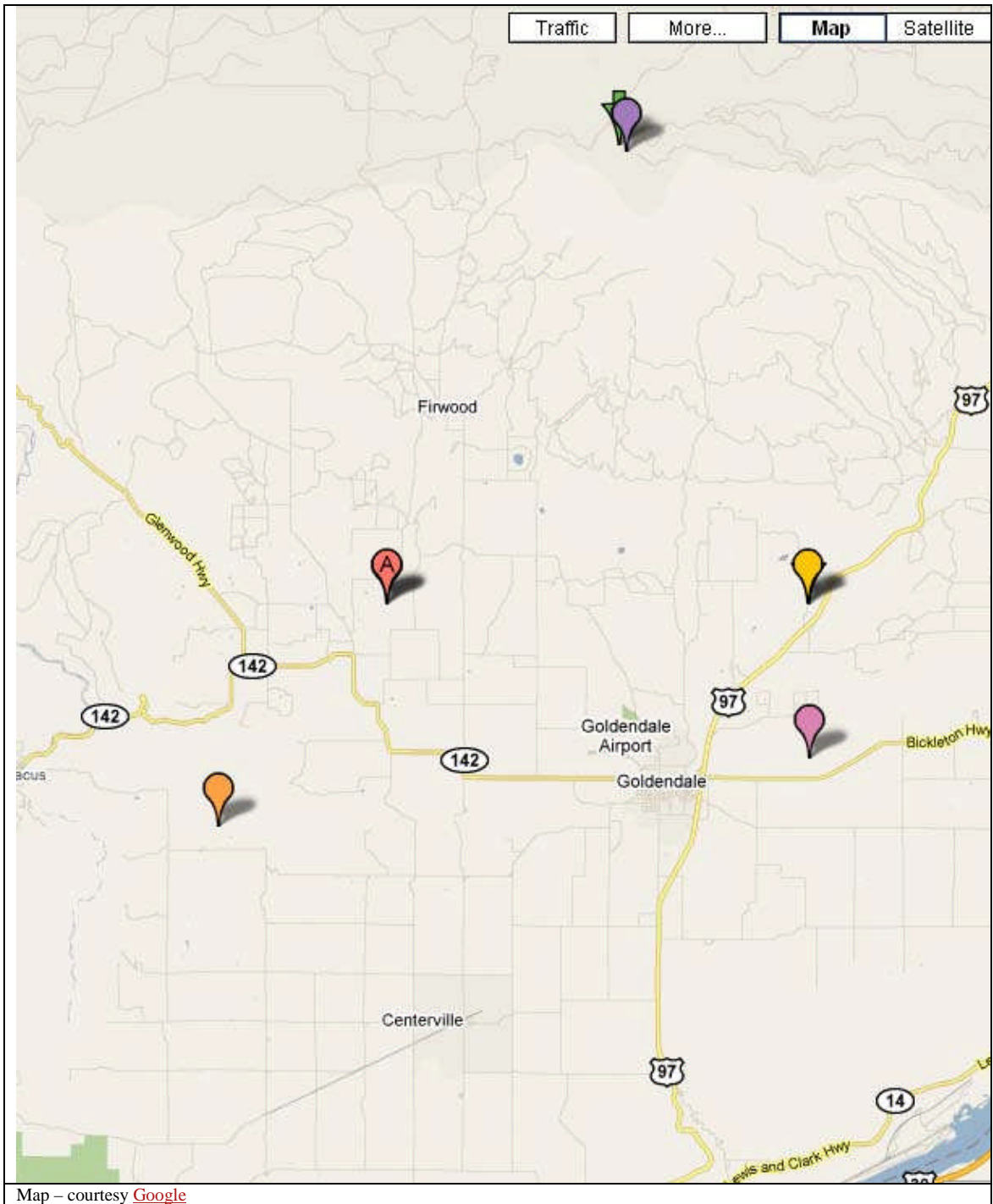
The house and shop area totaling 2178 square feet are heated, preferentially by an air heat pump, then by a liquefied propane (LP) gas furnace.

