PROJECT REPORT

SMALL WIND TURBINE PROJECT IN SMARTHOME

LI DI

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NOMENCLATURE

AC	Alternative Current
ARRA	American Recovery and Reinvestment Act
AWEA	American Wind Energy Association
DC	Direct Current
DOE	Department of Energy
EES	Engineering Equation Solver
EWEA	European Wind Energy Association
GWEC	Global Wind Energy Council
ITC	Investment Tax Credit
LED	Light-emitting diode
NC	North Carolina
NCUC	North Carolina Utilities Commission
NREL	National Renewable Energy Laboratory
PTC	Production Tax Credit
SPDT	Single pole double throw
SPST	Single pole single throw
SWTs	Small Wind Turbines

1. EXECUTIVE SUMMARY

Smart home, at Duke University is dedicated to utilizing renewable energy and smart technology as the means of improving the quality of life. One projects of the summer 2009 is the research on small wind turbines (SWTs) for power generation. There will be a demonstration for wind power generation at Smart Home by installation of one existing wind turbines at Pratt engineering school.

The goals of this project are:

- Study the feasibility of SWTs for power generation in smart home
- Comparison of wind power of smart home with coast NC
- Design, installation and operation OF SWTs
- Measure the SWTs

After paper research and initial design, the relative questions need to be decided in detail design, such as the method choosing one from two wind turbines which will be installed in Smart Home, the exact location, height, the mode of electricity generation, environmental impacts, public and neighbor reaction, facility and human safety control, maintenance mode, future work connection and continuity and so on. The problem will be mainly followed by credible guideline, or solved by discussion with experts, engineers.

Then commercial issue would be calculated, such as capital cost, tax incentive, return period, and the like. Then comes to the step of detail construction drawing design, certain software AutoCAD or the like may be involved. The order may go along with the design, considering the time delaying.

The final stage is the installation and commissioning, skilled workers or training may be needed. There must be quite a few modification need to be decided on site. After days of operation, the paper work should be sorted out in order to be easily research for the next researcher. The project will be end with the final presentation.

2. BACKGROUND INFORMATION

From the research paper, apparently, wind energy is developing with high speed recent years in the world, as well as in the US. North Huge amount object of wind energy production is expected in North Carolina, especial in the coast and mountain regions.

Duke University in Durham is not an ideal place for utility scale wind power development. But for small wind turbine utilization, there is still some chance, though it's not as windy as Beaufort, the power output is not that high. The advantage of using small wind power in Smart Home is that the small wind turbines are already available in Pratt engineering school, meaning big amount of cost will be saved. Great experts are easy to reach in Duke University, who will be really helpful during the project.

3. SYSTEM DESIGN

In this part, the location, hub height and tower type of SWTs will be chose. The designs of system, components are followed.

3.1. Location planning

Smart home is a south-face resident building with the size of 72' X 24' (21.95m X 7.32m) (Appendix D). The south wall and the north wall are 24' and 30'high separately. The birdview of Smart home is shown in Figure 3.1. The picture was supposed to be taken in June or July, 2007, because in this period, the green roof was completed but the solar panel had not. Though it is not the latest birdview, the main structure has been completed. Despite of the change of the temporary structures and equipments, the surrounding trees still remain the same. The smart home is roughly circled by 100-foot tall trees. The measure method of trees is shown in Appendix E. The distances from the house to the trees are from 10 - 40 m, to the south, east and north. To the southwest, there is a bigger space due to the low building of Freeman Center for Jewish Life. So the space around Smart home below 200 ft can be taken as wind turbulent zone (DOE 2005). And within this space, the altitude elevation rises from 112m in the south to 116m in the north.

Figure 3.1 Bird view of Smart home (taken from Google Earth 5.0 6.7.2009)

3.1.1. System plan

Three prospective designs are planned, shown below.

- Plan 1: Roof mounted 10 ft
- Plan 2: Front/back yard 30/60 ft with guyed tower/monopole
- Plan 3: Heat pump cooling fans energy recovery

In the plan 1, the SWTs monopole will be mounted in the front wall, around 10 ft high, so the hub height of SWTs will be 32 ft. This kind of tower is available in the market, for instance, AIR Roof Mount Tower from Southwest Windpower. The height of the pole is maxed at 12 ft (4m) (Southwest Windpower 2009d). And mounting turbines on rooftops would cause some problems, because all wind turbines vibrate and transmit the vibration to the structure on which they are mounted. This can lead to noise and structural problems with the building and the rooftop can cause excessive turbulence that can shorten the life of the turbine (DOE 2005).

