Renewable Energy for Oak Grove, Kentucky

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Problem Research

Kentucky's modern agriculture was founded off fossil fuels such as coal, gas and oil. Currently Kentucky is ranked 5th in the largest coal producer in the United States. Many studies have shown that the burning of these fossil fuels has a detrimental effect on people's health and the environment. These studies have opened the eyes of many Kentuckians to make the shift towards creating new technologies and resources for cleaner renewable energy and ridding the use of fossil fuels. Kentucky continues to heavily rely on the use of fossil fuels, mainly coal. Coal is a nonrenewable energy and is being used at a quicker rate than its rate of regeneration. This means coal will eventually run out. However, the renewable energy resources would be around indefinitely and do not run the risk of elimination.

From research there are different avenues of renewable energy sources that could be used in the "Bluegrass" state. These include hydro dams, mini hydro water systems, solar power, and biomass. However, surprisingly enough Kentucky has not yet focused on providing a lot of opportunities for people to have renewable energy in their homes or businesses.

In wind power, Kentucky is ranked to have low potential for production because of the geographical location of the state. These is not enough wind speed averages to generate wind-power turbines. According to U.S. Department of Energy, Kentucky has low potential and is not favorable for geothermal. Geothermal energy comes from the heat in the earth, this energy could be used to heat people's homes and buildings. The western part of the United States has the highest potential for geothermal energy, some states include New Mexico, Arizona, Nevada, and California. Kentucky has a lot of opportunities to provide hydropower electricity as a renewable energy source. Kentucky currently generates about 4% of their electricity from hydropower. The current hydro-power producers are Kentucky Dam, Barkley Dam, Laurel River Dam, Wolf Creek

Dam, Mother Ann Lee Hydroelectric Station, Dix Dam, and Ohio Falls Generation Station. Kentucky has a lot of untapped potential to generate electricity from water flowing over existing dams with in the state. There are 33 other dams that could be utilized for hydropower in Kentucky. There is also a lot of potential to use biomass as a renewable energy alternative. Biomass is any biological mass (plant or animal) that can be burned to create electricity or fuel. This can include agricultural residues, animal manure, wood wastes, food and paper industry residues, sewage sludge, and a variety of grasses and crops. Kentucky has 14 plant species that are considered suitable for biomass energy production. Kentucky currently offers incentives for people to produce, utilize, or develop bio-based energy technologies. Solar power energy has been at a steady growth in Kentucky, this is due to new technological improvements of solar photovoltaic systems and a variety of financial incentives offered to consumers. Kentucky has good potential for solar power energy, the state gets four to five peak hours of sunlight a day, and up to six hours in the summertime (depending on the exact location where someone lives). There are many residents in Kentucky that use solar panels in their homes.

Oak Grove Home Renewable Energy Considerations

For this research project the Kentucky residence being focused on is in a little rural town called Oak Grove. Oak Grove is in Christian County and has a population of 7,500 residents. The house is located at 735 Shetland Drive in Oak Grove, Kentucky. It is a single-family, 3-bedroom home that is 1,200 square feet on a 0.31-acre lot.

The home currently gets its electricity from Pennyrile Rural Electric Co-Op. Pennyrile Electric is a cooperative that purchases its electricity from Tennessee Valley Authority (TVA). TVA is a corporate agency that provides electricity for many different businesses and power companies in the southeastern part of the United States. TVA provides electricity to about 10

million consumers. Pennyrile Electric partners with TVA to provide different options for renewable energy inside homes and businesses. One of these programs is called the Green Power Program, which helps with the costs of installing a solar panel system.

Researching about the different renewable energy options for this home it was determined that wind power and hydro-electric power would not be a favorable or feasible option. Wind speeds in Oak Grove have a speed of 4.5 miles per hour (mph), the max wind speed recorded for this area in 2018 was 6.6 mph. Even the smallest wind power system requires about 8 miles per hour of wind to work properly and generate electricity. A small wind system also needs a half acre to work ideally, the home only had 0.31 acres of land. Hydro-electric power is not a favorable option because the home's location is not close enough to a useable water source.