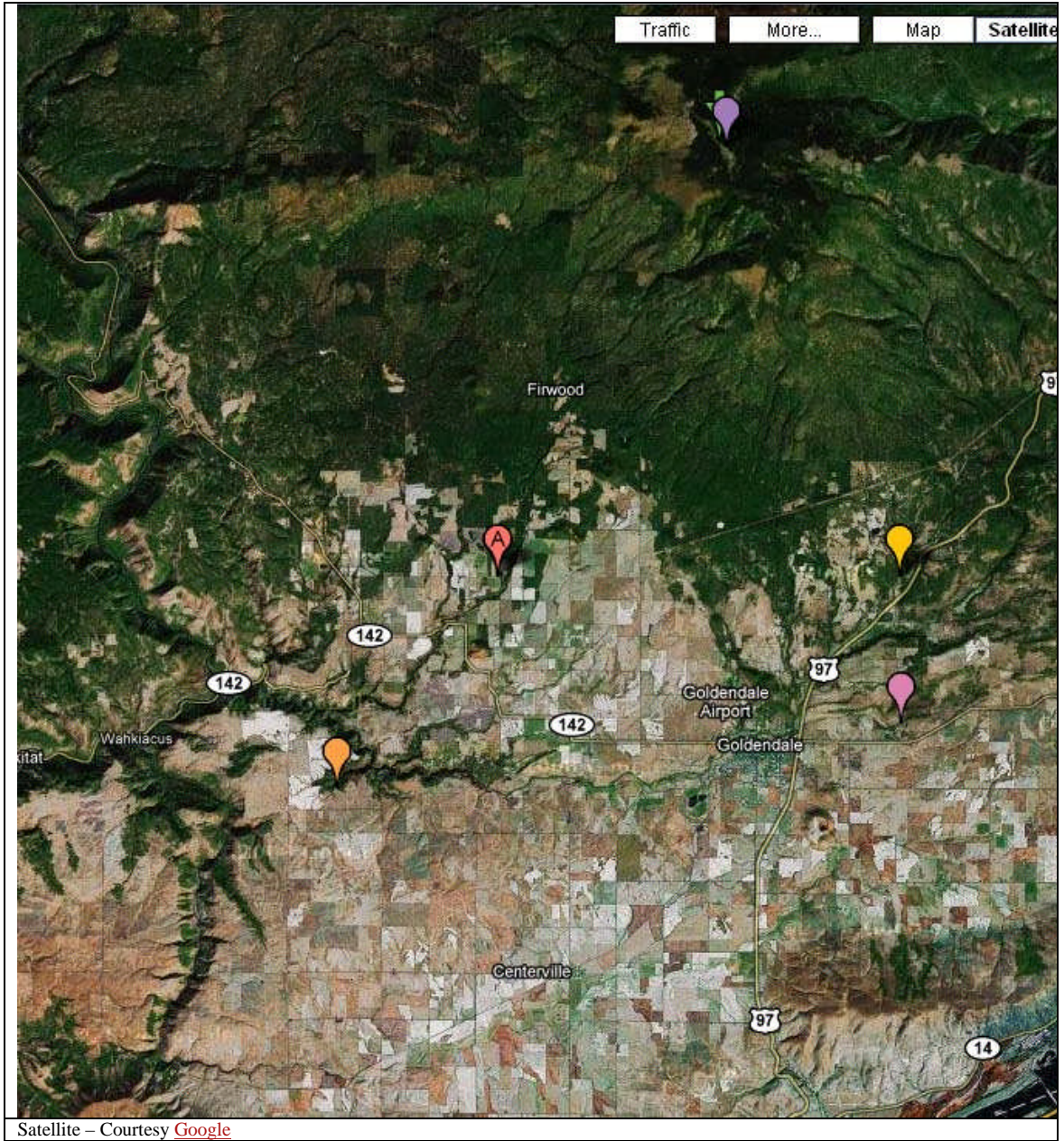
During a 10 year period, annual electrical demand averaged 9400 kilowatt-hours (kwh). LP is used when the heat pump efficiency degrades, typically at about 33-35F. Typical electrical demand without use of the heat pump is 350 kwh.

### Area Wind Potential

According to [NREL's Western Wind Resources Dataset](#), the nominal wind speed in the central Klickitat County area is about 14.5 mph. It is necessary to download the station ID metafile ([http://wind.nrel.gov/Web\\_nrel/site\\_meta.csv](http://wind.nrel.gov/Web_nrel/site_meta.csv)) to locate where data points have been developed in the county. The datasets provide longitude and latitude for location. Using GPS coordinates for the house (point A), selecting WA as state, and using the longitudes and latitudes in the table help in identifying the appropriate site ID's to determine whether adequate wind resource would be available. The house location (A on map and satellite) and closest western wind data locations (27125, 27136, 27304, 27473) are shown below. Wind speed is between 6.1 m/s (13.6 mph) and 6.8 m/s (15.2 mph) with 21 to 27% capacity. These results are acceptable. Obviously, a longer term onsite survey using an anemometer through the year should be performed prior to turbine purchase and installation.