Plan 2 is most popular installation for SWTs, there are several options, first is the location, back yard has more space than front yard, but it is more near the tall trees. Front yard, especially in the right middle of Figure 3.1, between a small tree and Smart home, it is ideally away from tall trees, but the space is limited and installation for high guyed tower may be difficult to achieve. And two kinds of tower are considered, monopole takes smaller space, but more expensive than guyed tower. And at higher places, SWTs can produce more energy, which is calculated in Chapter 2, but the costs rise as well.

Plan 3 has a creative view; there are two heat pump cooling fans outside the Smart home which run to cool down the R410a, refrigerant in the heat pump system. Near the fans, more windy air is felt, so if putting SWTs near the fans, or with a guided cover, more energy will produced, and expensive pole installation fee will be saved. But this kind of design is quite new, and there seems to be no application available in the market in the US, only one patent is similar by using existed wind turbine to recovery wind energy from mill tunnel fans (Berenda et al 1996). The influence of the fans and the heat pump performance is unknown, more detail research is needed.

3.1.2. Plan comparison

The plans are compared in technology maturity, investment costs, energy production, payback time, and so on. Due to summer project, there are restrains on budget and time of research.

Mounted roof pole, guyed tower and monopole are available in the market, but for fan recovery technology, information is rarely to find.

Investment costs include turbines, tower, and others. Turbines are free in the project, and the tower reference price list is based on www.affordable-solar.com, shown in Appendix F. The price for tower could be simply taken as two parts, tower kit and pole. The prices for 30 ft and 60 ft guyed tower are $170 and $300, and the prices are assumed to the same for the monopoles. The unit prices for guyed tower pole and monopole are $10/ft and $60/ft, therefore, the prices list for pole are seen below.

- 30ft guyed tower $300

- 60ft guyed tower $600
- 30ft monopole $1800
- 60 ft monopole $3600

So the total prices for tower are as below

- 30ft guyed tower $470
- 60ft guyed tower $900
- 30ft monopole $1970
- 60 ft monopole $3900

And for roof mount tower, the price is $110 for the kit and $120 for 12 ft pole, so total price is $230.

And for other expense including battery, wire, meters, Lightning Arrestor, and so on is assumed as $300.

There is big difference in the energy production talked before by two methods for 10m hub height, which could be 12 kWh/yr or 118 kWh/yr. Here the average value, 65 kWh/yr, is used for comparison, and for 20m hub height, 96 kWh/yr is still be used. And the energy purchase price is assumed as $0.1/kWh. Money saved per year for different height is shown below.

- 30ft guyed tower/monopole$6.5/yr
- 60ft guyed tower/monopole $9.6/yr
- Roof mount tower $6.5/yr

And the average wind speed near the cooling tower is assumed as 5m/s, the annual power output is 384kWh (from table 2.9), and the money saved is $38.4/yr.

So the investment cost and payback time is shown in Table 3.1.

Table 3.1 Economical comparison

Plan		Investment	Money saved	Payback time
		$	$/yr	yr
1		530	6.5	82
2*	30G	770	6.5	118
	30M	1200	9.6	125
	60G	2270	6.5	349
	60M	4200	9.6	438
3		300	38.4	8

* G stands for guyed tower, M stands for monopole

All the plans will be compared based on the technical, economical, time factors based on the following criteria. Total points is 100, technical factor and time accounts for 25 points each, and economical factor divides into 2 sub factors, investment and payback time, each 25 points. For each factor, the credit is given between 0-1. For technical factor, fully mature market gets full point, limited available market gets 0.5, only in research stage gets 0.1, and totally new idea gets 0. For investment below 300 gets 1, and the credit drops as the price rises, if investment is over $1000, 0 credits is given. Payback time below 10 year credits 1 and drop 0.1 every five year until 0. Installation aim can be achieved within 10 weeks gets 1, if not, gets 0.

The systems that get higher points means better for the project. And the total comparison is shown in Table 3.2. Eventually, Plan 1 gets highest points, and is the best solution for this project.

Table 3.2 Total comparison

Plan		Tech.	Invest.	Payback	Time	Total points
		25	25	25	25	100
1		1	0.7	0	1	67
2*	30G	1	0.3	0	1	58
	30M	1	0	0	1	50
	60G	1	0	0	1	50
	60M	1	0	0	1	50
3		0.1	1	1	0	53

* G stands for guyed tower, M stands for monopole

3.2. Detail design

Plan 1 is chosen finally, and the wind turbine will be installed at the front of Smart Home on the balcony of the 1st floor. The pole of wind turbine will be attached to the steel column of the building. The detail design for mechanical part and electrical part will be described below. The whole system scheme is shown in Figure 3.2.

