Use of Renewable Energy
For a Self Sufficient Small Farm in Eastern Washington

Scenario 2: You have inherited 40 acres a few miles north of the Columbia River in Eastern Washington. Most of the land is comprised of rolling hills and your parents used to raise wheat here. You are not quite sure what to do with the land because you have a business degree, but you would rather not sell the property because it has been in the family for years. Your idea is to build a completely self-sufficient home but you're short on funds and need to be very frugal. How could you use renewable energy to help build you your dream home?

From a personal standpoint, the posed situation is similar to my present condition. My plans today incorporate what I have learned from this course and are quite a bit different than the approach I used 10 years ago.

A. Overview

The summary design philosophy is to use the following renewables:

- Solar as primary electrical source and hot water source
- Wind as secondary electrical source
- Passive Solar as primary heat source
- Biomass (wheat or other feedstock) as supplemental heat source

The house design incorporates elements of the Passivhaus low energy philosophy.

This paper further discusses use of the land, rainwater usage, house design, zoning, permits, and costs. The focus is on a self-sustaining cultural approach. Other design ideas were considered before the final approaches described were adapted.

The approach does include interconnection to the grid. The local public utility district (PUD) will only pay back for customer-generated electricity to the level consumed by the customer. However, the state has a program that will pay for customer generated electricity and the local PUD does offer rebates for renewable equipment.

B. Details

<u>The Location</u>

Data for the Klickitat county area varies somewhat. The Western Regional Climate Center reports that Goldendale has an average annual 6251 heating degree days for a base of 65F. In 2008 and 2009, the heating degree-days were 6126 and 6096, respectively. Goldendale nominally receives 4-5 kwh/m^2/day. (References A.1-A.7).

