ETM
ENGINEERING & TECHNOLOGY MANAGEMENT

Economic Analysis of Residential Alternative Energy Production in Oregon

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Table of Contents

1. Abstract

Since there are many renewable energy alternatives available to homeowners to help their house become more eco- friendly, especially in Pacific Northwest area. This project will help them analyze what alternative is suitable for their house and worth for investment. In the research, we have identified three technologies which are solar power, wind power, and geothermal power and they will be virtually applied to one of our member's house which located in Portland metropolitan area.

This project will analyze the financial feasibility for each alternative by applying NPV, IRR, incremental IRR, and Benefit -Cost analysis techniques in order to obtain the best alternative. The alternative's information has been gathered by literature reviews on costs and benefits such as installation and maintenance costs, energy saving cost, and incentives for each technology. Besides the sensitivity analysis is conducted in order to investigate uncertain variables that have an influence on the research results.

2. Introduction

Economic theory suggests that residential expenditures on energy conservation and renewable energy sources will be determined by the ability of households to purchase conservation inputs, their incentive to invest in conserving energy, the energy efficiency of existing homes and miscellaneous factors such as climate and age of the homeowner. From this concept, this project will analyze the economic factors for alternative forms of energy production in residential applications, specifically for homes in the Portland metropolitan area. There are many technologies available to the Oregon homeowner today including solar power generation, small scale wind power generation, geothermal heat generation, and solar thermal heat generation. The research in our project will determine the viability of these types of systems based primarily, if not solely, on economic factors. The eco-friendly nature of these options is worth mentioning, but will not be the primary focus of this project. It may be the case that the question becomes, "How much are you willing to pay to be eco-friendly?"

2.1 Problem Definition

Because of ongoing efforts to promote energy efficiency and conservation, they are succeeding in the United States. The research will focus on three types of energy saving alternatives: Solar Cells, Wind Turbines, and Geothermal Energy in Oregon. Indeed, this project will analyze the various types of systems, economic tools such as cash flows, net present values, internal rates of return, and cost/benefit analysis using equivalent uniform annualized figures will be utilized where applicable.Moreover, to measure instability of the interest rate, we will apply the sensitivity analysis to know how much our alternative are sensitive to change. In some cases, there may be options for leasing the systems, or financing the cost. A team member owns a typical, newer, single-family home in SE Portland, and this residence may be used as a sample home for discussion.

2.2 Research Question

In recent years, due to increasing energy demand, the use of renewable energy technologies has grown dramatically. Therefore, people are more interested in purchasing some renewable energy technologies like solar cells, wind turbines, and geothermal energy. And to know which of these technologies is more applicable regarding cost/benefit economic analysis, we have addressed some research questions, which alternative makes more sustainable energy saving in the SE of Portland area? Which alternative more efficient in providing energy?

2.3 Residential Information

Location : SE Lexington St, Portland, Oregon
Year Built : 2005
Type of facility : Two story single house with a single garage
The facility's area : Building Area is 874 sq.ft , yard Area is 436 sq.ft, and the roof area is 900 sq.ft with a small skylight.

Figure 1: Front Side of the House

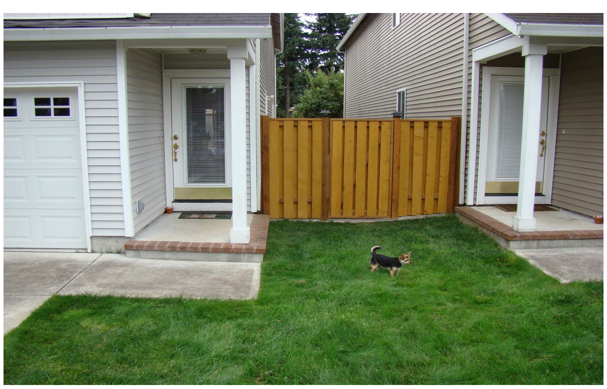


Figure 2: Front Yard of the House

Figure 3: Back Yard of the House

2.4 Historical Residential Energy Use

Month	Electric Use (kwh)	Amount ($)
3/24/2017 - 4/24/2017	615	109.50
2/23/2017 - 3/24/2017	685	109.50
1/24/2017 - 2/23/2017	780	109.56
12/22/2016 - 1/24/2017	933	109.62
11/21/2016 - 12/22/2016	767	109.62
10/21/2016 - 11/21/2016	713	109.62
9/22/2016 - 10/21/2016	694	109.62
8/23/2016 - 9/22/2016	897	109.62
7/25/2016 - 8/23/2016	1133	145.42
6/23/2016 - 7/25/2016	1027	249.58
5/24/2016 - 6/23/2016	956	120.59
4/25/2016 - 5/24/2016	775	114.63
Average	831.25	115.52

Table 1: Historical Residential Energy use

3. Literature Review

The main reason why people in U.S have to adapt one kind or more of renewable electricity generation is to reduce the amount of fossil fuel consumption for U.S. electric power [1]. However, policymakers may decide that growth in renewable electricity is desirable because of concerns about greenhouse gas emissions and climate change, because fossil fuel supplies are ultimately finite, and because of a desire to position the United States as a global leader in renewable energy technology and manufacturing [1]. Renewables could be made more cost competitive by means of improved renewable technologies or revised cost of carbon-based fuels, but financial or regulatory incentives may be required to make certain renewable sources more economically viable in the short term [1].

From 2006 to 2010 U.S. renewable electricity generation capacity was doubled approximately 22 GW to nearly 55 GW.125 In 2010 [2]. Indeed, renewable sources of energy provided about 11% (7% from hydropower and 4% from other renewables) of total net electricity generation. From Energy Information Administration project estimated that renewable energy production will show an increasing between 14% and 15% by 2035 [3]. It means that U.S government and policymakers are encouraging into applying these eco-friendly and sustainable kinds of resources in all states of the U.S.

Indeed, some studies have shown that improving the energy efficiency of buildings in the United States could save $170 billion per year in energy costs through 2030 [4]. Thus, this paper will provide the answers to this fundamental questions by using the advanced engineering economic tools.

3.1 Study Overview

Electricity production from renewable energy of a residential area can use several technologies. In this project, we focus on three technologies which are solar cell system, wind system, and geothermal system.

Solar energy

The solar energy is becoming the most rapid renewable energy source among other renewable energy sources in Oregon [5]. The solar system is not a new technology, and it is there for more than decades. it provides many tangibles and The tangible benefits, for example, reducing the monthly bill of the electricity and guarantee for having a power backup systems. Moreover, it will increase the market value of the house. The intangible benefits to the homeowners that you will save the environment and you are becoming an eco-friendly supporter by reducing the carbon emission [6]. For instance, the yearly reduction in carbon from generating electricity from an average 4 kW solar system is equivalent to the amount of carbon absorbed by half an acre of trees [8].

As people increasingly move to the solar system, the prices go down over the years. However, the future cost will be controlled by several factors including but not limited to, labor cost, permitting fees, and customer acquisition [5]. In this paper, the solar system that has been chosen is the 4kW system because it is a typical system for a customer who has an average of 800 ft2 for the roof .