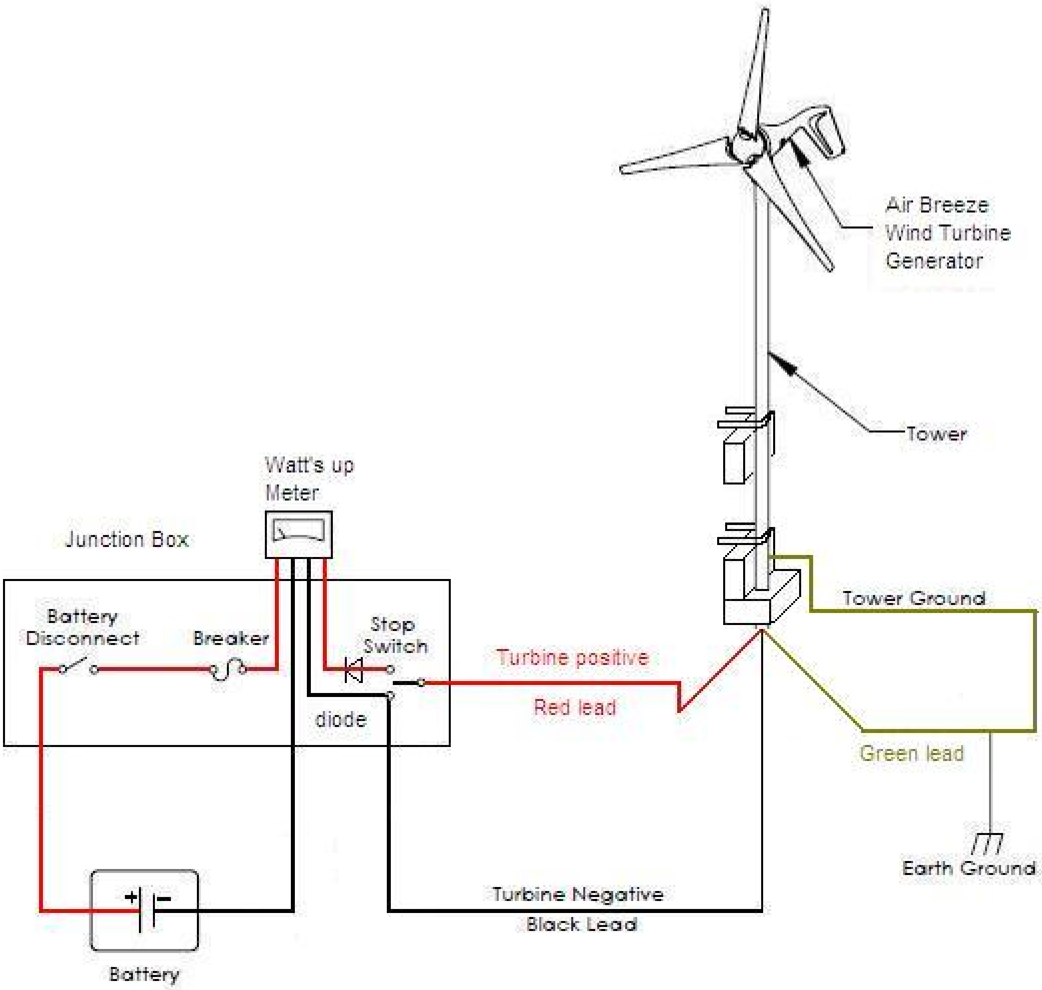

Figure 3.2 Wind turbine system scheme

3.2.1. Mechanical part

The wind turbine is supposed to attach the steel I-beam column, two plans are considered. The first plan is to weld a piece of steel where the holes are drilled before, which is similar with the way the solar panels attached on the column. Because drilling a 5/16” holes on the steel I-beam is thought to be difficult by a small hand drill, Ryobi P203, which is only available in Smart Home, but the holes would be easy to be drilled in Machine shop by big milling machine. And the drilling holes on the column could hurt the structure of Smart Home. However the welding machine is hard to get. And many holes, even large ones are found on the lower part the I-beams, which are drilled by former students before. So Plan B, drilling holes on steel I-beam, is eventually used.

At first, clamps are considered to attach the pole on the column, which is mentioned in the roof mount kit owner’s manual, but the suitable size clamps are not easy to get. Thanks to Professor Matthew and Professor John, the idea of U-Bolts made things easier.

So finally, the plan for mechanical part is to attach the pole by U-bolts to I-beam and the holes are drilled directly on the I-beam by hand drill. And the parts and tools are listed below.

<u>Parts list</u>

Wooden block	X3
U bolts	X2
Mounting pole	X1

<u>Tools required</u>

Measuring tape
Pencil
Plumb bob
Power drill

Wrench
Hacksaw
Ladder
Eye protection

Dimensions of the parts

Pole

The outside diameter of the pole is 1 15/16” and the length is 12’4”, the material is aluminum of 1/8” wall thickness.

