Muncie's Bright Future

An Honors Thesis (HONR 499)

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May 2020

Expected Graduation

May 2020

Abstract

This thesis is an attempt to create a working database that can theorize and simulate the net benefit that a solar farm could generate in a specific city or location. It analyzes the current technology and scope of the solar farm as well as desired results, displaying them after doing 2000 simulations, showing the varying levels of success and the likelihood of having a positive benefit. This project aims to not only cover the monetary aspects but also the environmental benefits generated by renewable energy, using a monetary basis. The results of this project successfully affirm the decision to build this solar farm in the Muncie area as it generates a positive net benefit in over 90% of simulations. As our society begins to see the benefits of using cleaner energy, having methods like this that city planners or developers can use can attempt to speed up the clean energy revolution.

Acknowledgments

I would like to acknowledge Dr. Scott Rice-Snow, who was my mentor for my undergraduate thesis. He was the professor to originally get me interested in the current situation of the environment as well as helped me find ways to channel my skills and knowledge in the finance field to try and make a difference. The resources he showed me were extremely valuable to the success of this project and I give my sincerest gratitude.

Process Analysis Statement

After learning of the possibilities to applying knowledge in economics into environmental conditions, I began to seek out ways to use what I know in the finance field to potentially make a difference in the current energy crisis. As groups are desperately trying to find ways to improve nonrenewable resources to match the current fuel sources we have, there are people who will continue to assume that renewable energy is not in our near future.

I have always been fascinated with the implementation and increasing success of solar energy. It seems to be one of the most universal renewable resources as the only requirement is the amount of direct sunlight a location is receiving. Being able to harness the power of the sun to generate electricity that people can use has been something I have always wanted to be a part of. While my knowledge in electrical engineering is lacking, by using my knowledge in building databases and user-friendly systems I wanted to be able to synthesize something that a more knowledgeable electrician could understand and perfect, while a city planner with little knowledge in the field could comprehend and use for further development and strengthen confidence with solar farms and their production.

My goal was to create a database that took the many factors that went into creating a solar farm, seeing the overall benefit gained from it (monetary and environmental) and comparing it to the potential costs that would be had in building and maintaining a solar farm. I made this database to be interactive, allowing for others to plug in the values of their situation to then do 2000 simulations on the variability of success, showing the potential gains or losses that would be seen with the creation of a solar farm in their area. This would allow for city planners to see the impact of their decision through projections, allowing more informed decisions to be 2 made and strengthening the development of solar farms across the nation. My knowledge in the renewable energy and the specifics on how a solar farm operates are lacking, likely being the most impeding part to my work. However, by working with Dr. Scott Rice-Snow, department chair of the Department of Environmental, Geology, and Natural Resources and a professor of geological sciences, I was able to reach out and fill in any gaps I may have had in my initial knowledge of the operations of a solar farm.

This project has adapted my view of renewable energy and the feasibility to create sustainable sources of renewable energy. Before I had seen the idea as something to look forward to, hoping with enough technological advancement society would be able to replace the current energy structure to house less harmful sources. After seeing the possibility of the addition to this solar farm and the value it can generate, there are likely many cities that can begin this initiative to change to cleaner energy, therefore starting this idea I had seen to be a far off hope.

Muncie Development

Muncie is a constantly growing and evolving city in Indiana that has gone through some revitalization within its downtown area. It has seen many efforts to bring life and new people into its new areas with festivals, gallery walks, and other inclusive activities. Being a city that has aimed to be innovative and progressive, many were excited to hear that with the purchase of the local General Motors factory there were plans to turn the location into a large-scale solar farm.

The development of this solar farm was exciting to many, as Muncie energy costs are relatively high, and the city plans to become more self-sufficient in their energy consumption.

This move is innovative as a large portion of Indiana’s energy consumption is fueled by coal, which is seen to be one of the most environmentally harmful fuel sources in current use.

With the news of this acquisition made by Muncie officials, I wished to see if I could do my part in helping push a city towards a brighter fuel source. This led me to try to use my knowledge in finance and economic practices to potentially make a difference or bring some expectations to how this solar farm could impact the city, and if it would really be beneficial after the costs to build and maintain such a large solar farm.

Purpose

As a student who has taken great interest in the current energy crisis and search for better solutions, I have often found myself fascinated with the advancements in solar technologies as well as all of the factors behind environmental economics. Many people value renewable energy sources very highly, but there should always be a breaking point in not using it if it not as effective in the long run. This is the balancing act that many have been trying to figure out over the last several years, since we have been waiting for these renewable resources to be more efficient than the current fossil fuels before having to invest insane amounts of money to overhaul the energy grid to focus on these renewable sources.

I was able to come up with a way to generate my own value in this discussion by using the building blocks I was taught in my environmental economics class, where we were able to take a case study of a paper recycling plant and find the net benefit it would be generating for the community. This case study took real life application of many monetary factors as well as set the environmental benefit of recycling paper to a monetary base. This allowed us to use money as a common denominator and ultimately decide if the costs of creating a plant like this would be beneficial to the residents in a ten-year period.