In my cost benefit calculations, I used a capacity factor of 25% since this was in a range similar to the closest western wind data locations. I had also noted in a [NREL conference paper](#) that a locally installed 10 kw turbine was not generating the 34% capacity often used in industry references. Since the tower is only 60 to 100 feet high, a lower capacity factor should be expected. There are two 10 kw wind turbine systems located near Saxton-Bane Road east of Goldendale on or near Luna Butte. Based on discussions with the owners, their recovery is about 13000-15000 kwh per year. These levels correspond to a capacity factors of 15 to 17%.





## B. Details

### Electrical Loads

Annual electrical consumption during the 10 years that we have owned our home has averaged 9400 kwh. Consumption has varied between 300 and 1200 kwh per month. A heat pump is the primary heat source with a LP gas furnace for heating as a backup. The heat pump also acts as a cooling source.

Significant electrical loads include:

Refrigerator	Stove	Microwave oven
Freezers	Well pump (1.5 hp)	Lighting
Washer	Dryer	TV
Heat Pump	Computer	Vacuum cleaner
Tools (shearer, saws, drills)	Radio	Space heaters
Electric blanket		

Freezers are used for storage of garden vegetables and fruits and meat. No electrical consumption reduction can be achieved with these or the refrigerator other than periodically cleaning the refrigeration coils and checking for unit cooling leakage.

“Ghost” electrical losses include indications for TV, microwave, stove, computer, monitor. To reduce ghost electrical loads, power strip sources are used to shut off power when equipment is not in use.

An electrical dryer is used during the rainy and humid seasons. To reduce dryer use, a clothesline is used for drying.

Lights and computer can sometimes draw more load. To reduce use, lights have been converted to fluorescents (compact and shop) except in few cases. Lights are turned off when not used. Computer and monitor are left in standby mode if not turned off when not in use.

### Water

A 200 foot well with 1.5 hp well pump is the water source. Water is used for watering vegetable garden, flowers, and yard trees. Water is also used for humans and animals (sheep and dogs). In earlier years, grass was watered.

To reduce water and associated electrical consumption we shifted to xeriscape landscaping.

### Heating Loads

Heating is provided for a 1528 square foot house. A 650 square foot shop area is maintained about 5 to 10F cooler than the house during the heating season. Daytime temperature is maintained at 65F in the heating season and 85F maximum in the cooling season.

### Additional Conservation Efforts

A 500 gallon LP gas fill runs about \$800-900. To reduce costs due to use of LP and heat pump, local space heaters have been used as have 2 inch styrofoam window inserts and mylar sheeting. A combination of the two is now used. Garage and shop doors use ½ inch styrofoam inserts in glass areas. Caulk and insulation is used to cut heat loss. Storm doors have also been added.

To reduce energy consumption for heating, nighttime temperature is maintained at 55 to 60F. Unless outside temperature drops to 10F, the furnace rarely runs. With a 10F outside temperature and 65F in the house, the furnace would be running most of the time.

### Cooling Loads

Although air conditioning (A/C) using the heat pump is available, it is rarely used. At 1900 feet elevation, temperature typically drops 30 F or more at night during the summer. By opening windows at night during the summer, household temperature drops to between 55 and 70F. By closing windows and drapes/blinds during the day household temperature usually stays less than 80F. On those rare occasions when household temperature exceeds 85F, the air conditioning is used. Most years, the A/C is only used 3 to 5 times when outside temperatures run to 110-115F for several days in a row.

The heat pump is typically used for heating when temperatures remain consistently between 60F and 35F. Below 40F, the heat pump loses efficiency. Below 35F the LP gas furnace is used since the heat pump tends to freeze up.