U Bolts

U Bolts is round bend type, seen in Figure 3.3, the dimensions of the U Bolts are as followed.

A: 5/16”
B: 2 1/2”
C: 5 3/16”
D: 3”

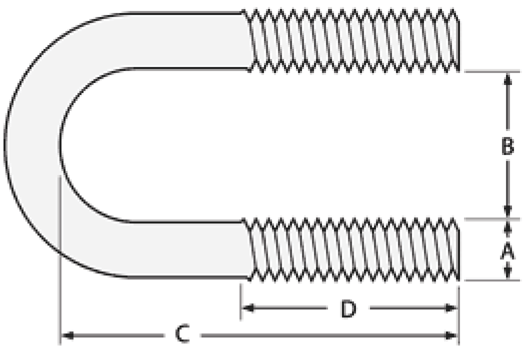

Figure 3.3 U Bolts dimensions

In realty, the U Bolts are made by bending zinc plated threaded rods, with the size of 5/16”-18X24”, in addition, the relative nuts and washers are bought.

Wooden block

Two wooden blocked are put between the pole and the column, with the dimensions 2”X5 1/2”X5 1/4”

Another wooden blocked is used as bottom, with the dimension of 3 1/2”X5 1/4”X8”.

2 pairs of holds will be drilled on the column, with diameter of 5/16”, and 2 13/16” between centers. They are drilled by black oxide bit and bronze oxide bits and first by using 7/32” bits and then 5/16” ones.

The upper pairs are set at 3” below the top, and the lower pairs are set 12” above the bottom.

The thrust

At the wind speed of 100mph (45m/2), the thrust is 52lb (230N) (Southwest Windpower 2009a). And the wind turbine can survive at the wind speed of 110 mph.

A test for the pole is done on July. 20^{th}, the pole didn’t bend at the weight of 24kg (52lb) at one end and the supporting point at 4’ from another end. So the pole can survive at 100mph as well.

The nuts and washers are tested under the load of 24kg for each as well on July. 27^{th}.

Mounting the tower

The pole, bought from waste metal shop by Jim and me, costs only 18 dollars, far cheaper than a new one bought from manufacture or other places.

In realty, the suitable size U-bolts are not found in Home Depot, because the ones we need are much longer than in the market. So U-bolts are made by bending zinc plated threaded rods, with the size of 5/16”-18X24”, in addition, the relative nuts and washers are bought. That’s Jim’s idea, which is really good. Because the threaded rods are not very thick, it’s not so hard to bend by hand and some basic tools. I use the table clamp to bend the rods around 90 degrees, and then bend them just by hand, using the pole in between.

The wooden block is cut by hand, and then I found there's an electrical saw. So when making the frame for control box, I use the electrical saw with normal saw blade. But the saw blade should be set near to the block and starts with low speed, and increase gradually. Otherwise the saw blade shakes very much and is easy to be broken.

On drilling the holes, I actually had some trouble like what I expected before. There are four holes need to be drilled totally. Things looked fine at the drilling of the first two holes. I used first 7/32" bits and then 5/16" bits of black oxide and bronze oxide bits; it took me around two hours to make them. But for the upper two holes, I spent two days and there was nothing to improve. Only few black powders fell down from the bits, instead of the metal scrap metal like before. I thought it could be the problem of bits, which were ruined after drilling the two holes, or maybe the hardness of the tips of I-beam is harder. After checking online and discussing with Jim and other peoples, I got some tips. First I understand why it was good way to drill by small bits first, because the pressure could be not that big, and the drilling could be easier. And then the drilling should be slow, and spill some water in the holes and on the bits, in order to cool down the bits. If the temperature of the bits is too high, they will be quickly ruined. So I know I made a mistake before, the instruction of the bits says black oxide high speed steel drill bits, and I though it should use high speed. Actually, it's just the name of the material, and it can withstand higher temperatures without losing its hardness than high carbon steel. But it still need low speed and cooling down as drilling on the steel. So later I tried to drilled with small bits first with low speed and cooling down by water, I made it by only another two hours. But there were still some lesson to be learnt, first, it can't be drilled from both sides, because it was very hard to make them exact position, and it can not be drilled when half through due to high toque. Second, the two sizes of bits could not be too close, I first use 17/64" to drill through, and when I want to expend the hole with 5/16" bits, the drill was just stuck in the hole, and throw you aside, which is very dangerous when working on the ladder at high places. The good way is to spill some water and drill with 11/64" bit for 30 seconds, which makes around a eighth inch deep hole, then spill some water again and change 5/16" one to drill another 30 seconds. And make sure not press to hard in the beginning, and hold the drill stable.