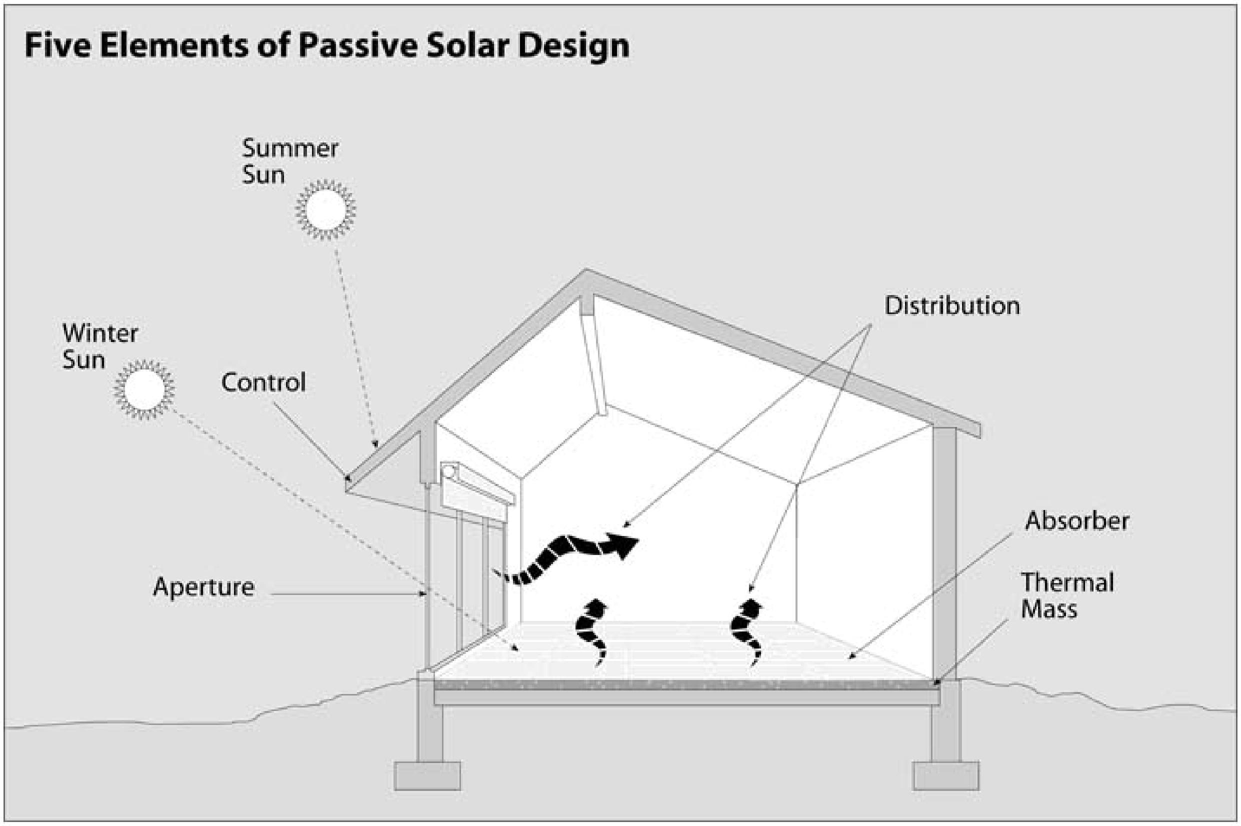
<u>The Land</u>

Since the land had been used to grow wheat before, I would continue to grow wheat or related crops, e.g. triticale, which can be grown to provide a reasonable crop without irrigation. Along that line, I would use sheep that could periodically use the fields for pasture or be fed in pens with the cut grain. From my experience with 20 acres, a 40 acre plot should be able to provide enough grain, not only to feed the sheep, but also to provide enough grain for operating a grain burning stove for home heating. With 12 acres plowed, I was able to get 10 tons of grain (triticale, of which five tons could be used to feed the sheep, the remainder could be used to run the heating stove, as needed, through the year). According to some websites, higher production rates should be obtained. On a 40 acre parcel and not considering irrigation, there would be adequate grain provided for home heating, stock feeding, and sale. The following figures show the height of a grain crop that could be developed without irrigation. The picture on the left shows an area (~4 feet high) where no manure was added; the right side picture shows the increased height (~5 feet) from use of limited sheep manure.

House Design

After experience with stick built and modular homes and recent barn construction, I decided to look for less expensive alternatives. I considered use of straw bales or intermodal shipping containers as part of the package, but decided to use reinforced concrete although reinforced concrete slabs and structures can be relatively expensive. Effectively this house design uses less concrete than the traditional basement.

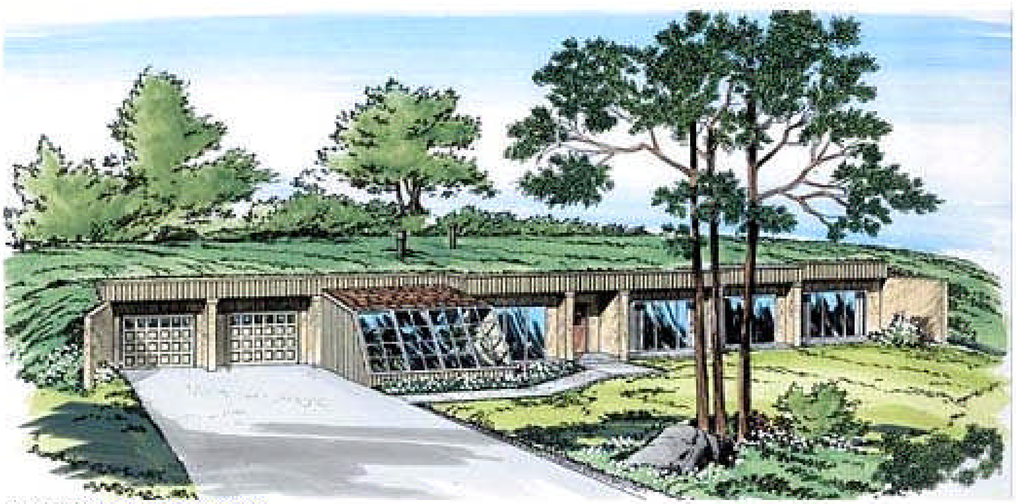
The Passivhaus approach appears to be a good way of reducing heating costs. An earth berm design would further reduce heat loss. An open central area (living room, dining room, kitchen) would incorporate passive solar design elements as shown in the figure below.