Wind energy

Wind energy[9] is one of the renewable power recently in our community. It comes from air current flowing across the earth's surface; then it will transfer to the power and provide the electricity for home(small residential), school and business applications (medium community), or farm (large utility scales).In this project, we use Small Wind Turbines (SWTs) as the alternative for the residential house.

Comparing the technology between the small and large wind turbines are their controlling system, and the large one is more mature than the small one in the market. The project goal is that we need to choose different types [10] of the alternative to replace the half electricity, which is small wind turbine is one of the alternatives. After calculating the average of annual electricity, we choose 2kWh small wind turbine as our wind energy alternative[11].

Geothermal energy

Geothermal energy is another renewable energy that increases the energy efficiency of residential. The geothermal system is used for heating and cooling a house or building by transferring heat from or to the ground which maintains a constant temperature about 55 degree all year long. In winter, ground temperature is higher than the air above. Thus heat is transferred from the ground to the house to keep the house warm. On the other hand, heat from the house is transfer to the ground in summer.

3.2 The Six Proposed Alternatives

This paper proposes six alternatives which are:

Energy Saving Alternative 1: Keep using PGE electricity (Do nothing)
Energy Saving Alternative 2: Installing rooftop solar panel of 4 kW system
Energy Saving Alternative 3: Installing wind turbine of 2 kW system
Energy Saving Alternative 4: Installing a 2.2 kW hybrid system of solar panel (1kW) and wind turbine (1.2 kW).
Energy Saving Alternative 5: Installing a 6 kW hybrid system of solar panel(4 kW) and wind turbine(2 kW).
Energy Saving Alternative 6: Geothermal system

4. Methodology

The methodology that will be applied in this project starting with economic analysis for the alternatives to choose the best one by using the incremental IRR and Benefit Cost analysis to the alternatives. Also, we did the payback period to let our resident know which alternatives would payback sooner

To verify our analysis and results, we will use the sensitivity analysis on the options. This process will help to cover all the possibilities that might happen such as increase/decrease on the MARR[12] or increase/decrease the cost of the electricity. This analysis will give a full picture to the homeowner to know at which point he should consider his best alternative among the other alternatives.

5. Analysis of the Proposed Alternatives

5.1 Alternative 1 : PGE (Do nothing)

Do nothing means we will stay with Portland General Electric (PGE) and pay what our resident needs to pay now, but this alternative does not match the goal of our team project because our resident wants to know about “How much are you willing to pay to be eco-friendly?”

5.2 Alternative 2 : Solar System (4kW)

Cost: our proposed alternative is a 4kW solar system where the total installed cost is $16,000. However, the homeowner will get three discounts as it is explained below:

1. $2,560 from Energy Trust incentive ($0.64/watt for customer owned system)
2. $4,032 Federal Tax Credit (30% of $13,440)
3. $6,000 Oregon Tax Credit ($1.50/watt)

As a result, the net cost to homeowner is just $3,408 [13].
Maintenance: the maintenance fee comes from the 1~1.5 percentage initial cost, and it increases 2.2% per year because 2.2% was the average inflation in us last decade[14].
Benefits: the income comes from monthly saving. This system can generate 12.8kWh daily and monthly 384 kWh which generate $53.37/ month, and it likely increases 4.6% per year because the electricity rate is increasing each year by 4.6% [15].

Appendix 1 shows our calculation based on the loan option when the rate is 3.5%. The results that we have got for this alternative can be summarized in these points:

- IRR = 17.93%
- NPW= $7,550.54
- Payback= 6.17 year

5.3 Alternative 3 : Wind System (2kW)

Cost: our proposed alternative is a 2kW wind turbine system where the total installed cost is $13,399. However, the homeowner will get three discounts as it is explained below:

1. $0 from Energy Trust incentive base on they don not offer incentive to small wind turbine anymore
2. $4,020 Federal Tax Credit (30% of $13,399)
3. $4,000 Oregon Tax Credit ($2/watt)

As a result, the net cost to homeowner is just $5,379.
Maintenance: the maintenance fee comes from the 1.5 percentage initial cost, and it increases 2.2% per year because 2.2% was the average inflation in us last decade[14].
Benefits: the income comes from monthly saving. This system can generate produce monthly 390 kWh which generate $54.2/ month, and it likely increases 4.6% per year because the electricity rate is increasing each year by 4.6% [15],and it offers 50% of electricity demand.

Appendix 2 shows our calculation based on the loan option when the rate is 3.5%. The results that we have got for this alternative can be summarized in these points:

- IRR = 10.62%
- NPW= $5,089.18
- Payback= 9.41 year

5.4 Alternative 4 : Hybrid System of Solar and Wind (2.2 kW)

The Hybrid 2.2kW system had a configuration fee $3,000 for connecting two system together. On the other hand, the net cost looks cheap than the solar or the wind system because this system is the small power system for both, so the equipment cost is cheaper. The Hybrid system can also get the incentive from the Energy Trust based on solar part of the machine.

Cost: our proposed alternative is a 2.2kW wind turbine system where the total installed cost is $8,570. However, the homeowner will get three discounts as it is explained below:

1. $1,280 from Energy Trust incentive
2. $2,187 Federal Tax Credit (30% of $ total cost total cost)
3. $4,400 Oregon Tax Credit ($2/watt)

As a result, the net cost to homeowner is just $3,703.

Maintenance: the maintenance fee comes from the 1.5 percentage initial cost, and it increases 2.2% per year because 2.2% was the average inflation in us last decade[14].

Benefits: the income comes from monthly saving. This system can generate produce monthly 400 kWh which generate $55.59/ month, and it likely increases 4.6% per year because the electricity rate is increasing each year by 4.6% [15], and it offers 50% of electricity demand.

Appendix 3 shows our calculation based on the loan option when the rate is 3.5%. The results that we have got for this alternative can be summarized in these points:

- IRR = 18.282%
- NPW= $8,367.09
- Payback= 6.04 year

5.5 Alternative 5 : Hybrid System of Solar and Wind (6 kW)

The Hybrid 6kW system, we combined the alternative 2 (solar 4kW) and alternative 3(wind 2kw) together, but it also had a configuration fee $3,000 for connecting two system together. The net cost looks more expensive than other alternatives because the system could produce 95% of the power for our residential house.

Cost: our proposed alternative is a 6kW wind turbine system where the total installed cost is $8,570. However, the homeowner will get three discounts as it is explained below:

1. $1,280 from Energy Trust incentive
2. $2,187 Federal Tax Credit (30% of $ total cost total cost)
3. $4,400 Oregon Tax Credit ($2/watt)

As a result, the net cost to homeowner is just $11,787.

Maintenance: the maintenance fee comes from the 1.5 percentage initial cost, and it increases 2.2% per year because 2.2% was the average inflation in us last decade[14].