After all the parts were done, the wind turbine is attached on the top of the pole, with wires inside. Luckily the length of wires is just fine. And the design is well followed so there is no need for cut the wooden block or drill holes on pole for wires.

On the mounting, first put the bottom of the pole to the end of the balcony, and lift the wind turbine side up onto the top of the column, attach with U-bolts, and fasten a lit, and erect up the whole wind turbine, check whether it was straight. And fasten all the U-bolts. I should have cut the U-bolts shorter first, because nuts can not be screwed by hand, and the U-bolts are really long, it took me around 2 hours to just fasten four nuts.

3.2.2. Electrical part

The electrical system connection is shown in Figure 3.4.

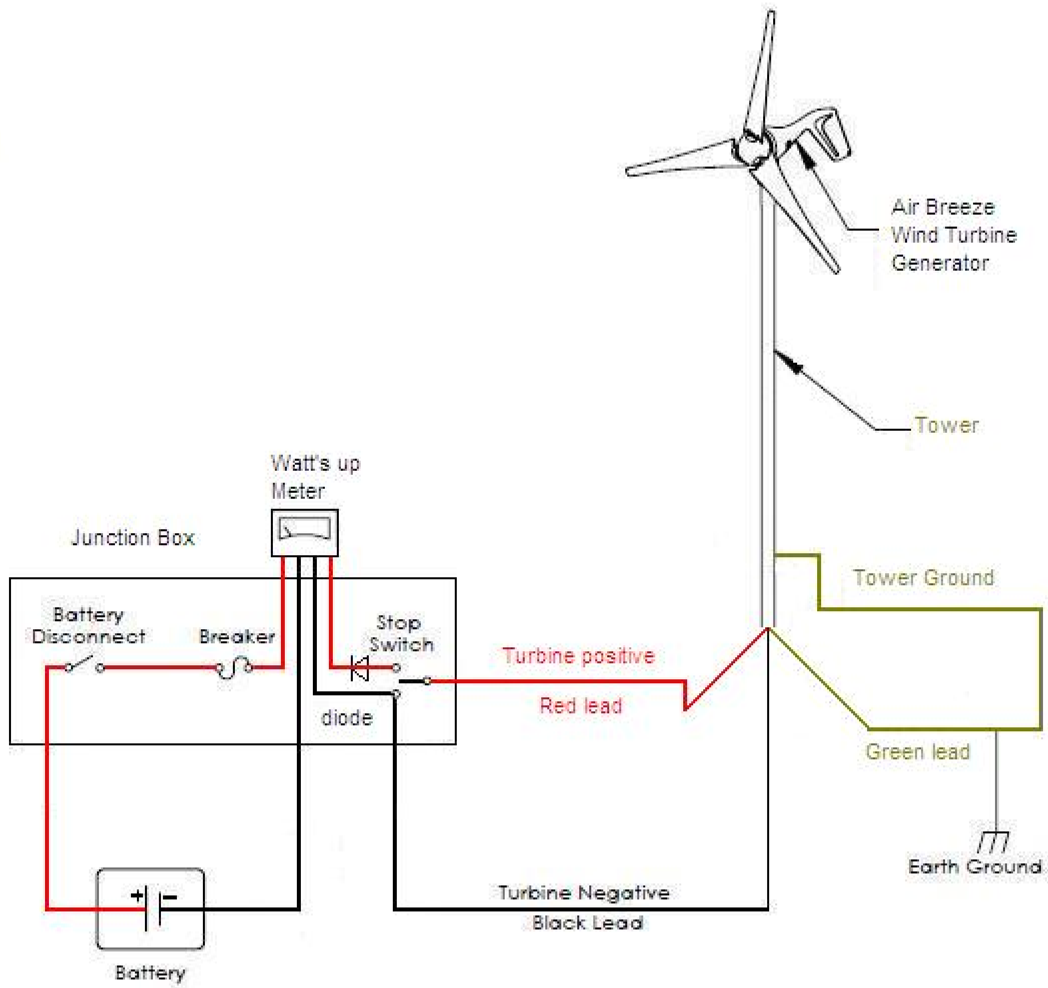

Figure 3.4 System electrical connection

Parts list

Battery
Breaker
Stop switch
Diode
Meter
Wire
Junction box

Specifications

The length of wire is 10ft or 3m, with AWG No. 10 or the metric wire size is 6mm^{2,} and AWG No. 12, 4mm^2.

SPDT (Single pole double throw) stop switch is break-then-make type, the switch first disconnect the battery and then shorts the turbine output wires together, in order to cause the turbine stop spinning. Shorting the turbine does not result in any damage or additional wear of the unit.

Another SPST (Single pole single throw) switch is used for disconnect the battery.