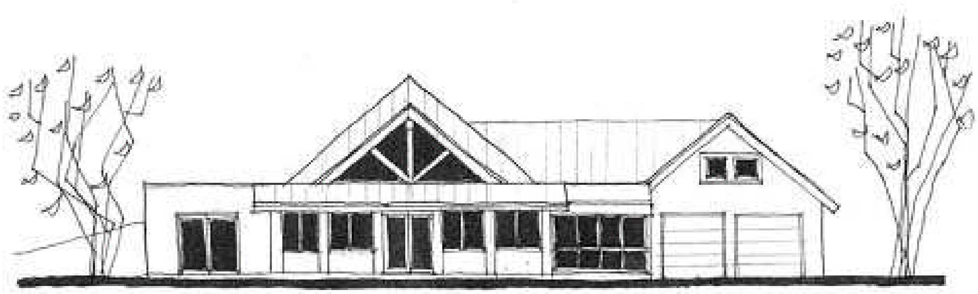
Courtesy Energy Savers

The house and garage would be 32 feet wide with three 20 foot long sections and a 2 car garage of 28 foot length. All walls except the south wall would be bermed. The west third of the house would have one bedroom, office/work space for weaving, closets and storage area. The central third would consist of an open living room, dining room and kitchen with pantry. The east third would have a 4 foot wide entrance area behind which would be a bathroom then a single bedroom. The front (south) walls of the east and west thirds would be trombe wall design with windows to allow some light into the respective area. The house design is intended to provide adequate storage/closet space on the outside (berm side) walls. The entrance area would have one door to the outside, one door to the central area and one door to the garage, which would be bermed on two sides. A heavy duty shop area would be in the back of the garage. A root cellar would be behind the garage under the berm. The south part of the home would have a downward slope to the south to exceed a 52 lb/sq ft snow load; the north part of the home would have a downward slope to the north with clerestory windows facing south. Conceptually, the house design is a merge of the designs illustrated by the homes shown below.

Courtesy TractorByNet



Courtesy recentpastnation.org



Courtesy Dream Green Homes

Courtesy Earth Sheltered Technology

Courtesy HomeBuilding.TheFun.TimesGuide

Courtesy TractorByNet, recentpastnation.org, Dream Green Homes, Earth Sheltered Technology, HomeBuilding.TheFunTimesGuide

In reviewing building designs, I particularly liked the Energy Efficient Building Technologies design because it allowed a lot of light into the house while meeting energy efficiency objectives.

Use of the insulated concrete form (ICF) approach to building could be used to provide adequate insulation. The two infrared photos below show thermal leakage from a conventionally framed home on the left and an ICF home on the right. ICF homes use the insulation as part of the structure in the concrete pouring process. Similar approaches could be used in construction without dependence on the specially designed LEGO-block type panels. It is important to ensure the insulating panels are protected from deterioration for the life of the structure. ICF construction was an approach I had considered 10 years ago when I was looking into simplified construction techniques.

Courtesy zeropowerhouse.com

The floor would be an insulated poured slab to provide the thermal mass element. Water utilities would be concentrated in one area with supply piping and sewage piping routed under the entrance area for easier access. Water pressure tank, hot water heater, washer and dryer would be located in the garage.

Home heating needs and costs could be reduced by having the house earth sheltered on 3 sides. Sufficient outside light would be brought from the southern exposure and by use of clerestories to provide added light in the northern part of the building, as well provide cooling in the summer. (References B.1-B.10)

Berm

The berm would be brought up to a level that would not result in snowfall overlapping from ground to roof. It is expected at least 2.5 foot clearance would be needed. The pictures below illustrate the snow levels that can occur in the area.

Insulation

Following the Passivhaus approach, 14 inches of sidewall insulation and 20 inches of roof insulation would greatly reduce home heating loss. I had originally considered using straw bales or sheep wool. These could be obtained since the location is in an agricultural area. Since this is a dream home, I decided to go with standard insulation. A review of straw bale technology indicated costs were comparable to normal construction. Sheep wool would have to be cleaned and treated. Normal insulation costs are expected to have comparable costs. (References G.1-G.2).

During the review of alternative insulation forms, the following information was found. The thermal resistance or R-value of sheep's wool batts is about R-3.5 per inch. Straw bales tested by Oak Ridge National Laboratory yielded R-values of R-2.4 to R-3.0 per inch. But at least one straw bale expert claims R-2.4 per inch is more representative of typical straw bale construction due to the many gaps between the stacked bales.

Home Heating

Home heating energy requirements could be met by using an Envirotec Model 5775 stove which is designed for burning grain products. Anecdotal reports are positive. The stove burns about 1 bushel of corn or grain a day. That corresponds to approximately 56 lbs. The stove produces 60000 BTU/hr and can heat an area of 2400 square feet. This would be more than adequate to meet heating needs. The corn stove (burner) is expected to cost between $1500 and $2500.

Using the Passivhaus approach, outside air would be ground heated by using an 8 inch diameter underground pipe of at least 130 foot length at 5 feet depth.

Home heating costs are also reduced by keeping daytime temperature between 60 and 65F and nighttime temperature between 55 and 60F. (References F.1-F.4)

Home Cooling

A location several miles north of the Columbia is at an elevation above 1000 feet. From my living experiences near the Columbia Gorge and in eastern Idaho, such an elevation allows adequate cooling by opening windows at night during the summer since there is usually a 30-40F temperature drop. Even with temperatures to 115F during the day, a well insulated house can often remain below 85F inside. Air conditioner cooling is rarely needed.