According to National Renewable Energy Laboratory (NREL), Christian County has about 150 tons of biomass resources. Biomass could be used to help generate power into the home. However, there are many environmental considerations before trying to use biomass energy in Kentucky.

For this project, the predicted most feasible and favorable renewable energy source for this home was solar. According to NREL, the home's location has a high potential to produce solar power energy, with 4.4 peak hours of sun insolation. Pennyrile Electric company also makes it possible for an installation of a solar system into the home. The best option believed is to install a solar photovoltaic (PV) system for the home. In the thesis defense it will prove if installing a solar power system would be feasible and favorable.

Job and Career Research

Andrew Sendy Biography

Andrew Sendy is currently the Chairman of Solar Investments Inc. and the Chief Executive Officer of Solar Wholesalers. Solar Investments Inc. oversees three web-based solar companies for the United States: Solar Reviews, Solar Estimates, and Solar Panel Talk. Solar Wholesalers is a company started by Mr. Sendy in 2008 and was one of the first solar power companies in Australia. Andrew Sendy earned his Bachelor of Law degree from Flinders University in Adelaide, Australia in 2001. He was awarded the Piper Alderman Prize from Flinders University. In 2005, he earned a bachelor's degree in commerce also from Flinders University. Andrew started as a corporate lawyer for two major corporates in Australia in the early 2000's. In November 1999 he created and operated the company Strategic Ecommerce Limited (SEL). SEL is a company that supplies e-procurement solutions and related services to Australian buyers and sellers. In 2007 he sold the company to Secure pay. After he sold the company he followed his interest and research in solar power and continues with that field today. Andrew has written many publications about the residential solar industry in the United States. He currently resides in Denver, Colorado and is working with various U.S. solar power companies in helping consumers who are considering going solar. He is one of the first people to help consumers through a web-based friendly environment get solar power system information and projected costs to install solar system into a resident or business.

Career

Andrew Sendy has Solar Power Project Manager listed under occupations on his LinkedIn webpage. He has helped be a project manager for many solar system projects within the United States and internationally. According to U.S. Bureau of Labor, the median salary for a Solar Project Manager is $83,000 annually and the job outlook is expected to increase 13% from 2016-2026. The required education for a Solar Project Manager is a bachelor's degree and a

Project Management Professional (PMP) certificate. Similar careers to a Solar Project Manager include: Wind Farm Site Manager, Wind Energy Project Manager, and Construction Management.

Use of Mathematical Models in Research/Publications

Andrew Sendy was one of the first to create a web-based way for consumers to accurately get information about the costs of installing solar panels into their homes. Andrew Sendy's helped create the website Solar Estimate and currently oversees the web-page. This web-page shows the costs solar panels for a specific residents or building. It also shows different ways to view different solar power costs for a specific home or building. Solar Estimate was a helpful tool used in research about the costs and type of solar panel system would be needed for the home.

Aron P. Dobos Biography

Aron Dobos is currently the Director of Solar and Wind Analytics at the Envision Energy. Here he helps lead product development and management for Envision Energy for both wind and solar technologies. Prior to being the director, he was the Senior Engineer for National Renewable Energy Laboratory from August 2008 to March 2017. He earned his bachelor's degree in mechanical engineering from Swarthmore College in 2006, a master's degree in electrical engineering from the University of Washington in 2007, and a Doctor in Philosophy (Ph.D.) in mechanical engineering from the Colorado State University in 2016. He has sixteen publications that vary in engineering expertise, including many about renewable energy. He has earned four different awards the: NREL Outstanding Public Information Award, the NREL Outstanding Business Collaboration Award, the NREL President's Award, and the Swarthmore College McCabe Engineering Award.