Breaker is made of fuse and fuse holder, at 20 Amps DC.

Battery is 12V, 12Ah.

Diode is 14.2V, 15A.

Meter is digital, by which DC amps, amp-hours, watt-hours, volts and watts can be measured.

Junction box is shown in Figure 3.4

Connections

The best Junction box is that it can be used outside, and the meter can be red easily. But I made a mistake for buying a box which is for basically for wire connections, meter reading is really hard. Besides, there is no room for the meter inside, so I plan to put the meter outside with the rain cover. Three holes are drilled on the face of the junction box, and two switches and fuse are put there. Connecting the wire in such a small space is difficult, because the wires are not easy to bend, so I abandon the idea for compacting the wires and integrity the meter and the junction box tightly together. I connected all the wires with junction box and stretch the wires outside and then connect the meter. The joining of two or three wires is another problem, the meter has soft multiple wires but the connection wires are much thicker. I tried welding the wires together, or made hooks, but all were not good, due to loose connection or easy to break. So finally I whirl the wires together and cover with black insulation tapes.

One big problem happened when I tried to connect the battery, the fuse burnt, and I checked all the wire connection and different parts, and finally I realize that when the wind turbine doesn't turn, it is no more than wires, so the battery is short circuited. So the diode is considered to be connected in the circuit after checking online and discussion with experts. After visited Radio shack, I bought a 60V, 6A diode, and finally the system works.

3.2.3. Load side application

The load will connect with the battery as 12V DC, from production side, around 5-10kWh/month or 167-333Wh/day electricity can be produced.

So the load could be 10W for 24 hour usage, 50W for 5 hours daily, or 200W for one hour a day.

Some of the perspective applications are mentioned below.

- LED Lights

LED could be used for lighting, which uses tiny energy; each LED is around 4-5 W. it can be used in the media room for picture decoration, or light the LEED plate in the common zone.

- Anti-mosquito light: 12W for 100 ft^2

Another practical application is anti-mosquito light. Mosquitoes are quite bothering during the summer time, especially outside the house. Some anti-mosquito light could use DC with 12W for 100ft^2.

- Battery Charger

It could be used as the battery charger only. In smart home, there is a bicycle with 12V DC battery, so the wind turbines can be used as the charger.

- Rechargeable Flashlight

Some flashlights use LED with rechargeable battery, 5W each.

- Bed warmer

Some bed warmers or pad warmers can use 12 V DC, with 200W.

- Aquarium

Smart Home could have a small aquarium with some fishes, and the lights and bubbler can be powered by battery.

4. ECONOMIC ANALYSIS

Everything bought in the project is by cash, no loan nor mortgage, due to the small size. The average price of electricity from current provider is assumed as 0.07USD per kWh, and considering inflation, electricity price is expected to increase at the rate of 2%/year. The total installed cost is USD132.56, and the breakdown is shown in Table 4.1

Table 4.1 Installed cost

Parts	Price/ USD	Comment
Small wind turbine	0.00	Pratt bought in 2008
Pole	18.00	Waste metal shop
Meter	72.34	Order online
Thread rods, nuts, washers, switches and junction box	30.27	Home Depot
Fuse and fuse holder	11.95	Radio shack
Wood block	0.00	Waste
Battery	0.00	Smart Home
Wires	0.00	Smart Home
Tools	0.00	Smart Home
Total	132.56	

The availability of the turbine, which is an allowance for wind turbine downtime, is assumed as 98%. Due to the hub height is only 10m, so the performance derating is considered as 10%, which is a derating of the wind turbine power curve for wind turbulence. So the payment time is 20 years. The cash flow is shown in Figure 4.1. The detail calculation and assumption is seen in Appendix G. The investment is far less than the estimated value in Chapter 6.1.2., because the pole and many parts are bought by far cheaper channel, instead of from manufactures.