### Prior renewable evaluation

When we initially bought our property and built the house in 2000, I evaluated use of wind turbine and solar. At that time, the renewable energy cost was not cost-competitive with paying the local public utility district's (PUD) installation cost of \$1600 to run the 800 foot of electrical line and related transformer and associated delivery costs of:

Basic Fee:	\$14.25
Energy Delivery Incremental Rate:	\$.0665 per kilowatt hour (kwh)

## Backup Generator

In 10 years, we have had several long periods (7 days+) where we were unable to leave the property due to heavy snow or and/or ice. Fortunately, power losses did not occur. The most serious load lost during an extended outage during most of the year would be a loss of water. During hot periods, it would be a loss of the freezers. We have a back-up generator Since heavy snows coincident with a power loss would be unacceptable.

### **C. Power Source Selection**

A range of small wind turbines are available in the range 400 watt to 10 kilowatts. Some, e.g. Sunforce 400 to 600 watt turbines are available from Lowe's and Home Depot. Others in the range of 1-2 kw are available from Bergey and Southwest Windpower. Bergey also have a 10 kw turbine that has a good reputation. I originally considered the Bergey 10 kw unit. After performing several cost-benefit evaluations, I selected smaller units. My evaluation included:

- Review of internet sites and references for the manufacturers, suppliers, customers, NREL
- Phone calls to people who have installed small scale wind turbines in the area
- Phone calls to the local utility, Klickitat Public Utility District
- Phone calls to the Klickitat County Building Department and Planning Department
- Review of the federal and state incentives for using renewable energy
- Review of typical generator kwh output data and kwh recommendations for the various generators.

The screening process was bounded on the upper end by the Bergey 10 KW unit. This unit would cover all of our needs. According to users, the unit is exceptionally reliable. However, the incentives would not ensure reasonable payback.

On the lower end, the turbine would likely pay off. However, I do have concern about the reliability of the cheaper units.

In the mid-range, the units are a compromise between not being able to supply all of the loads but having a reliable unit.

- a. 1 10 kW GridTek System  
<http://www.bergey.com/pages/10kwgridteksystem>

Bergey notes that additional costs may be due to shipping, sales tax, permit costs, foundation and anchoring, wire run, turbine and tower erection, electrical hook-up, and inspection fees. They recommend budgeting between \$6000 and \$15000. Sales tax would be about \$3500. Taking these factors into account, I'd estimate an additional \$12000 including the sales tax. Total cost estimated at \$59530.



10 kW BWC Excel-S w/ Powersync II inverter	\$31,770
100ft. guyed lattice tower kit	\$14,145
<u>Tower wiring kit</u>	<u>\$1,615</u>
Total costs	\$47,530

- b. 2 Bergey 1 kw XL-1 systems @ \$7010 x 2 = \$14020  
[http://www.bergey.com/pages/1\\_kw\\_remote\\_system](http://www.bergey.com/pages/1_kw_remote_system)

1 kW XL.1 Turbine, with PowerCenter	\$3,170
60ft. Tilt-up tower	\$2,165
5.3 kWh Battery Bank	\$500
<u>1,500 W Inverter System</u>	<u>\$1,175</u>
Total costs	\$7,010

This system provides some redundancy with 2 turbines and control center (charger), tower, battery bank, and inverter. The disadvantage is the equipment is not made in Washington. Extras budgeted at \$3000.

- c. 1 Bergey 2kw Homesure system  
[http://www.bergey.com/pages/2\\_kw\\_home\\_sure\\_system](http://www.bergey.com/pages/2_kw_home_sure_system)

2 x 1 kW BWC XL.1 Turbines, with Power Center	\$6340
2 x 60ft. Tubular Tilt up tower kit	\$4330
10.6 kWh, 2 string, Battery	\$1000
<u>2.5 kW Inverter System</u>	<u>\$3338</u>
Total costs	\$15008

The advantage of this system is that the inverter is made in Washington. Extras budgeted at \$5000.

- d. Sunforce system (2 turbines @ 600 watt)

2 Sunforce Tower Kit for 600 Watt Wind Generator Turbine, Model#45455. Smarthome cost (\$471.80ea)	\$944
2 Sunforce 45455 600 watt wind generators (\$800 ea)	\$1600
10.6 kWh Battery Bank	\$1000
<u>1,500 W Inverter System</u>	<u>\$1175</u>
Total costs	\$4719

Extras budgeted at \$2000.

Reviews of cost data for other turbine systems was conducted. Based on the calculator described below, total system costs should be in a range less than \$4400-\$5500 per kilowatt to be paid for in a 9.5 year period (assuming grid connect by January 1, 2011).