Well water

Considering the location is rural, a well would be required. Nominal house size pump would be 1.5 HP. This corresponds to an electrical load of 1.119 kw. However, the inverter should be sized for a max running power of 2.15 kw. This size is adequate to handle house, garden and animal watering demand.

Rainwater Collection

Washington state does not restrict rainwater collection for home use. Although the state suggests that rainwater collection on the east side of the Cascades may not be economical, it is worth considering. A 1920 square foot footprint in the central Klickitat county area could produce almost 18000 gallons of water assuming 15 inch annual rainfall. Storage of this amount of water would be the issue. Routing downspout discharge to a collection system then to an excavated covered bottom lined pond from which water could be used for garden watering is one approach. This method would reduce costs. A pond would eliminate the need for expensive tanks. Covering the pond would reduce evaporation. Alternatively, four swimming pools (15' diameter; 4' high) costing $200 each could be used to contain the runoff. Similarly, the pools should be covered. By excavating a flat area below ground the "pools" could be protected from the elements. The area (~ 35 x 35 feet) could be fenced with hog panels (34" high) and T posts to keep animals out. The stored water could be used for garden and animal watering and thus reduce need for submersible well pump electrical demand. (References H.1-H.6). Based on my experience with garden and tree watering, at a rate of 600 gallons per day, the recovery could provide 30 days of water (assuming no losses).

Hot Water

Hot water would be provided by a solar hot water heater using the drainback methodology. The Builditsolar approach appears to be an acceptable low cost ($1000) approach that would work in this area.

Electrical Loads - Initial

The objective is to design an electrical system for minimal demand.

Load	Kw required	Hours/day
Stove with oven		1-2
Refrigerator	.75	24
Lighting	.30	6
Washer	1.00	.5
Well Pump	1.20	1
Vacuum	1.00	.5
Freezer	.20	24
Tools	1.2	3
Exhaust Fan	.05	16-24

ABS Alaskan provides a good table for estimating demand of tools and appliances.

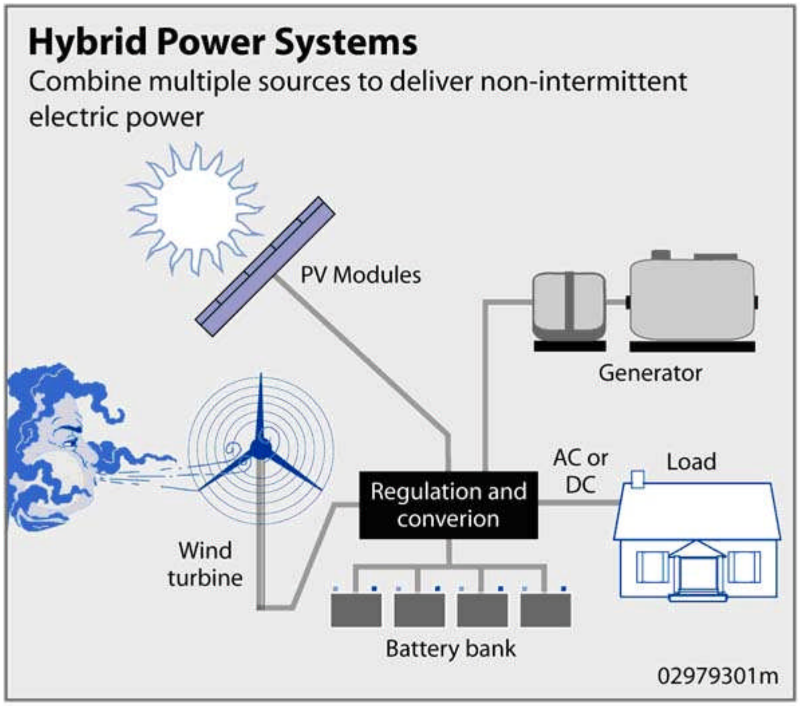
Ventilation

A small exhaust fan would be used to have adequate air turnover to prevent the air from becoming stale in the house. From my experience looking at homes, inadequate air turnover can sometimes be a problem with earth berm homes.

Electrical Power Supply

The power supply and distribution system should be designed to allow upgrading or addition of both generation sources and electrical loads, assuming we become more plush in the pocket in the future. Future loads could include a dryer, microwave oven and computer.