Benefits: the income comes from monthly saving. This system can generate produce monthly 774 kWh which generate $107.57/ month, and it likely increases 4.6% per year because the electricity rate is increasing each year by 4.6% [15], and it offers 95% of electricity demand.

Appendix 4 shows our calculation based on the loan option when the rate is 3.5%. The results that we have got for this alternative can be summarized in these points:

- IRR = 9.81%
- NPW= $9,639.72
- Payback= 9.89 year

5.6 Alternative 6 : Geothermal System

There are four types of a geothermal heat pump system. Three of them are horizontal, vertical, and pond/lake systems which are considered as closed loop systems and the fourth type is an open loop system. The close loop system is usually buried in the ground or submerged in water while the open loop system uses well or water resource on the ground for exchanging heat.

The area needed for installing the geothermal heat pump system depends on system types. The vertical system is suitable for a small house having limit area. However, the system requires space to install at least 20’ x 20’ and 300-400 feet depth from the surface [8]. Also, the area must be accessible for a drilling rig and free of utilities. There are some recommendations about vertical system installation that the system should be installed at least 10 feet away from property boundaries [7].

From the information of the house we have chosen in this project, the house yard area is approximately 436 ft^2. Thus after leaving 10 feet away from the house boundaries, the available area for installing will be 10’x 25’ which does not enough to install . Also, the area is difficult for drilling tool to access (the house’s plan is shown in appendix 6). Therefore geothermal heat pump system is discarded due to the unavailable space for the installation.

6. Results and Discussion

Since the 6th alternative is neglected because of unavailable installation space, there are currently five viable options which are Do nothing, Solar system, Wind system, a Hybrid system of solar and wind 2.2 kW, and Hybrid system of solar and wind 6 kW. We will be analyzing these five alternatives by applying two techniques which are the incremental internal rate of return analysis, and benefit-cost ratio analysis to select the best alternative.

6.1 Incremental Internal Rate of Return Analysis

Incremental IRR is an analysis of financial return applying to compare between two different alternatives. The table 6 below shows the cash flow and IRR for each of the alternatives. It can be seen that all alternatives except alternative 1 (Do Nothing) have IRR more than the minimum rate of return (3.5%).

Year	Alternative 1 Do nothing	Alternative 2 Solar	Alternative 3 Wind	Alternative 4 Hybrid 2.2kW	Alternative 5 Hybrid 6kW
0	0	-3,408.00	-$5,379.30	-3,703.00	-$11,787.30
1	0	480.40	$449.42	538.54	$929.83
2	0	506.34	$474.92	566.39	$981.26
3	0	533.56	$501.70	595.60	$1,035.25
4	0	562.11	$529.81	626.22	$1,091.92
5	0	592.07	$559.33	658.32	$1,151.40
6	0	623.49	$590.33	691.97	$1,213.82
7	0	656.45	$622.86	727.24	$1,279.31
8	0	691.03	$657.01	764.21	$1,348.03
9	0	727.29	$692.85	802.95	$1,420.13
10	0	765.31	$730.46	843.56	$1,495.77
11	0	805.19	$769.93	886.12	$1,575.11
12	0	847.00	$811.34	930.72	$1,658.34
13	0	890.84	$854.79	977.45	$1,745.63
14	0	936.80	$900.37	1,026.42	$1,837.18
15	0	984.99	$948.19	1,077.73	$1,933.18
16	0	1,035.51	$998.35	1,131.49	$2,033.86
17	0	1,088.46	$1,050.96	1,187.81	$2,139.42
18	0	1,143.97	$1,106.14	1,246.82	$2,250.11
19	0	1,202.16	$1,164.00	1,308.64	$2,366.16
20	0	1,263.14	$1,224.68	1,373.40	$2,487.82
IRR	-	17.9%	10.6%	18.3%	9.8%

Table 2: Cash flow and IRR of All Alternatives

The table 3 shows the incremental IRR analysis by comparing two alternatives from the lowest cost to the highest cost to select the best option. It is clearly seen that the hybrid of solar and wind 6 kW system is the best option for investing in all alternatives we have with incremental IRR 5%.

Year	Alt 2- Alt 1 (Solar - Do nothing)	Alt 4- Alt 2 (Hybrid 2.2k - Solar)	Alt 3 - Alt 4 (Wind - Hybrid 2.2k)	Alt5 -Alt4 (Hybrid 6 kW - Hybrid 2.2 kW)
0	-3,408.00	-295.00	-1,676.30	-8,084.30
1	480.40	58.13	-89.11	391.29
2	506.34	60.05	-91.47	414.87
3	533.56	62.04	-93.90	439.65
4	562.11	64.11	-96.41	465.70
5	592.07	66.25	-98.99	493.08
6	623.49	68.48	-101.64	521.85
7	656.45	70.79	-104.38	552.07
8	691.03	73.18	-107.20	583.83
9	727.29	75.67	-110.11	617.18
10	765.31	78.25	-113.10	652.21
11	805.19	80.93	-116.19	688.99
12	847.00	83.72	-119.38	727.62
13	890.84	86.61	-122.66	768.18
14	936.80	89.61	-126.04	810.76
15	984.99	92.73	-129.54	855.46
16	1,035.51	95.98	-133.14	902.37
17	1,088.46	99.34	-136.85	951.61
18	1,143.97	102.85	-140.68	1,003.29
19	1,202.16	106.48	-144.64	1,057.52
20	1,263.14	110.27	-148.72	1,114.42
Incremental IRR	17.9%	22.4%	All cash flow is negative	5%
Chosen option	Choose solar	Choose Hybrid 2.2 kW	Choose Hybrid 2.2 kW	Choose Hybrid 6 kW

Table 3: Incremental IRR analysis

6.2 Benefit-Cost Ratio Analysis

Another technique analysis is benefit- cost ratio. This method is comparing between cost and benefit to show if each alternative is acceptable at the given minimum rate of return. The table 4 provides costs, benefits, and B/C of each alternative. It is clearly that all alternatives except do nothing have a benefit-cost ratio more than one which means the alternatives are acceptable for investment.