## D. Incentives – Federal, State, Public Utility District

Federal incentives include wind turbines, solar systems, and biomass stoves. The small wind turbine (residential) federal tax credit is 30% of the cost with no upper limit. Tax credit includes installation costs. This credit expires December 31, 2016. The following restrictions apply to wind turbines - A wind turbine collects kinetic energy from the wind and converts it to electricity that is compatible with a home's electrical system. The turbine nameplate rating must be no more than 100 kw. Incentives are found at *Federal Tax Credits for Consumer Energy Efficiency*, Energy Star (US Environmental Protection Agency – US Department of Energy), [http://www.energystar.gov/index.cfm?c=tax\\_credits.tx\\_index](http://www.energystar.gov/index.cfm?c=tax_credits.tx_index)

In May 2005, Washington State Senate Bill 5101 established production incentives for individuals, businesses, and local governments that generate electricity from solar power, wind power or anaerobic digesters. The incentive amount paid to the producer starts at a base rate of \$0.15 per kilowatt-hour (kWh) and is adjusted by multiplying the incentive by the following factors applicable to wind:

- For electricity produced using a wind generator equipped with an inverter manufactured in Washington state: 1.2
- For electricity produced using a wind generator equipped with blades manufactured in Washington state: 1.0
- For all other electricity produced by wind: 0.8

The incentive for most cases would be \$0.12 per kWh based on  $0.8 \times .15$  since we cannot count on all appropriate equipment being manufactured within the state. This law was recently updated to allow recovery through June 30, 2020. Annual recovery shall not exceed \$5000 per individual. Payment is made by the state for the entire amount supplied to the grid.

Klickitat Public Utility District will pay back for energy used and supplied up to the total amount used. Thus, if you use 100 kwh in a month and supply 250 kwh, the PUD will pay back for the 100 kwh, but not for the overage of  $250-100=150$  kwh.

### Sample Cost-Benefit Calculation – Bergey 10 KW

#### Federal Tax Credit

Based on the \$59530 cost and 30% credit

Cost x Federal Tax Credit Rate = Federal Tax Credit

$\$59530 \times 0.3 = \$17859$  federal tax credit

Washington State Incentive

Using the 25% capacity, 10 kw, 8760 hours per year, \$0.12 per kwh state payback per year

Rated output x Hours per Year x Capacity Factor x Washington Incentive Rate = Washington State Incentive

$$10 \text{ kw} \times 8760 \text{ hr} \times .25 \times \$0.12 / \text{kwh} = \$2628 \text{ per year}$$

Between 1/1/2011 and 6/30/2020, 9.5 years would elapse.

Years until expiration of incentive x Washington State Incentive = Total Washington State Incentive

$$9.5 \text{ yrs} \times \$2626 / \text{yr} = \$24966 \text{ paid by state.}$$

Klickitat PUD Credit

Assuming 9400 hrs per year use, \$0.0665 per kwh costs, annual payment returned would be:

Annual average consumption rate x Electric Rate Charge = Annual Credit

$$9400 \text{ kwh} \times 0.0665 \text{ \$/kwh} = \$625.10 \text{ annual credit}$$

Annual Credit x Years for Comparison = Total Credit

$$\$625.10 \times 9.5 = \$ 5938.45$$

Total benefit through 6/30/2020

Federal tax credit	\$ 17859
State incentive	\$ 24966
Klickitat PUD credit	\$ 5938
Total	\$48763

## Excel Calculator

A calculator was setup using Microsoft Excel based on the equations used above to allow calculations for any wind generator setup. In the calculator, the Turbine System COST includes the total cost for turbine, tower, charger, batteries, inverter, structures, support equipment, taxes and installation costs. The calculator does not factor in maintenance, insurance, property taxes, interest.



Microsoft Excel  
Worksheet

The results are presented in the worksheet for the Bergey, Southwest Wind, and Sunforce wind turbines. The following table illustrates the results for several wind turbines considered. The **calculator** worksheet allows input for conducting evaluations. The **samples** worksheet provides a number of examples and test cases.