Career

As a Senior Engineer for NREL his job description closely related to that of a mechanical engineer. A mechanical engineer designs, develops, builds, and tests mechanical and thermal sensors and devices, including tools, engines, and machines. A mechanical engineer generally works in an office environment and occasionally visits worksites where a problem has arisen, or equipment needs their attention. Mechanical engineers work in engineering services, research and development companies, and manufacturing industries. The education required is a bachelor's degree preferably in a mechanical engineering or mechanical engineering technology program. According to the U.S. Bureau of Labor the annual pay for a mechanical engineer is $87,370, and the hourly is $42.00. The job outlook is expected to increase about 9% from 2016-2026, this is about average compared to other jobs in the United States. Similar careers and occupations include: Drafters, Materials Engineers, Mathematicians and Statisticians, Mechanical Engineering Technicians, Natural Sciences Managers, Nuclear Engineers, Petroleum Engineers, Physicists and Astronomers, and Sales Engineers.

Use of Mathematical Models in Research/Publications

In September 2014, Aaron Dobos released the most up to date version of the PVWatts Technical Manual Report. In this report he explains the different geometrical models used to make up the inputs and calculations used in the PVWatts calculator. This report was useful in comprehending the different algorithm models used by the PVWatts system.

Mathematical Tools

NREL's PV Watts Calculator

During the research one mathematical tool used was the PVWatts Calculator. This calculator is used by a wide variety of solar power installation estimate web-pages, including

Solar Estimate. The PVWatts Calculator was created by the U.S. Department of Energy's National Renewable Energy Laboratory (NREL). It estimates the electricity production and energy value of a grid-connected roof or ground-mounted photovoltaic system based on a few specific inputs about the location, design parameters, and system economics. It estimates the energy production and the cost of energy for solar photovoltaic (PV) systems for residents. The PVWatts system uses the hourly meteorological year (TMY) data from the NREL National Solar Radiation Database (NSRDB), to calculate how much potential an area has for solar power. It calculates the estimates of monthly and annual electricity production of a photovoltaic system using an hour-by-hour simulation over a year.

The calculator has six different input values including: DC system size, Module Type, Array Type, System losses, Array tilt angle, and array azimuth angle. The DC System size is the direct current power rating of the photovoltaic array in kilowatts (kW) at standard test conditions (STC). The default photovoltaic system size is 4 kW, a 4kW DC system would have a 3.65 kW AC inverter rating. The mathematical equation to estimate the system size based on the area available for the array is: Size (kW) = Array Area (m^2) x 1kW/m^2 x Module Efficiency (%). The Model type shows the solar panel efficiency in the array. The default setting is "standard", which is a module type made up of poly- or mono-crystalline silicon materials with efficiencies that was normal of 15%, and temperature coefficient of power is 0.47%/C°. Solar panel efficiency is the solar panel's ability to convert sunlight to electricity. The array type describes whether the photovoltaic modules in the array are fixed or move to track the movement of the sun across the sky with one or two axes of rotation. The default setting for the array type is "fixed", because it is the most popular system used. the fixed systems implement standard geometrical calculations for the angle of incidence. The system losses are the standardized assumptions about the

performance losses you can expect. The tilt input is the measurement in degree angle of the roof in which the solar panels are being installed. The azimuth refers to the directions that the panels will face. For maximum electricity productions, the panels would face perfectly south, an azimuth angle of 180°.

Using the NREL's PVWatts Calculator for the home, the data showed the monthly solar radiation for the area, the AC energy, and value. For the home, the DC System size was 22.7 kWh, the module type was standard, the array type was Fixed (roof mount), the array tilt was 20°, and the system losses were 14.06%.

Total Costs of Solar Panel Installation

Pennyrile Electric has specific cost requirements for consumers wanting to participate in solar power installation for their homes. These fees include: $50 Reserve Fee, $500 Application Fee, and a $500 Engineering Fee. These total costs would be $1,050 for a new consumer.

According to the Pennyrile Electric account web-page the Oak Grove home uses a daily average of 80.31 kilo-watts per hour (kWh). The monthly average was about 2,409.3 kWh and the average monthly bill was $250. The annual average is 29,313.15kWh. For this research project, the cost estimates were taken to match 100% of the current energy use in the home to solar energy.

First step was finding exactly what size PV system would best satisfy the home's needs. To do this, the kWh need to be converted to just kilo-watts (kW). To get the kW divide the daily average of energy use in the home by the daily average (in hours) of the sun insolation for the area. For the Oak Grove home, the sun isolation is 4.4 hours. The mathematical equation is:

$P_{(kW)} = E_{(kWh)} / t_{(h)}$.