Alternatives	Do Nothing	Solar	Wind	Hybrid 2.2kW	Hybrid 6kW
PW of Costs	0	6,157.24	$8,833	5,911.84	7,990.02
PW of Benefits	0	13,707.78	13,921.96	14,278.93	27,629.74
B/C	0	2.23	1.58	2.42	1.54
NPW	0	7,550.54	$5,089	8367.09	9639.72

Table 4: Benefit-Cost Ratio

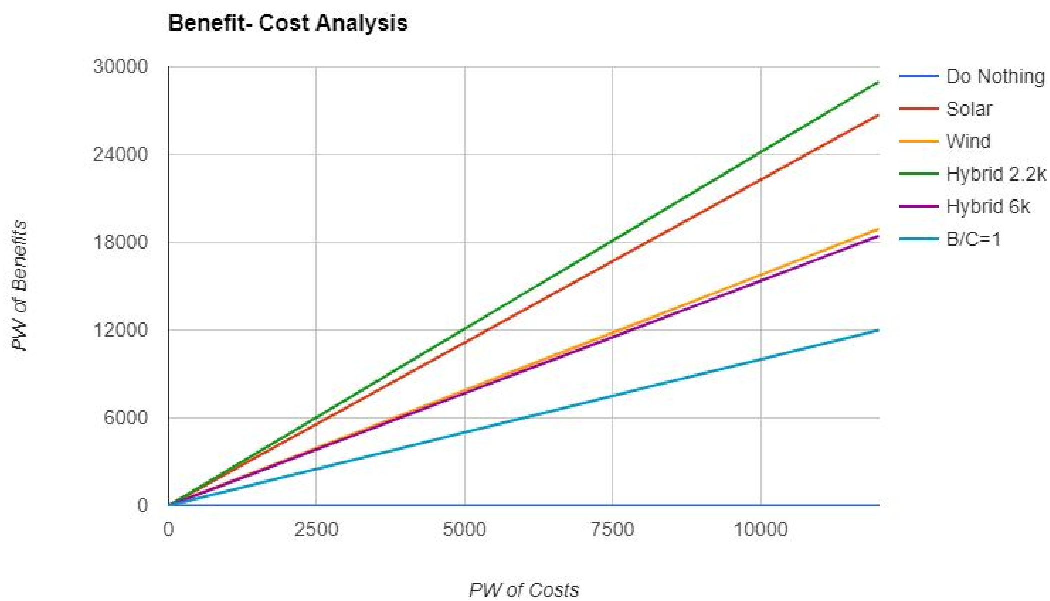


Figure 4: Graph of Benefit Cost Ratio

To select the best alternative, we have calculated the incremental benefit- cost ratio as shown in Table 5 below and the outcome shows that the best option is hybrid of solar and wind 6 kW.

Alternatives	Hybrid 2.2 kW - Do nothing	Solar - Hybrid 2.2 kW	Wind - Hybrid 2.2 kW	Hybrid 6 kW - Hybrid 2.2 kW
PW of Costs	5,911.84	245.40	$2,921	12,078.17
PW of Benefits	14,278.93	-571.16	-356.97	13,350.80
B/C	2.42	-2.33	-0.12	1.11
Result	choose hybrid 2.2 kW	choose hybrid 2.2 kW	choose hybrid 2.2 kW	choose hybrid 6 kW

Table 5: Benefit-Cost Analysis

7. Sensitivity Analysis

Sensitivity analysis is performed to study how the result would change if there is changing of uncertain variables. In this project, the input variables are a loan of interest (MARR), and cost of electricity. The sensitivity analysis is conducted with four alternatives which are the solar system, wind system, hybrid of solar and wind 2.2kW system, and hybrid of solar and wind 6 kW system. Since there are two variable inputs, the sensitivity analysis will be conducted in 2 criteria which are

1. Change MARR under increasing the electricity rate
2. Change electricity cost under fixed MARR

7.1 Change MARR under Increasing the Electricity Rate

The table 6 provides sensitivity analysis when MARR is increasingly or decreasingly changed from the minimum rate of return which is 3.5%. The result shows that if MARR is equal or more than 4.9%, the best alternative will change from the hybrid of solar and wind 6 kW system to the hybrid of solar and wind 2.2 kW system.

Change in factor	MARR	PW			
		Solar system	Wind system	Hybrid 6kW	Hybrid 2.2kW
-60%	1.4	10,429.90	7,856.06	15,285.96	11,522.39
-50%	1.75	9,884.99	7,332.29	14,217.29	10,925.42
-40%	2.1	9,368.20	6,835.61	13,203.81	10,359.19
-30%	2.45	8,877.87	6,364.41	12,242.27	9,821.88
-20%	2.8	8,412.43	5,917.19	11,329.62	9,311.81
-10%	3.15	7,970.44	5,492.55	10,462.99	8,827.37
0%	3.5	7,550.54	5,089.18	9,639.72	8,367.09
10%	3.85	7,151.44	4,705.86	8,857.31	7,929.58
20%	4.2	6,771.97	4,341.43	8,113.40	7,513.52
30%	4.55	6,411.00	3,994.81	7,405.82	7,117.71
40%	4.9	6,067.49	3,665.00	6,732.49	6,741.00
50%	5.25	5,740.45	3,351.05	6,091.50	6,382.31
60%	5.6	5,428.97	3,052.07	5,481.03	6,040.64
70%	5.95	5,132.17	2,767.22	4,899.39	5,715.05
80%	6.3	4,849.25	2,495.74	4,344.99	5,404.64
90%	6.65	4,579.45	2,236.88	3,816.33	5,108.60
100%	7	4,322.06	1,989.95	3,312.00	4,826.13
110%	7.35	4,076.39	1,754.31	2,830.70	4,556.50
120%	7.7	3,841.83	1,529.34	2,371.17	4,299.02
130%	8.05	3,617.77	1,314.49	1,932.26	4,053.05
140%	8.4	3,403.67	1,109.20	1,512.87	3,817.97
150%	8.75	3,198.99	912.98	1,111.97	3,593.21
160%	9.1	3,003.23	725.35	728.59	3,378.23
170%	9.45	2,815.95	545.86	361.81	3,172.53
180%	9.8	2,636.69	374.09	10.78	2,975.61
190%	10.15	2,465.05	209.63	-325.32	2,787.04

Table 6: Sensitivity Analysis by Changing MARR

7.2 Change Electricity Cost under Fixed MARR

The table 7 provides sensitivity analysis when the cost of electricity changes from the base value which is $0.14/kwh, and the result shows how net present value (NPV) for each alternative will change accordingly. If the electricity cost drops by 20% to $0.112/kwh, the best alternative will change from the hybrid of solar and wind 6 kW to the hybrid of solar and wind 2.2 kW system.

Change in factor	Cost of electricity ($)	PW			
		Solar	Wind	Hybrid 2.2	Hybrid 6
-60%	0.056	-633.74	-3,222.97	-158.20	-6,856.71
-50%	0.07	747.14	-1,820.52	1,280.22	-4,073.38
-40%	0.084	2,128.01	-418.07	2,718.63	-1,290.05
-30%	0.098	3,508.89	984.39	4,157.04	1,493.27
-20%	0.112	4,889.76	2,386.84	5,595.45	4,276.60
-10%	0.126	6,270.64	3,789.29	7,033.86	7,059.93
0%	0.14	7,550.54	5,191.74	8,472.28	9,639.72
10%	0.154	9,032.39	6,594.19	9,910.69	12,626.58
20%	0.168	10,413.26	7,996.64	11,349.10	15,409.91
30%	0.182	11,794.14	9,399.09	12,787.51	18,193.23
40%	0.196	13,175.02	10,801.55	14,225.92	20,976.56
50%	0.21	14,555.89	12,204.00	15,664.34	23,759.89
60%	0.224	15,936.77	13,606.45	17,102.75	26,543.22

Table 7: Sensitivity Analysis by changing the Cost of Electricity

The graphs represented the sensitivity analysis of each alternative with both 2 criteria are shown in the appendix 5.