A wind turbine and solar panels would provide electrical supply. For a 400 kwh household in our area, solar assessment tools recommend a 3.9 kw system. My preference would be to use a hybrid wind-solar system to ensure reliability.



Courtesy Energy Savers

Wind

According to NREL's Western Wind Resources Dataset, the nominal windspeed in the central Klickitat County area is about 14.5 mph or more. It is necessary to download the station ID metafile (http://wind.nrel.gov/Web_nrel/site_meta.csv) to locate where data points have been developed in the county. The datasets use longitude and latitude for location. Using Goldendale as the approximate point, the associated longitude is 120.83 degrees west and latitude is 45.83 degrees north. Selecting WA as state and longitudes and latitudes in the Goldendale helps in identifying the likely wind resource available. The results are acceptable for using wind.

Tip-up 60 foot towers would be used.for each wind turbine installed.

Solar

According to NREL's PVWatts v.2, the solar levels are acceptable for the Klickitat county area at about 4.5 kwh/m^2/day. Solar photovoltaic panels would be used for the hot water and as a separate supplement for the wind turbines. PVWatts is a really handy tool.

Battery Bank

A standard battery package would consist of 2 strings of 4 batteries rated at 6V with the string voltage at 24VDC. A 48 VDC system could also be considered. 2 packages would be used, one for wind and one for solar.

Inverter

A standard inverter included as part of a package is rated at 2.5kw. Since the well pump requires 2.15 kw and a washer, refrigerator, and possibly a stove could be operating at the same time, a higher rated inverter or two inverters should be used. My preference would be to have two inverters of at least 2 kw each supplying a load center.

Transformer

Since the inverter output is 120 VAC, a step-up transformer with a 240 VAC output must be used to supply the stove, well pump, and dryer (when added). Transformer sizing should address future needs rather than current needs only.

Electrical Distribution

The electrical power coming from the supply feeds to a load center (circuit breaker box) located in the house. Although not needed immediately, a 200 amp box is recommended for long-term expansion, as needed.

Disconnects

Electrical disconnects must be included in the system design to allow maintenance. The ability to isolate the power sources, batteries, inverter should be provided.

Batteries

Batteries should be kept in a moderate temperature ventilated area. High or low temperatures would degrade battery performance. Since the batteries could potentially give off hydrogen gas, isolation from the garage or gas fumes would be appropriate.

Backup Electrical Generation

Backup electrical generation would be provided by a 5 to 7 kw generator.

System Comparisons

I considered Bergey, Southwest Windpower, and Windspire Wind Turbines that would produce approximately 5000 kwh per year at a minimum.

Bergey has 1,2 and 10kw packages. Horizontal shaft generator.

Southwest Windpower has . Horizontal shaft generator.
Windspire has 1.2 kw packages. Vetical shaft generator.

Guyed tower would be used since the cost is considerably less than the monopole.

My preference would be a Bergey package because of their extensive experience.

I considered Sunforce and Kyocera solar panels and related systems.

My preference would be the Sunforce system because they are more easily available. However, the cost of the Solar Sky packages is enticing.

A calculator, described later, was developed to evaluate payback.