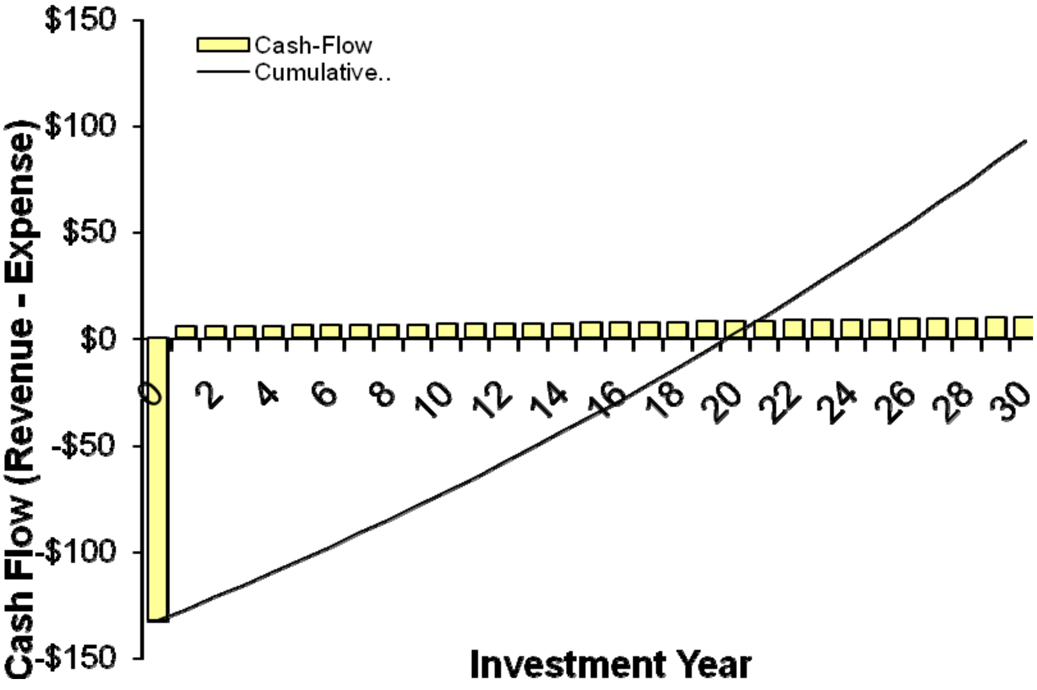

Figure 4.1 30-year nominal dollar cash flow

5. LESSONS LEARNED

The installation of SWTs for Smart Home is completed at night on August 9th, 2009, while the project started from June 15. It took 8 weeks totally, 2 weeks for paper research and 6 weeks for installation. Now it's a new attraction for Smart Home tour. From this summer course, I have learnt quite a lot on wind turbine through peer review and hand on study.

Most of the time, things are not as easy as they seem to be. Many small troubles come out which never be expected, like how to connect wires, how to drill the holes, waterproof, and so on. And other things that worked well for your project are list below

A good way to solve those problems is searching online and discuss with experienced people. I like the lunch talking every Thursday. The idea of using U-bolts is just from the lunch table.

- The most important solution in installation is that the diode is used between battery and wind turbine for protection during the slow and none wind period to prevent the battery to short circuited. Even the wind turbine manufacture ignores this issue, there is nothing mentioned in their documents.
- Right way for drilling
- Various software utilization, Auto CAD, HOMER, DateFit, and so on.

For future work on wind turbine at Smart Home, some subjects are listed below

- Load side application should be attached, and the simulation of load and power production can be done in software HOMER.
- The rain cover could be improved from the view of aesthetics.
- Tracking and reading the energy output
- The pole strength should be double checked as strong wind

Finally, thank Smart home and Duke University for giving me this opportunity to do this project.

REFERENCE

Tony Burton, David Sharpe, Nick Jenkins, Ervin Bossanyi (2001), Wind energy: handbook, John Wiley and Sons, New York, USA

GWEC (2009), Global wind report 2008, GWEC, Renewable energy house, Brussels, Belgium

Enercon (2007), World's most powerful wind turbine installed near Emden, WINDBLATT, Issue 04, 2007, Enercon GmbH, Aurich, Germany

EWEA (2009), EWEA 2008 annual report, EWEA, Brussels, Belgium

AWEA (2009a), Annual wind industry report year ending 2008, AWEA, Washington DC, USA

DOE (2008), 20% wind energy by 2030, US Department of Energy, Springfield, USA

NREL (2009a), United States - 50-Meter wind resource map, available at www.windpoweringamerica.gov, last modified 19. 5, 2009, as accessed 23.6, 2009

NREL (2009b), North Carolina Wind Resource Map, available at www.windpoweringamerica.gov, last modified 12.9, 2008, as accessed 23.6, 2009

DOE (2005), Small wind electric systems a North Carolina consumer's guide, US Department of Energy, available at www.windpoweringamerica.gov, last modified 9.9, 2008, as accessed 24.6, 2009

EWEA (2008), Wind energy the fact, EWEA, available at www.wind-energy-the-facts.org, last modified 2008, as accessed 24.6, 2009

AWEA (2009b), AWEA small wind turbine global market study year ending 2008, AWEA, Washington DC, USA

NC wind energy (2009), North Carolina wind energy at Appalachian State University, Appalachian state university, available at www.wind.appstate.edu, last modified 2009, as accessed 24.6, 2009

AWEA (2009c), Small wind in North Carolina, AWEA, available at www.awea.org, last modified 13.5, 2005, as accessed 24.6, 2009