$P_{(kW)}$ = 80.31kWh/4.4 hours

$P_{(kW)}$ = 18.252kW

After getting the kW of 18.252kW, the standard energy losses of the solar photovoltaic system need to be determined. To do this: take the kW(18.252kW) multiply 1.3 (increases the size of the PV system by 30%), this will give the actual size of the system needed for the home.

18.252kW x 1.3 = 23.73 kW

This home would need a 23.73kW solar PV system to satisfy this home's energy needs for 100% solar power energy. According to the TVA website, a 23.8kWh system would cost an average of $52,976, using the Green Power Program. According to TVA, the monthly net electric cost for electric would be $157(without GPP Program) and $112 (GPP Program).

There are multiple incentives offered by the state of Kentucky for installing a solar system. According to DSire USA, in Kentucky there are 80 different programs and incentives to help pay for a solar system. The guaranteed incentive is the federal solar tax credit or investment tax credit (ITC). This credit allows the solar system owner to deduct 30% of the total costs of the newly installed solar system from their federal taxes. The total cost of the solar system for the Oak Grove home estimated to be $52, 976. The ITC for this solar system would be:

$52,976 x 30% (.30) = $15,892.80. The ITC would be $15,893.

Thesis Defense

Cost-Benefit Analysis

For the cost-benefit analysis, the electricity bills from Pennyrile Electric from the home were used to find the annual costs of electricity used. This information can be seen in Table 1:

Table 1. 2018 Pennyrile Electricity Bill Totals and kWh Totals

Month	Total Paid	Total kWh
January	$251	2,785
February	$269	3,024
March	$220	2,238
April	$243	2,402
May	$271	3,065
June	$269	3,023
July	$280	3,204
August	$255	2,876
September	$250	2,768
October	$251	2,856
November	$249	2,751
December	$270	3,026

After analyzing the electric bills, the average annual electricity use for the home was 29,313.13kWh and the electricity costs were $3,078. As previously stated, TVA quoted the solar system would cost $52,976 including installation costs and a 20-year warranty. The guaranteed one-time tax credit for this solar system would be $15,893.

According to EnergySage, the life expectancy of a solar system is about 40 years. The Net Present Value (NPV) evaluation is done at a 40-year period because of the solar system's life expectancy. The future avoided electricity costs from Pennyrile Electric were calculated using the annual 2018 electricity costs of $3,078. To get an accurate calculation for 40 years, the inflation rate needs to be accounted for regarding the electricity in Kentucky. According to U.S. Department of Energy, the inflation rate of electricity for residential Kentucky consumers is 0.2% from 2018 to 2050.

Once the future avoided electricity costs have been determined, with the inflation rate, the annual cash flow can be calculated. The NPV is determined by the annual cash flows calculated each year at a discounted rate. The discounted rate was determined by the average bank interest loan rate on a 40-year loan. The average rate for a 40-year loan is about 6%, making 6% the discount rate. Table 2 shows the Cost-Benefit Analysis of a 40-year Solar System Installation at a 6% discount rate.

Table 2. Cost-Benefit Analysis – Newly Installed Solar Panel System for Oak Grove, KY Home