Example Costs

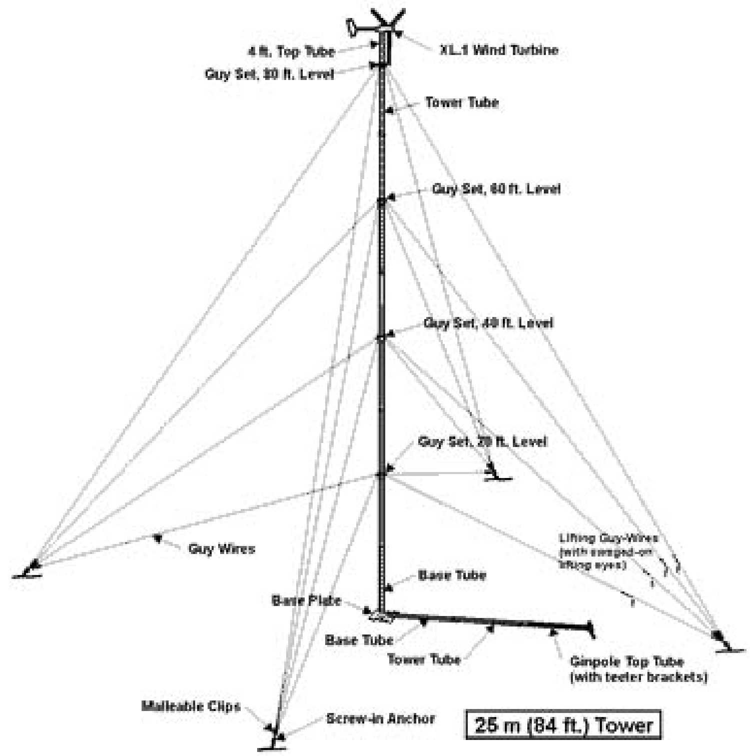
Wind

Bergey

a.	1 kw Wind Turbine	$2768
b.	1.2 kw hybrid system	$9341
c.	10 kw GridTek system (includes tower)	$47530
d.	60 ft Tilt Up Tower for XL1 Wind Turbine	$1697
e.	80 ft Guyed tower	$2660
f.	100 ft Guyed tower	$3130

Southwest Windpower

a.	400 Watt AirX Wind Generator	$649
b.	Skystream 3.7	$6212
b.	80Ft Whisper Guyed Tower Kit Whi100/200	$1995
d.	60ft Monopole Tower	$11119
e.	70ft Guyed tower	$1252
f.	Ground attachment bolts	$515



Tilt.Tower Major Components

Windspire

a. 1.2 kw turbine, tower, charger $9200
   2-3 would be needed.

<u>Solar</u>

a.	Sunforce 1300 Watt Solar Panel Kit	$10000
b.	Kyocera 235W Solar Panels (6@$639)	3834
c.	Fronius IG4000 4000W Grid-Tie Inverter	$2948
d.	Xantrex GT3.8-NA-240/208 UL-05 Grid-Tie Inverter	$2313
e.	Xantrex XW Solar Charge Controller	$557
f.	Outback Flexmax 80 Solar Charge Controller	$684
g.	Bergey 180 watt solar panels with mounting brackets	$1336
h.	Outback 3600 watt inverter	$1939
i.	Xantrex 6000 watt hybrid system inverter	$3656
j.	Solar Sky grid-tie System 3,220/2,873 watts	10384
k.	Solar Sky grid-tie System 5,060/4,515 watts	15615
l.	Solar Sky grid-tie System 6,440/5,746watts	19356
m.	Solar Sky grid-tie System 10,120/9,029watts	31435

Miscellaneous

a.	10.6 kwh battery bank	$1000
b.	1500 watt inverter system	$1175
c.	Solar panel mounting brackets	$10

C. Incentives – Federal, State, Public Utility District

Federal incentives include wind turbines, solar systems, and biomass stoves. The small wind turbine (residential) and solar energy system 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:

a. Wind turbine - 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.
b. Solar energy - At least half of the energy generated by the "qualifying property" must come from the sun. The system must be certified by the Solar Rating and Certification Corporation (SRCC) or a comparable entity endorsed by the government of the state in which the property is installed. The credit is not available for expenses for swimming pools or hot tubs. The water must be used in the dwelling. Photovoltaic systems must provide electricity for the residence, and must meet applicable fire and electrical code requirement.
c. Biomass stoves – The tax credit is for 30% of the cost up to $1500. The credit may not be used for new construction and thus would not apply.

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

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:

- For electricity produced using solar modules manufactured in Washington state: 2.4
- For electricity produced using a solar or a wind generator equipped with an inverter manufactured in Washington state: 1.2
- For electricity produced using an anaerobic digester, or by other solar equipment or using a wind generator equipped with blades manufactured in Washington state: 1.0
- For all other electricity produced by wind: 0.8.

No individual, household, business, or local governmental entity is eligible for incentives exceeding $5000 per year. The law was recently updated to allow recovery through June 30, 2020. 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.

<u>Sample Cost-Benefit Calculation – Combined Wind and Solar only</u>
Since this is new construction, the biomass credit would not apply.

<u>Federal Tax Credit</u>

Based on the $59530 cost for wind, $8550 for solar panels, and $1000 for solar water heating system with a 30% credit

Cost x Federal Tax Credit Rate = Federal Tax Credit

$68550 x 0.3 = $20565 federal tax credit

<u>Washington State Incentive</u>

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

<u>Wind Turbine</u>
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 Wind Incentive Rate = Washington State Wind Incentive

10 kw x 8760 hr x .25 x $0.12 /kwh = $2628 per year

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

9.5 yrs x $2626 /yr = $24966 paid by state.

<u>Solar</u>
Assuming use of solar panels and an inverter manufactured in Washington state, factors would be 2.4 x 1.2 = 2.88. Using the $0.432 (i.e. 2.4 x 1.2 x $0.15) per kwh state payback per year

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

Note – PVWatts2 for zip code 98620 shows that a 4KW system would yield 4781 kwh per year. Ratioing for a 1.23 kw solar system, kwh would be 1195 kwh annually.