NC GreenPower (2009), North Carolina Green Power, available at www.ncgreenpower.org, last modified 2009, as accessed 24.6, 2009

Southwest Windpower (2009a), Air breeze, available at www.windenergy.com, last modified 2009, as accessed 1.7, 2009

Southwest Windpower (2009b), Air X, available at www.windenergy.com, last

modified 2009, as accessed 1.7, 2009
Southwest Windpower (2009c), Air Breeze™ and Air X™, available at www.windenergy.com, last modified 2009, as accessed 1.7, 2009
J. van Dam, M. Meadors, H. Link, P. Migliore (2003), Power performance test report for the Southwest Windpower AIR-X wind turbine, NREL, Golden, Colorado, USA
Paul Gipe (2007), Field Tests on Air Breeze BR0001068, available at www.wind-works.org, last modified 27/12/2007, as accessed 1.7, 2009
Dennis Scanlin (2009), E-mail communication with Dennis Scanlin, director of North Carolina Small Wind Initiative, July 1, 2009
Southwest Windpower (2009d), Roof mount kit owners manual version 1.5, available at www.windenergy.com, last modified 2009, as accessed 7.7, 2009
Berenda, Robert M, Ferenci, Jack (1996), Exhaust air recovery system, United States Patent 5512788, Publication Date 30.4, 1996, available at www.freepatentsonline.com, last modified 30.4, 1996, as accessed 7.7, 2009

APPENDIX D

Floor plan list of Smart home.

1. Main level
2. Mechanical Room
3. Roof Plan
4. Upper Level

APPENDIX E

Method of measuring of the height of trees

1. Choose the tallest and most straight trees around Smart home.
2. Choose a sunny day, measure the length from the root of the trees to their tip of shadows, and note down the length and the time.
3. Use online solar elevation calculator available at http://www.srrb.noaa.gov/highlights/sunrise/azel.html
4. Take smart home for example, choose lat/long at city, enter the lat/long as 26^{o}00’02”N / 78^{o}55’16”W, UTC=5, and Daylight saving time = yes. Then choose the date of measuring, and click “calculate solar position”.
5. Height of trees= tan(solar position)X length of shadow.

APPENDIX F

Price list for tower from www.affordable-solar.com.

Bergey Energy			Southwest Windpower	
Product	Price		Product	Price
Excel Standard Guyed Tower 60'	$ 9,947.00		Augers, 36", set of 4	$ 110.00
Excel Standard Guyed Tower 80'	$ 10,682.00		Augers, 48" Galvanized , set of 4	$ 185.00
Excel Standard Guyed Tower 100'	$ 12,642.00		Augers, 48", set of 4	$ 123.00
Excel Standard Guyed Tower 120'	$ 14,896.00		Augers, 60" Galvanized, set of 4	$ 239.00
Excel Standard Guyed Tower 140'	$ 16,856.00		AIR Roof Mount Tower Kit with Seal	$ 110.00
Excel Tilt-Up Guyed Tower 60'	$ 11,172.00		AIR Roof Mount Tower Kit without Seal	$ 97.00
Excel Tilt-Up Guyed Tower 80'	$ 12,377.00		AIR Roof Mount Kit Seal	$ 57.00
Excel Tilt-Up Guyed Tower 100'	$ 14,582.00		AIR Marine Tower Hardware Kit	$ 193.00
Excel Tilt-Up Guyed Tower GripHoist Kit 60' & 80'	$ 3,014.00		AIR Marine Aluminum Pole Set 9'	$ 208.00
Excel Tilt-Up Guyed Tower GripHoist Kit 100'	$ 3,381.00		AIR EZ Tower Kit 29'	$ 573.00
Raising Kit	$ 1,950.00		AIR Guyed Tower Kit 27'	$ 169.00
XL.1 Tower Raising Kit	$ 348.00		AIR Guyed Tower Kit 45'	$ 299.00
XL.1 Tilt-Up Guyed Tower Kit 60'	$ 1,838.00		Whisper 100/200 24' Guyed Tower Kit	$ 308.00
XL.1 Tilt-Up Guyed Tower Kit 80'	$ 2,249.00		Whisper 100/200 30' Guyed Tower Kit	$ 495.00
XL.1 Tilt-Up Guyed Tower Kit 100'	$ 2,671.00		Whisper 100/200 50' Guyed Tower Kit	$ 687.00
			Whisper 100/200 65' Guyed Tower Kit	$ 935.00
			Whisper 100/200 80' Guyed Tower Kit	$ 1,145.00
			Whisper 500 30' Guyed tower kit	$ 949.00
			Whisper 500 42' Guyed tower kit	$ 1,035.00
			Whisper 500 70' Guyed tower kit	$ 1,517.00