8. Conclusion and Recommendation

From the literature review and the economic analysis, a conclusion can be referred that the renewable electricity generation research conducted for this report indicates that the potential may exist for renewable energy sources to make a sizeable contribution toward total U.S. electricity generation demand.

To sum up, after we have done the sensitivity analysis, this paper cannot guarantee the best alternative among these alternatives that have proposed to the homeowner. Therefore we come up with these recommendations to help the homeowner to choose the best option under these factors:

1. If MARR is equal to 3.5% or less than 4.9%, Wind-Solar 6kW System is the best alternative for this residential among other alternatives from IRR analysis because it has the highest value of the NPW (9639.72) as we are looking to maximize the net present worth.
2. If the MARR is equal or greater than 4.9%, the choice becomes Wind-Solar 2.2kW System because it's NPW becomes higher than other alternatives.

References

[1] P. Brown and G.Whitney, U.S. Renewable Electricity Generation: Resources and Challenges, CRS Report for Congress Prepared for Members and Committees of Congress, August 5, 2011.

[2] Eckhart, M. “Renewable Energy Exceeds 50 GW and Enters Decade of Scale-Up,” Infrastructure Solutions Magazine, April 2011, available at http://www.acore.org/wp-content/uploads/2011/04/Infrastructure-Magazine-Article-V4.pdf.

[3] Energy Information Administration, “Annual Energy Outlook 2011: with projections to 2035,” DOE/EIA-0383(2011), April 2011, available at http://www.eia.gov/forecasts/aeo/pdf/0383(2011).pdf.

[4] Rich Brown, Sam Borgeson, Jon Koomey, Peter Biermayer, “U.S. Building-Sector Energy Efficiency Potential”,Environmental Energy Technologies Division, Ernest Orlando Lawrence Berkeley National Laboratory, Report LBNL-1096E, September 2008.

[5] “Energy in Oregon,” State of Oregon: Energy in Oregon - Solar. [Online]. Available: https://www.oregon.gov/energy/energy-oregon/Pages/Solar.aspx. [Accessed: 11-Jun-2017].

[6] “Why Go Solar,” Solar Oregon Portland, OR. [Online]. Available: http://solaroregon.org/why-go-solar/. [Accessed: 11-Jun-2017].

[7] Michigan DNRE. “Best Practices for Geothermal Vertical Closed-Loop Installations.” Internet: https://www.michigan.gov/documents/mpsc/geo_best_practises_327048_7.pdf, Apr.2010 [June. 06, 2017

[8] Yoder Drilling & Geothermal, Inc. “ Installation Options.” Internet: http://www.yodergeothermal.com/faq.[June. 06, 2017].].

[9] H. Fathabadi, “Novel standalone hybrid solar/wind/fuel cell power generation system for remote areas,” Solar Energy, vol. 146, pp. 30–43, 2017.

[10] Wijayapala, W. D. A. S., and HP Hemantha Kumara. "An Optimum Wind Solar Hybrid System for Stand–Alone Power Generation." Engineer: Journal of the Institution of Engineers, Sri Lanka 48.4 (2015).

[11] "Introduction". Wind-energy-the-facts.org. N.p., 2017. https://www.wind-energy-the-facts.org/introduction-5.html.[June. 10, 2017].

[12] "FICO® Score | FICO®". FICO® | Decisions. N.p., 2017. http://www.fico.com/en/products/fico-score.[June. 10, 2017].

[13]“Typical Costs,” Solar Oregon Portland, OR. [Online]. Available: http://solaroregon.org/how-to-go-solar/solar-electricity-for-home-owners/typical-costs/. [Accessed: 11-Jun-2017].

[14] "Current US Inflation Rates: 2006-2017". US Inflation Calculator. N.p., 2017. http://www.usinflationcalculator.com/inflation/current-inflation-rates/.[June. 10, 2017].

[15] “Public Utility Commission (Home) 2014 PORTLAND GENERAL ELECTRIC (PGE) RATE CHANGE REQUEST UE 283". Puc.state.or.us. N.p., 2017.http://www.puc.state.or.us/Pages/electric_gas/2014-PORTLAND-GENERAL-ELECTRIC-%28PGE%29-RATE-CHANGE-REQUEST-UE-283.aspx.[June. 10, 2017].

Appendix

Appendix-1 : Solar System (4kW) Calculations

Year	Cost	Income	Maintenance	Cashflow	Cumulative Cash Flow
0	-$3,408	$0.0	$0.0	-$3,408	-$3,408.0
1		$640.4	-$160.0	$480.4	-$2,927.6
2		$669.9	-$163.5	$506.3	-$2,421.3
3		$700.7	-$167.1	$533.6	-$1,887.7
4		$732.9	-$170.8	$562.1	-$1,325.6
5		$766.6	-$174.6	$592.1	-$733.5
6		$801.9	-$178.4	$623.5	-$110.0
7		$838.8	-$182.3	$656.5	$546.4
8		$877.4	-$186.3	$691.0	$1,237.5
9		$917.7	-$190.4	$727.3	$1,964.7
10		$959.9	-$194.6	$765.3	$2,730.1
11		$1,004.1	-$198.9	$805.2	$3,535.2
12		$1,050.3	-$203.3	$847.0	$4,382.2
13		$1,098.6	-$207.7	$890.8	$5,273.1
14		$1,149.1	-$212.3	$936.8	$6,209.9
15		$1,202.0	-$217.0	$985.0	$7,194.9
16		$1,257.3	-$221.8	$1,035.5	$8,230.4
17		$1,315.1	-$226.6	$1,088.5	$9,318.8
18		$1,375.6	-$231.6	$1,144.0	$10,462.8
19		$1,438.9	-$236.7	$1,202.2	$11,665.0
20		$1,505.1	-$241.9	$1,263.1	$12,928.1

Cash Flow of 4 kW Solar System

Appendix-2 : Wind System (2kW) Calculations

Year	Cost	Income	Maintenance	Cashflow	Cumulative Cash Flow
0	($5,379)	0	0	($5,379)	($5,379)
1		650.41	$ (200.99)	449.42	($4,930)
2		680.33	$ (205.41)	474.92	($4,455)
3		711.62	$ (209.93)	501.70	($3,953)
4		744.36	$ (214.54)	529.81	($3,423)
5		778.60	$ (219.26)	559.33	($2,864)
6		814.41	$ (224.09)	590.33	($2,274)
7		851.88	$ (229.02)	622.86	($1,651)
8		891.06	$ (234.06)	657.01	($994)
9		932.05	$ (239.21)	692.85	($301)
10		974.93	$ (244.47)	730.46	$429
11		1019.77	$ (249.85)	769.93	$1,199
12		1066.68	$ (255.34)	811.34	$2,011
13		1115.75	$ (260.96)	854.79	$2,865
14		1167.07	$ (266.70)	900.37	$3,766
15		1220.76	$ (272.57)	948.19	$4,714
16		1276.91	$ (278.57)	998.35	$5,712
17		1335.65	$ (284.69)	1050.96	$6,763
18		1397.09	$ (290.96)	1106.14	$7,869
19		1461.36	$ (297.36)	1164.00	$9,033
20		1528.58	$ (303.90)	1224.68	$10,258