1195 kwh x $0.432 /kwh = $635 per year

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

9.5 yrs x $635 /yr = $6034 paid by state.

Total state incentive for wind & solar for the 9.5 years is:

$24966 + 6034 = $31004 (rounded).

<u>Klickitat PUD Credit</u>

Assuming 4800 hrs per year use, $0.0665 per kwh costs, annual payment returned would be:

Annual average consumption rate x Electric Rate Charge = Annual Credit

4800 kwh x 0.0665 $/kwh = $319 annual credit

Annual Credit x Years for Comparison = Total Credit

$319 x 9.5 = $ 3033

<u>Total benefit through 6/30/2020</u>

Federal wind and solar tax credit	$ 20565
State wind & solar incentive	$ 31004
Klickitat PUD credit	$ 3033
Total	$54602

<u>Excel Calculator</u>

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 respective units address total System COST, e.g. total cost for turbine, tower, charger, solar panels, 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 sample manufacturers and models listed. The **calculator** worksheet allows input for conducting evaluations. The **samples** worksheet provides a number of examples and test cases.

Test cases were run using the calculator. I ran cases of wind only, hybrid wind and solar, and solar only. I am hesitant to use a wind only or solar only system unless the system is really oversized. In doing the case studies, I took the base costs and added about 25 to 30% for contingencies.

I was really surprised to find that for **systems depending more on solar, the benefit (federal, state, and KPUD incentives) were close to or exceeded the cost**. Of course, a lot depends on the system selected and reliability of the components. Based on the sensitivity studies, **I would select a 1 kw wind and 3.9 to 5 kw solar package as these would be the most cost-effective.** Please see the sample calculations that show BENEFIT exceeds COST in the Excel spreadsheet for the basis.

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 windspeed generation point), tower height and windspeeds in the installation location. For solar panels, efficiency losses occur as described in the PVWatts data system.

After I had set up the calculator, I came across an Energy Trust of Oregon solar calculator which could be helpful for Oregon residents since Oregon's incentives are different, and appear to be higher, than Washington's. I did use the example costs given by Portland General Electric on their Costs & Incentives page as one of the test cases in the Excel calculator. In that case, the costs and benefits (payback) were close to breakeven. However, I am somewhat skeptical of the PGE's costs stated as I've generally seen higher values for both wind and solar systems.

D. System Design

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

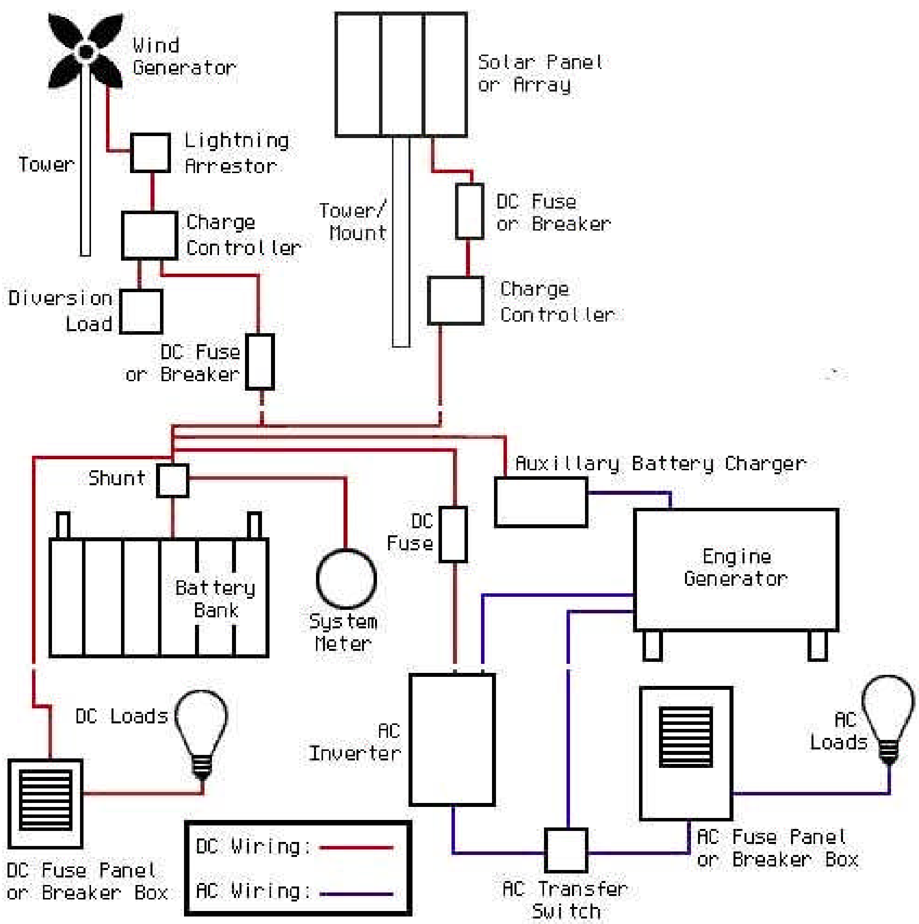
Wind turbine, Tower and guy wires
Battery charger (controller), Batteries
Inverter