# of Years	Year	Solar System Costs	ITC Credit	Avoided Future Electric Costs	Annual Cash Flow	NPV of Annual Cash Flow	Cumulative NPV
0	2019	($52,976)	$0.00	$0.00	($52,976)	($52,976)	($52,976)
1	2020	$0.00	$15,893	$3,084.16	$18,977.16	$17,838.53	($35,137.47)
2	2021	$0.00	$0.00	$3,090.32	$3,090.32	$2,904.9	($32,232.57)
3	2022	$0.00	$0.00	$3,096.50	$3,096.50	$2,910.71	($29,321.86)
4	2023	$0.00	$0.00	$3,102.69	$3,102.89	$2,916.72	($26,405.14)
5	2024	$0.00	$0.00	$3,108.90	$3,108.90	$2,922.37	($23,482.77)
6	2025	$0.00	$0.00	$3,115.12	$3,115.12	$2,928.21	($20,554.56)
7	2026	$0.00	$0.00	$3,121.35	$3,121.35	$2,934.07	($17,620.49)
8	2027	$0.00	$0.00	$3,127.59	$3,127.59	$2,939.93	($14,680.65)
9	2028	$0.00	$0.00	$3,133.85	$3,133.85	$2,945.82	($11,734.74)
10	2029	$0.00	$0.00	$3,140.07	$3,140.07	$2,951.67	($8,783.07)
11	2030	$0.00	$0.00	$3,146.35	$3,146.35	$2,957.57	($5,825.50)
12	2031	$0.00	$0.00	$3,152.64	$3,152.64	$2,963.48	($2,862.02)
13	2032	$0.00	$0.00	$3,158.95	$3,158.95	$2,969.41	$107.39
14	2033	$0.00	$0.00	$3,165.27	$3,165.27	$2,975.35	$3,082.74
15	2034	$0.00	$0.00	$3,171.60	$3,171.60	$2,981.30	$6,064.04
16	2035	$0.00	$0.00	$3,177.94	$3,177.94	$2,987.26	$9,051.30
17	2036	$0.00	$0.00	$3,184.29	$3,184.29	$2,993.23	$12,044.53
18	2037	$0.00	$0.00	$3,190.66	$3,190.66	$2,999.22	$15,043.75
19	2038	$0.00	$0.00	$3,197.04	$3,197.04	$3,005.22	$18,048.97
20	2039	$0.00	$0.00	$3,203.43	$3,203.43	$3,011.22	$21,060.19
21	2040	$0.00	$0.00	$3,209.84	$3,209.84	$3,017.25	$24,077.44
22	2041	$0.00	$0.00	$3,216.30	$3,216.30	$3,023.32	$27,100.76
23	2042	$0.00	$0.00	$3,222.73	$3,222.73	$3,029.37	$30,130.13
24	2043	$0.00	$0.00	$3,229.18	$3,229.18	$3,035.43	$33,165.56
25	2044	$0.00	$0.00	$3,235.64	$3,235.64	$3,041.50	$36,207.06
26	2045	$0.00	$0.00	$3,242.11	$3,242.11	$3,047.58	$39,254.64
27	2046	$0.00	$0.00	$3,248.59	$3,248.59	$3,053.67	$42,308.31
28	2047	$0.00	$0.00	$3,255.09	$3,255.09	$3,059.79	$45,368.10
29	2048	$0.00	$0.00	$3,261.60	$3,261.60	$3,065.90	$48,434.00
30	2049	$0.00	$0.00	$3,268.12	$3,268.12	$3,072.03	$51,506.03
31	2050	$0.00	$0.00	$3,274.66	$3,274.66	$3,078.18	$54,584.21
32	2051	$0.00	$0.00	$3,281.12	$3,281.12	$3,084.25	$57,668.46
33	2052	$0.00	$0.00	$3,287.68	$3,287.68	$3,090.42	$60,758.88
34	2053	$0.00	$0.00	$3,294.26	$3,294.26	$3,096.60	$63,855.48
35	2054	$0.00	$0.00	$3,300.85	$3,300.85	$3,102.80	$66,958.28
36	2055	$0.00	$0.00	$3,307.45	$3,307.45	$3,109.00	$70,067.28
37	2056	$0.00	$0.00	$3,314.06	$3,314.06	$3,115.22	$73,182.50
38	2057	$0.00	$0.00	$3,320.69	$3,320.69	$3,121.45	$76,303.95
39	2058	$0.00	$0.00	$3,327.33	$3,327.33	$3,127.69	$79,431.64
40	2059	$0.00	$0.00	$3,333.98	$3,333.98	$3,133.94	$82,565.58

The payback year would be year 13 in 2032. Meaning that after 13 years the system will start to generate a positive cash flow and no longer be a burden to the Oak Grove home's financials. The cumulative NPV after 40 years is $82,565.58. The financial benefits outweigh the total costs of a new solar power system installation and resulted in a positive cost-benefit analysis. The solar power system would prove to be beneficial and favorable to the home and the environment. It would also be a positive financial investment for the homeowner.