Cash Flow of 2 kW Wind System

Appendix-3 : Hybrid System of Solar and Wind (2.2kW) Calculations

Year	Configuration	Cost of Hybrid	Income	Maintenance	Cashflow	Cumulative Cash Flow
0	($3,000)	($703)	$0.0	$0.0	-3,703.00	-3,703.00
1		0	667.09	$ (128.55)	538.54	-3,164.46
2		0	697.77	$ (131.38)	566.39	-2,598.07
3		0	729.87	$ (134.27)	595.60	-2,002.47
4		0	763.44	$ (137.22)	626.22	-1,376.25
5		0	798.56	$ (140.24)	658.32	-717.93
6		0	835.30	$ (143.33)	691.97	-25.96
7		0	873.72	$ (146.48)	727.24	701.28
8		0	913.91	$ (149.70)	764.21	1,465.49
9		0	955.95	$ (153.00)	802.95	2,268.44
10		0	999.92	$ (156.36)	843.56	3,112.01
11		0	1045.92	$ (159.80)	886.12	3,998.12
12		0	1094.03	$ (163.32)	930.72	4,928.84
13		0	1144.36	$ (166.91)	977.45	5,906.29
14		0	1197.00	$ (170.58)	1,026.42	6,932.71
15		0	1252.06	$ (174.34)	1,077.73	8,010.43
16		0	1309.66	$ (178.17)	1,131.49	9,141.92
17		0	1369.90	$ (182.09)	1,187.81	10,329.73
18		0	1432.92	$ (186.10)	1,246.82	11,576.54
19		0	1498.83	$ (190.19)	1,308.64	12,885.18
20		0	1567.78	$ (194.37)	1,373.40	14,258.58

Cash Flow of 2.2 kW Hybrid System

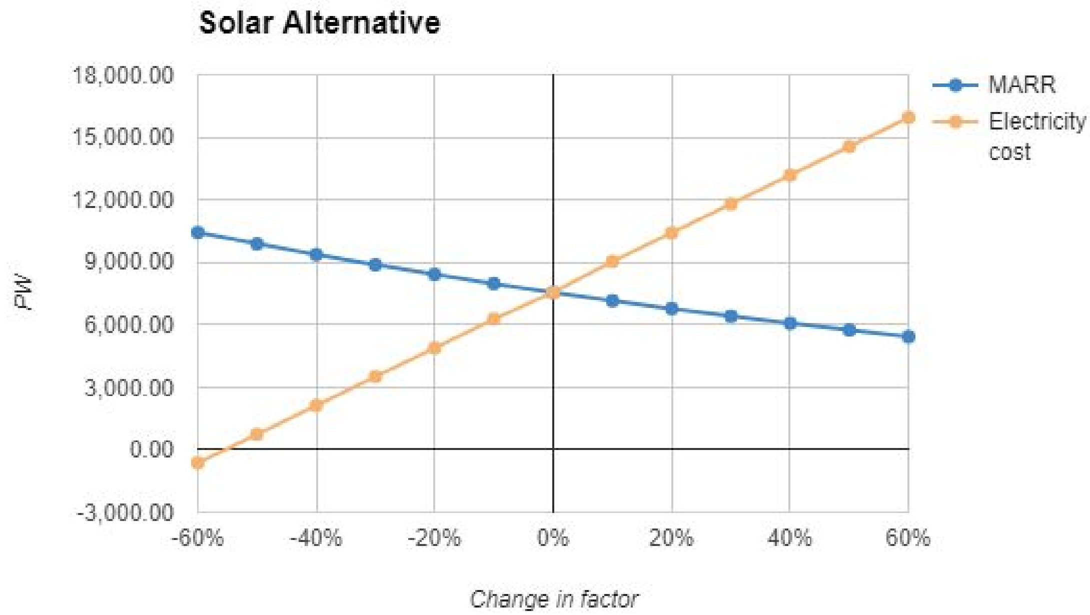
Appendix-4 : Hybrid System of Solar and Wind (6kW) Calculations

Year	Cost of Wind	Cost of Solar	Configuration	Total Cost	Income	Maintenance	Cashflow	Cumulative Cash Flow
0	-5,379.30	-3,408.00	-3000	-11,787.30	$0.0	$0.0	-11,787.30	-11,787.30
1					$1,290.8	-$361.0	929.83	-10,857.47
2					$1,350.2	-$368.9	981.26	-9,876.21
3					$1,412.3	-$377.0	1,035.25	-8,840.96
4					$1,477.3	-$385.3	1,091.92	-7,749.03
5					$1,545.2	-$393.8	1,151.40	-6,597.63
6					$1,616.3	-$402.5	1,213.82	-5,383.81
7					$1,690.6	-$411.3	1,279.31	-4,104.50
8					$1,768.4	-$420.4	1,348.03	-2,756.47
9					$1,849.8	-$429.6	1,420.13	-1,336.34
10					$1,934.9	-$439.1	1,495.77	159.43
11					$2,023.9	-$448.7	1,575.11	1,734.55
12					$2,117.0	-$458.6	1,658.34	3,392.88
13					$2,214.3	-$468.7	1,745.63	5,138.51
14					$2,316.2	-$479.0	1,837.18	6,975.69
15					$2,422.7	-$489.6	1,933.18	8,908.87
16					$2,534.2	-$500.3	2,033.86	10,942.73
17					$2,650.8	-$511.3	2,139.42	13,082.15
18					$2,772.7	-$522.6	2,250.11	15,332.26
19					$2,900.2	-$534.1	2,366.16	17,698.42
20					$3,033.6	-$545.8	2,487.82	20,186.23