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

Solar panels, charger, batteries, and inverter.

Portable gas backup generator

The figure below illustrates the system components.



Courtesy ABS Alaskan

The above drawing is modified from the original ABS Alaskan diagram to only include applicable components.The grid connection would be through the AC transfer switch. The AC transfer switch takes AC input from engine generator, grid, or the dc system, which receives supply from the batteries, wind generator, or solar panels.

The preferred solar water heating system is illustrated in Reference B11. Designs shown in Reference B12 would also be considered.

Reference C15 has some decent wind generator system diagrams.

E. Building Requirements

In Klickitat County, the Building Department would review, approve, and inspect the home and self-sufficient energy system. The process starts with a building permit application with initial fee. A building and structural plan would need to be submitted. The county building department would conduct the building and 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 would be in the Extensive Agriculture zone. Since the location is several miles north of the Columbia, it would likely be in the Energy Overlay Zone defined in the Klickitat County Zoning Ordinance. Based on review of the Zoning Ordinance and discussions with the Planning department personnel, a conditional use permit would not be required.

Section 2.30.2.5 of the Klickitat County Zoning Ordinance states "Energy systems that can generate no more than 25kw, solar panels attached to a building or providing energy primarily for on-site use, and wind turbines 120 feet in height or less are permitted outright by Section 2.30:4, but are not subject to the additional requirements of this chapter."

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.

F. Conclusion

A cost-effective self sufficient wind, solar and biomass solution for our property was selected. Novel concepts include use of a corn stove, berm design, trombe wall, clerestory windows, Passivhaus and ICF design and low cost solar water heater. A calculator was designed to determine payback on the renewable energy systems taking into account federal, state, and local utility credits. Factors that can affect payback were identified. Suppliers were contacted, where appropriate, to get pricing and technical information. The calculator is designed for use by others to modify for their own assessments. The building and permit process was described.

Based on the sensitivity studies that I ran for different wind and/or solar cases, I was really impressed. The solar contribution was much better than I expected.

All of the following references were used in the preparation of this paper.

References

A. Climate and Location Data

1. *Goldendale, Washington; Period of Record General Climate Summary - Heating Degree Days*, Western Regional Climate Center, http://www.wrcc.dri.edu/cgi-bin/cliMAIN.pl?wa3222

2. *US Solar Atlas*, DOE, NREL, http://mapserve2.nrel.gov/website/L48NEWPVWatts/viewer.htm

3. *National Solar Radiation Database*, National Renewable Energy Laboratory, http://rredc.nrel.gov/solar/old_data/nsrdb/

4. *Average Daily Solar Radiation Per Month – Annual, Flat Plate Tilted South at Latitude*, National Renewable Energy Laboratory Resource Assessment Program, http://www.energysavers.gov/pdfs/208.pdf

5. *Annual Average Precipitation*, Department of Ecology, Washington State, http://www.ecy.wa.gov/services/gis/maps/state/precip/ptm-a.pdf

6. *Dynamic Maps, GIS Data & Analysis Tools*, US Department of Energy, National Renewable Energy Laboratory, http://www.nrel.gov/gis/mapsearch.html, http://www.nrel.gov/gis/data_analysis.html, http://www.nrel.gov/rredc/pvwatts/version2.html, http://mapserve3.nrel.gov/PVWatts_Viewer/index.html, http://www.nrel.gov/wind/integrationdatasets/western/methodology.html, http://www.nrel.gov/wind/integrationdatasets/western/data.html, http://wind.nrel.gov/Web_nrel/

7. *Klickitat Public Utility District*, http://www.klickpud.com/

B. Solar

1. *Passive Solar Design*, Definition, Considerations, Commercial Status, Implementation Issues, Guidelines, http://passivesolar.sustainablesources.com/

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