Green Power Switch

The initial costs of installing a solar power system could prove to be too high for a new consumer. Many people want to add renewable energy in their electricity mix but do not have the financial means to do so. For this TVA created a cost friendly program called the Green Power Switch. In this program consumers of TVA can purchase energy blocks for a low-cost and incorporate renewable energy into their energy mix.

The Green Power Switch uses green power. Green Power is a subset creation of renewable energy and blocks of electricity produced from solar, wind, geothermal, biogas, some biomass, and low-impact small hydroelectric sources. The Green Power Switch by TVA offers a block of 150kWh renewable energy for $4 a month. This block of renewable energy is added to the TVA electricity mix.

735 Shetland Drive Residence and Green Power Switch

For the Oak Grove home, there would have to be 16 blocks of Green Power added to match the 100% of electricity used in that home. To determine the number of blocks needed for a home, divide the monthly average of electricity use by 150kWh. For the Oak Grove home: 2,409.3kWh/150kWh = 16 blocks a month for 100% green power match. With each block

costing $4 a month, for 16 blocks the total cost would be $64 (16 x 4) adding an additional $64 to the monthly electricity bill.

According to EPA, the 16 blocks of renewable energy would be a carbon reduction equivalent of: 164 gallons of gasoline, driving 3,466 miles, and burning 1,564 pounds of coal.

Oak Grove Green Power Switch

According to Suburbanstats, there are about 2,779 households in Oak Grove, KY. If every household in Oak Grove, KY bought a green power block for $4, that would be 2,779 blocks. This would be 416,850kWh (2,779 blocks x 150kWh) of renewable energy. This could provide the following: 2,779 blocks/ 16 blocks = 174

the carbon reduction for gasoline: 164 gallons x 174 = 28,536 gallons

driving: 3,466 miles x 174 = 603,084 miles

burning of coal: 1,564 pounds x 174 = 272,136 pounds

Tennessee Valley Authority Green Power Switch

Tennessee Valley Authority provides electricity for 10 million consumers. If every customer bought a $4 block of renewable energy, that would be 10 million blocks of renewable energy. This would be 1,500,000,000kWh of renewable energy (10 million x 150kWh). This could provide the following: 10,000,000 blocks/16 blocks = 625,000

The carbon reduction for gasoline: 164 gallons x 625,000 = 102,500,000 gallons

Driving: 3,466 miles x 625,000 = 2,166,250,000 miles

Burning of coal: 1,564 pounds x 625,000 = 977,500,000 pounds

This would reduce the emissions of CO_2 produced by coal-burning plants by almost one percent. Burning 2 pounds of coal emits about 3 pounds of CO_2. With the reduction of 977,500,000 pounds of burning coal, this would be a reduction of about 1,466,250,000 pounds of CO_2.

Conclusion

Studies have shown that Kentucky's over dependency on coal and other fossil fuels has taken a big impact on the environment and public health of Kentuckians. Research proved that the home in Oak Grove could make the switch to 100% solar power energy and that the solar system would be a financial investment. Installing a solar system would help decrease many environmental burdens such as: the impact on public health, impact on agriculture, impact on the forests, ecosystems, and reduce the CO_2 emissions. The cost-benefit analysis done for the new solar system, showed that the home would benefit financially after 13 years. After 13 years the solar system would begin to generate cash flow for the home and after the solar panels life expectancy of 40-years the final cumulative NPV would be $82,565.58. The initial costs of the new solar system were $52,976. This cost could be viewed as high among many people in the Oak Grove area. Because of this high cost TVA offers a Green Power Program, this program provides a cost-friendly way for Kentuckians to use and purchase renewable energy.

Prior to research about renewable energy options for the home in Oak Grove, it was believed that there were no available renewable energy options. However, the researched proved that the Oak Grove home does have renewable energy options available. It showed that the home can have a solar system installed and it would in fact be financially beneficial, while improving the Kentucky environment. The research project also showed that the electricity company, Pennyrile Electric through TVA have cost-friendly and easy ways that consumers can purchase renewable energy and reduce the use of fossil fuels as power production in Kentucky.

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