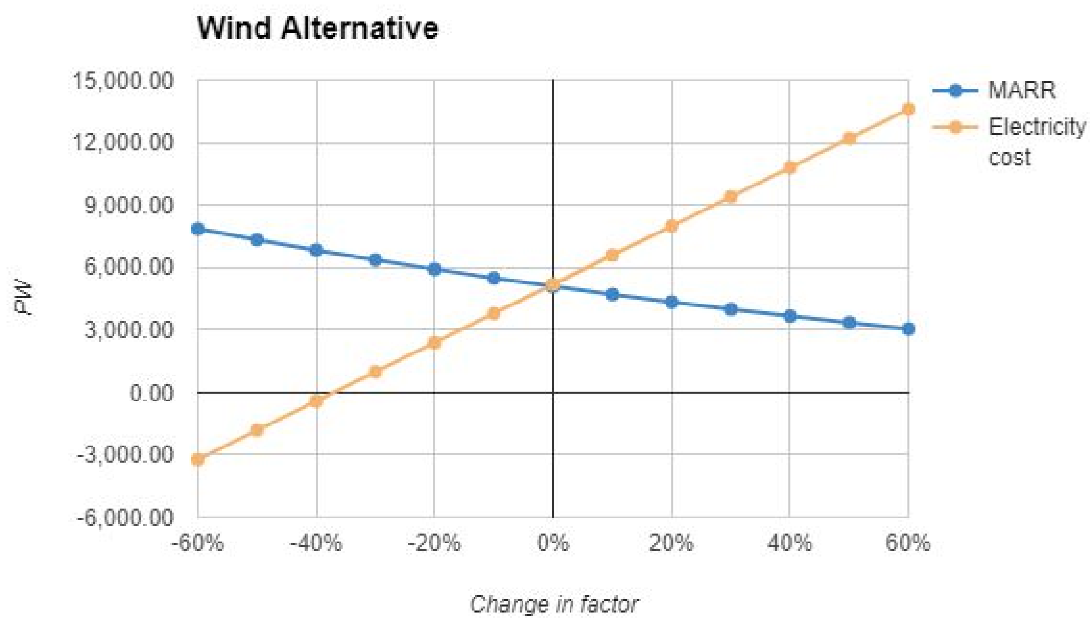
Cash Flow of 6 kW Hybrid System

Appendix-5 : Sensitivity Analysis

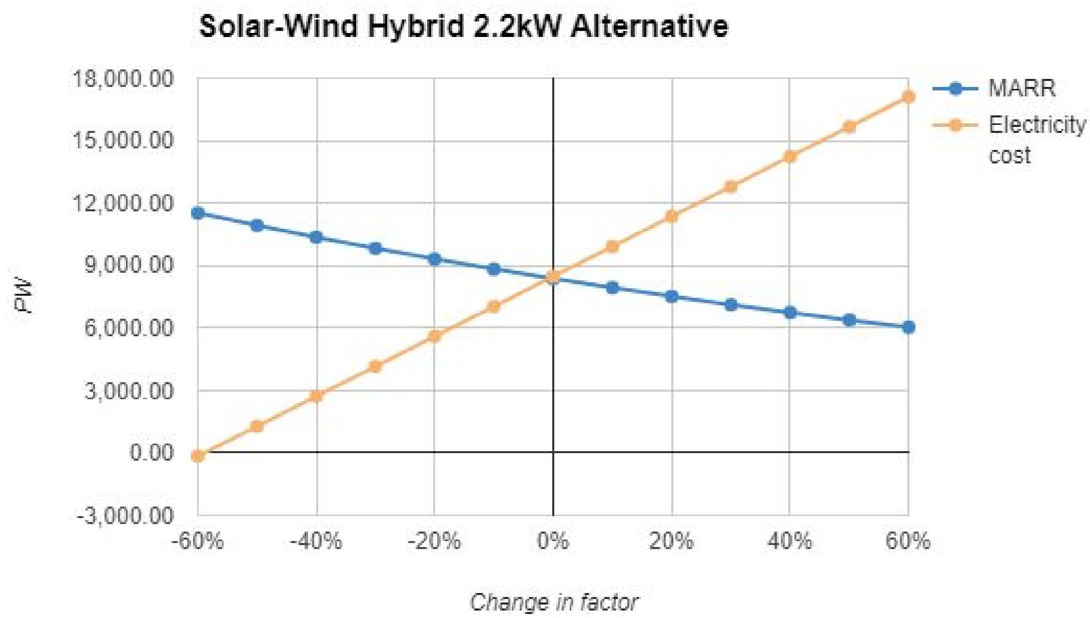
The graph below represents the sensitivity analysis of each alternative with both 2 criteria. Comparing between 2 changing variables which are MARR and electricity cost, the MARR has more sensitivity than electricity cost for every alternatives due to steeper slopes.



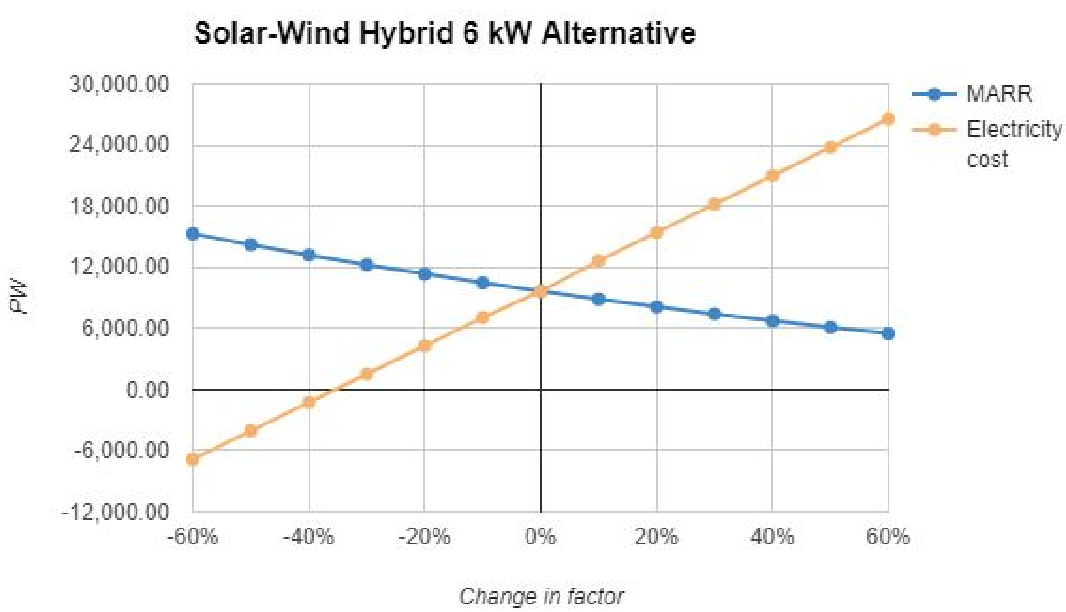
Sensitivity Analysis of Solar Alternative