Manufacturer	Bergey	Bergey 2KW	Sunforce	Bergey	test
Model	XL10	Homesure	45455	XL1	test
Turbine System COST	\$59,530.00	\$ 20,008.00	\$6,719.00	\$14,020.00	\$16,500.00
kw	10	2	1.2	2	3
hr/yr	8760	8760	8760	8760	8760
capacity	0.25	0.25	0.25	0.25	0.25
kwh generated	21900	4380	2628	4380	6570
Federal incentive rate	30%	30%	30%	30%	30%
Federal incentive	\$17,859.00	\$ 6,002.40	\$2,015.70	\$ 4,206.00	\$ 4,950.00
WA incentive rate	\$ 0.12	\$ 0.12	\$ 0.12	\$ 0.12	\$ 0.12
WA annual incentive	\$ 2,628.00	\$ 525.60	\$ 315.36	\$ 525.60	\$ 788.40
Years state incentive	9.5	9.5	9.5	9.5	9.5
Total WA incentive	\$24,966.00	\$ 4,993.20	\$2,995.92	\$ 4,993.20	\$ 7,489.80
KPUD use	9400	4380	2628	4380	6570
KPUD rate	\$ 0.0665	\$ 0.0665	\$ 0.0665	\$ 0.0665	\$ 0.0665
KPUD incentive	\$ 625.10	\$ 291.27	\$ 174.76	\$ 291.27	\$ 436.91
total KPUD incentive	\$ 5,938.45	\$ 2,767.07	\$1,660.24	\$ 2,767.07	\$ 4,150.60
Total BENEFIT	\$48,763.45	\$ 13,762.67	\$6,671.86	\$11,966.27	\$16,590.40

**For our usage, the only turbine which would pay for itself within 9.5 years would be the Sunforce 45455.**

Test cases were run using the calculator. Sensitivity studies on turbine system cost show that for turbines with 1 kw to 10 kw ratings can break even in the 9.5 year period if the

cost is between \$5542/kw for 1 kw and \$4419/kw for 10 kw. Thus these rule of thumb values could be used to check the various suppliers for cost-efficient units.

Maintenance, insurance, property taxes, interest would add to the costs but are not included. Also, the effect of inflation is not included.

It is important to note that variables include cost, turbine kw rating, annual electrical consumption, capacity, and grid connection date. Capacity can depend on the turbine (e.g. initial wind speed generation point), tower height and wind speeds in the installation location.

## E. System Design

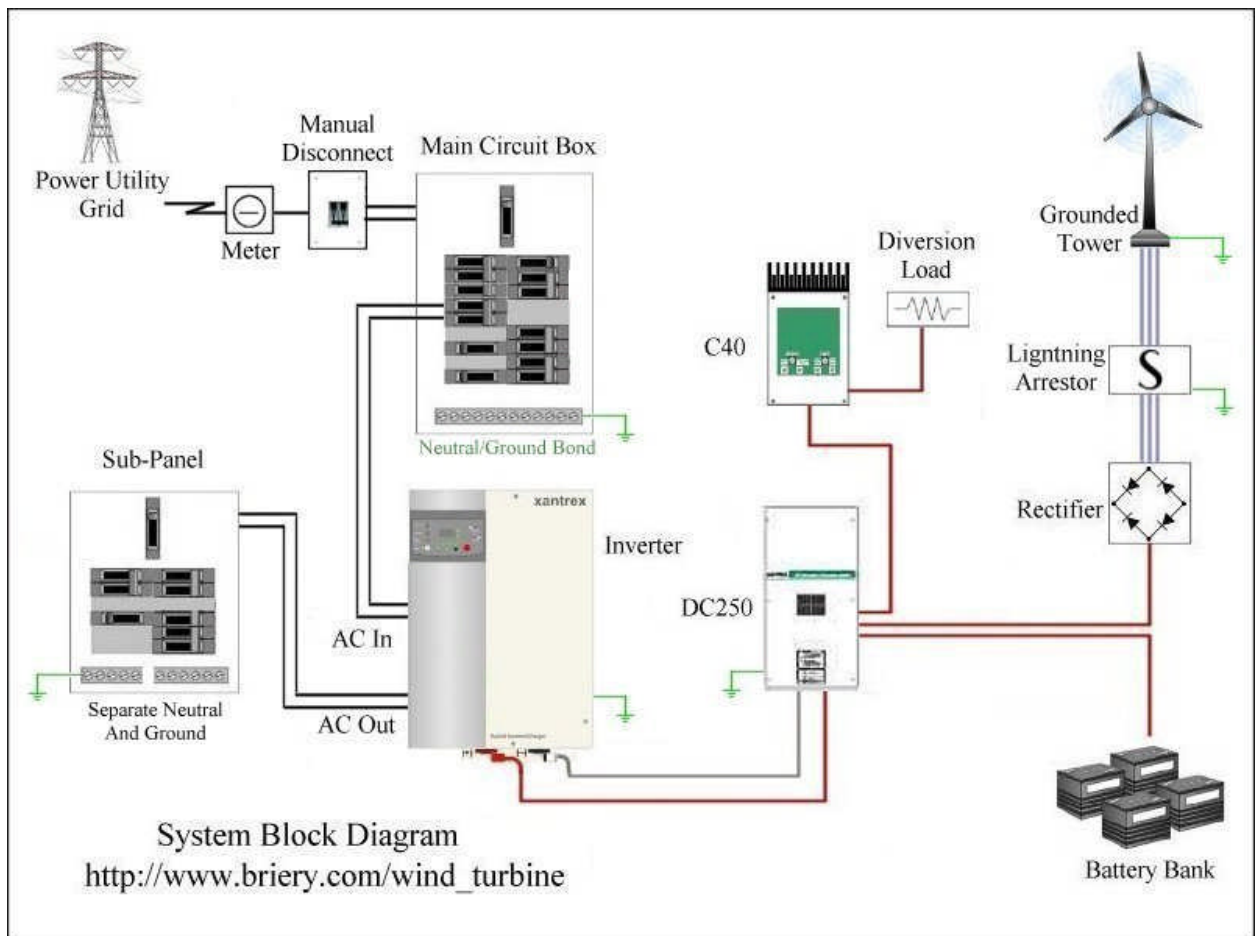
In designing the system, the following components must be included:

Wind turbine  
Tower and guy wires  
Battery charger (controller)  
Batteries  
Inverter

Ground structural support for tower  
Ground attachments for tower  
Housing for battery charger (may be part of turbine)  
Housing for batteries and inverter

Tower installation sequences, including a video, are provided by Southwest Wind Turbines.

The figure below illustrates the system components.



Courtesy [Briery Mountain Enterprises LLC](http://www.briery.com)

## F. Building Requirements

According to the Klickitat County Building Department, installation of a wind turbine would require a building permit with initial fee. A structural plan would need to be submitted. The county building department would conduct the structural review. Other conditions, e.g. setbacks would also be reviewed. If approved, the approval and related conditions would be provided with the final bill. This process provides an input to the county for future property assessments. The following links would be used for:

- [Building department permit FAQs](#)
- [Building Permit Process Information](#)
- [Applications](#)
- [Miscellaneous Forms](#)
- [Energy Code Compliance](#)
- [Electrical Permits and Inspections](#)

The parcel is in the Extensive Agriculture zone, but outside the Energy Overlay Zone defined in the [Klickitat County Zoning Ordinance](#). Based on discussions with the Planning department personnel, a wind turbine on our parcel would require a conditional use permit.

Installing a wind turbine and the related electrical circuits require compliance with Washington state electrical code. An electrical plan would need to be developed, submitted for review, then inspected by the state inspector. The following state web pages provide relevant requirements:

*Electrical Requirements*, Washington State Department of Labor & Industries,  
<http://www.lni.wa.gov/TradesLicensing/Electrical/>,  
<http://www.lni.wa.gov/TradesLicensing/Electrical/BasicElectInstall/default.asp>,  
<http://www.lni.wa.gov/TradesLicensing/Electrical/FeePermInsp/default.asp>,  
<http://www.lni.wa.gov/TradesLicensing/Electrical/Install/default.asp>

I am somewhat familiar with the building permit and inspection processes after having built a house, deck and barn. I am also familiar with electrical permit and inspection process after having designed circuits, wired circuits including breakers, outlets and switches, and passed the electrical licensing inspection.

## G. Conclusion

A cost-effective wind turbine solution for our property was selected. A calculator was designed to determine payback on wind turbine systems taking into account federal, state, and local utility credits. Factors that can affect payback were identified. A sensitivity study was conducted to determine the approximate \$ per kw cost that would allow cost recovery in 9.5 years. The calculator is designed for use by others to modify for their own assessments. The building and permit process was described. The following references were used in preparation of this paper.

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