Sensitivity Analysis of Wind Alternative

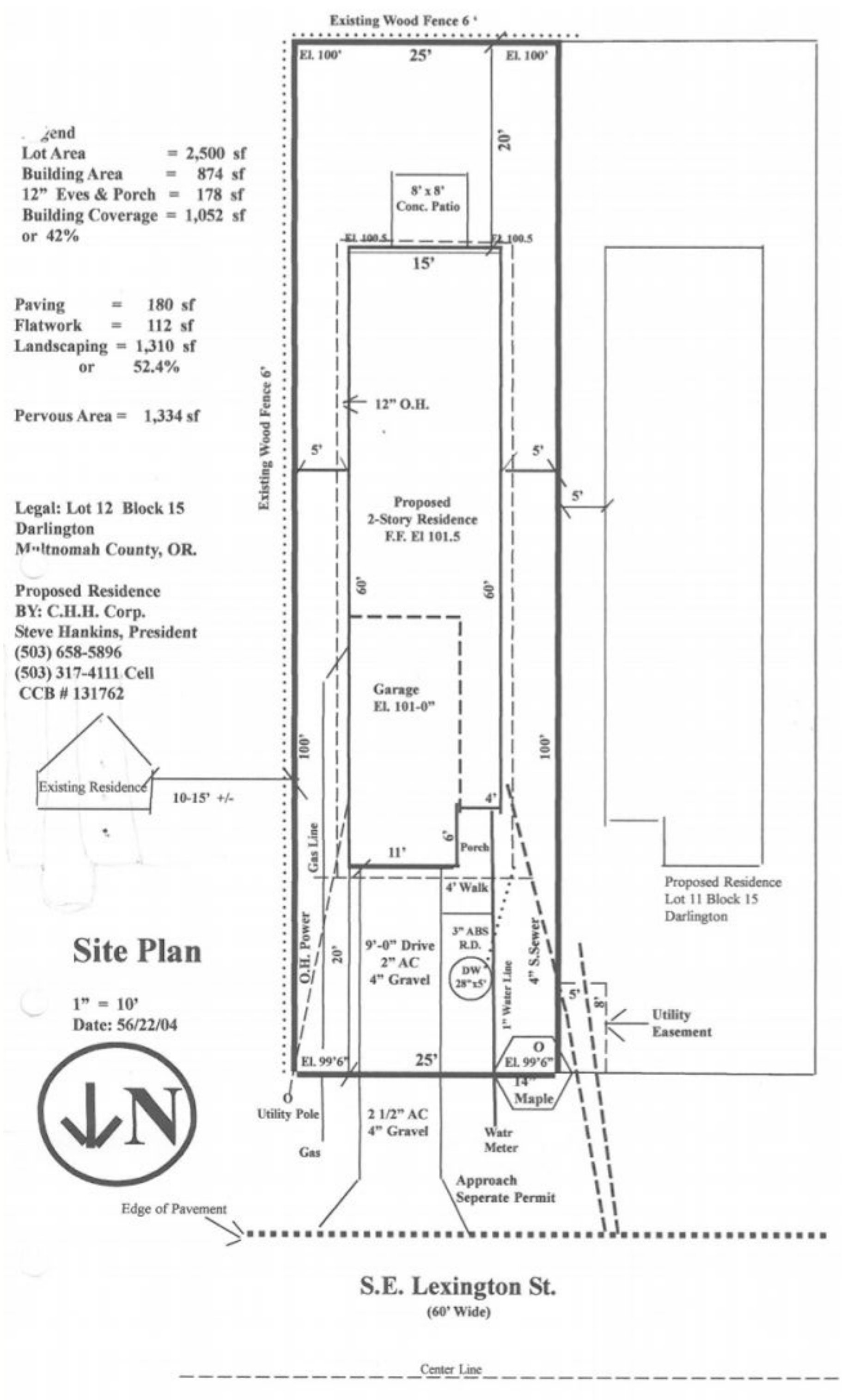


Sensitivity Analysis of Hybrid 2.2 kW System



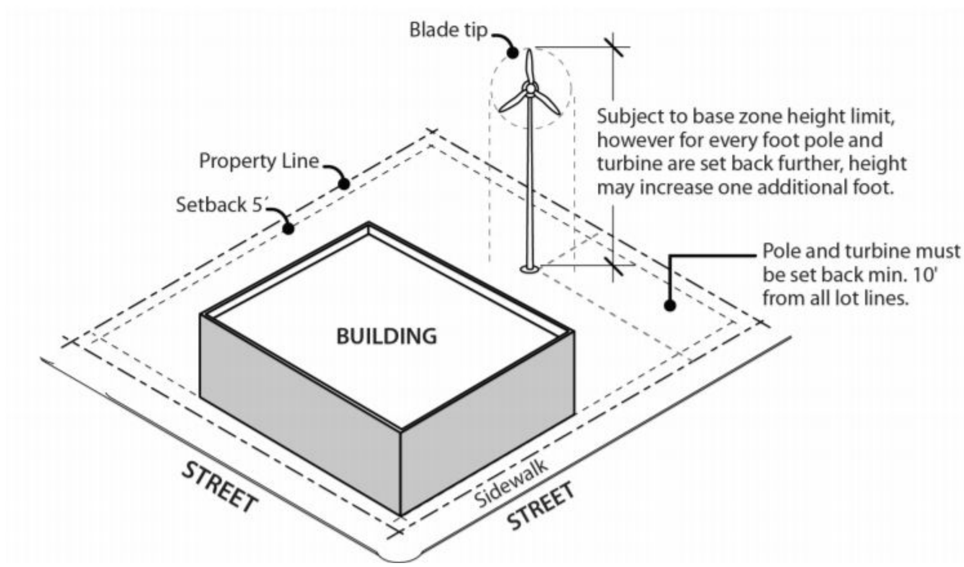
Sensitivity Analysis of Hybrid 6 kW System

Appendix-6 : Plan of the House

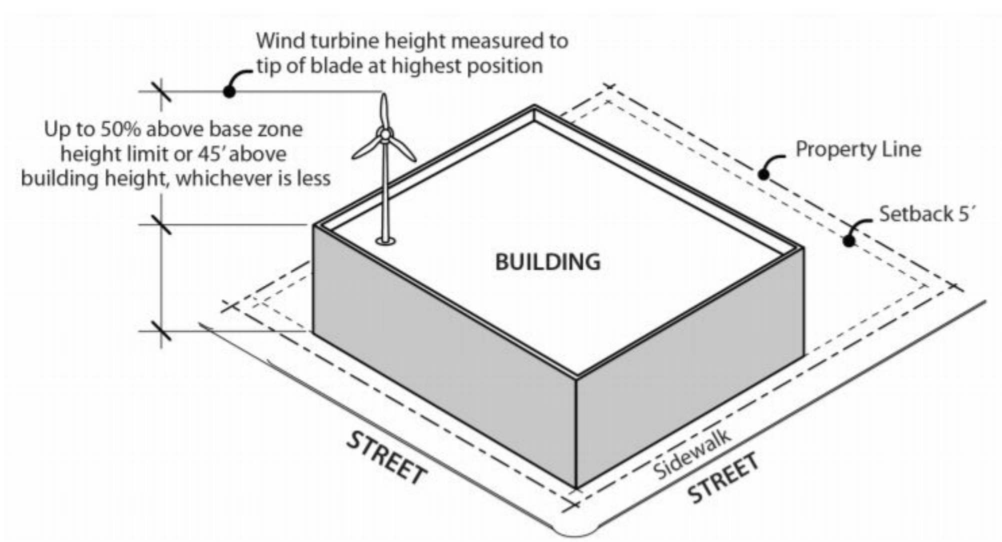


Appendix-7 : Law(33.299) of Wind Turbines in City of Portland

This law allows small urban-scale wind turbines. City of Portland wants to use the law to encourage further development of wind turbines that are appropriate for urban settings.



Pole-Mounted Wind Turbine



Building-Mounted Wind Turbine