My creation would be taking this idea and molding it into a sort of interactive set of simulations on excel that could ultimately be used to test the likelihood and amount of value a venture such as this solar farm could produce. I could use this current situation of Muncie's solar farm and get a direct answer on how much of a net benefit it would have on the community. This project would also be set in mind of other potential cities in the future, so making every variable interchangeable would allow other groups to plug in their information, making them able to use this spreadsheet to estimate the impacts of their solar farm and ultimately aid them in their decision-making process.

This project aims to ignore any potential government relief or grants that could be given to groups that use renewable energy, as these values are generally awarded after the use of this energy and vary heavily between states and their policies. It would also be disregarded as the governments assistance in monetary value would be desirable to the groups making the solar plant, but ultimately would be inflated value added and not the value that would be inherently generated by the solar farm itself.

Below is the completed interactive database that can be viewed with this thesis to show the practical application of the spreadsheet.

Thesis supplement.xlsx

<u>Assumptions</u>

Below will begin to address the assumptions needed to be considered at the planning phase of this spreadsheet. An impactful step in the creation process of a database is the strategizing and recognizing of important factors and variables that will be required for a sheet such as this. It is important to identify the potential net benefit a power plant would be able to generate, understanding the monetary assumptions of the direct currency generated and expended by the power plant. It will also require the assumptions of the value generated by the plant that is not strictly monetary, which can be seen by the environmental assumptions, which deal with the value created with making clean energy as opposed to the harmful side effects on the environment created when current non-renewable fuel sources are used.

While not all of the assumptions listed on the document are in use for the further calculations and simulations done, some are left open ended for future city planners and developers to be able to customize and expand on this database to fit their locations needs and requirements.

Assumptions	Min	Max	Mean
Population	65,000	70,000	67500
Capital cost of plant	$ 17,000,000.00	$ 20,000,000.00	$ 18,500,000.00
Energy per person per day (kwh)	55	61	58
Annual cost per person	$ 20,088.75	$ 22,280.25	$ 21,184.50
Annual cost of plant	$ 209,100.00	$ 246,000.00	$ 227,550.00
Annual energy generated a year (kwh)	20,910,000	24,600,000	22755000
Yearly energy produced per module (kwh)	913	913	913.125
likely number of modules	22,899	26,940	24,920
Daily production of energy (kwh)	57248.45996	67351.12936	62299.79466
City Energy requirment per day (kwh)	3575000	4270000	3915000
City energy requirment annual (kwh)	1305768750	1559617500	1429953750
Cost of plant per day	$ 572.48	$ 673.51	$ 623.00
Coal "Environmental" cost per (kwh)	$ 0.17	$ 0.27	$ 0.22
Oil "Environmental" cost per (kwh)	$ 0.08	$ 0.19	$ 0.14
Natural Gas "Environmental" cost per (kwh	$ 0.01	$ 0.02	$ 0.02
Discount Rate (%)	2%	9%	6%
Value of Energy Created per (kwh)	$ 0.08	$ 0.15	$ 0.12
Environmental benefit of solar per (kwh)	$ 0.12	$ 0.18	$ 0.15
Miscellaneous expenses	$ -	$ 2,000,000.00	$ 1,000,000.00
Module Expected (W)	300		
Daily Wattage produced (kwh)	2.5		

Percent of power currently:		Indiana
Coal	66.2%	6188
Natural Gas	25.7%	2400
Oil	0.3%	26
Other (environmental friendly)	7.8%	730
	100%	9344

Discount Rate Calculation (10 Years)		
Year	0.02	0.09
1	0.980392157	0.917431193
2	0.961168781	0.841679993
3	0.942322335	0.77218348
4	0.923845426	0.708425211
5	0.90573081	0.649931386
6	0.887971382	0.596267327
7	0.870560179	0.547034245
8	0.853490371	0.50186628
9	0.836755266	0.46042778
10	0.8203483	0.422410807
	8.982585006	6.417657701

Monetary Assumptions

Capital Cost of Plant

The Capital Cost of the Plant is the expected costs associated with the plant's development, building expenses, and original maintenance expected to become originally operational. This is seen as a one-time expense within the creation of a solar farm and therefore will be the largest expense seen on this database. It is noted that while this expense is an undertaking in order to begin generating clean energy, private investors or the government often give large loans or grants in order to offset these large costs, allowing foundations such as solar producers time to create value that will allow them to pay off this large debt.

Annual Cost of Plant

The annual cost of the plant may seem relatively straight forward, as it is the general costs of monitoring the farm, the annual operating costs, as well as the specific maintenance expenses generated for each year.

This value was derived from the general notion and estimation given by Solar Mango, a website dedicated to providing energy consumers with relevant, up to date, and practical information on the newest solar panel technology. While this estimate can be further refined, the minimum and maximum hovering around $225,000 a year seems accurate enough when compared to similar sized solar farms.

Annual Energy Generated per year (kwh)

The annual Energy Generated per year is a value that was originally stated by Muncie Mayor Dan Ridenour in an article by WFYI Indianapolis, a broadcast system in the Indianapolis area. This value shows the Kilowatt hours produced by the solar farm, giving us a basis on how much value is generated by the solar farm as we add the price of selling this energy generated to get the monetary value produced by the farm as well as later, we can see the environmental value of having this energy generated with solar panels as opposed to coal or natural gas.

Value of Energy Created (kwh)

The monetary value of energy created is the expected cost of one Kilowatt hour of energy being sold to the residents of Muncie. Our estimate stays between $0.08 to $0.15 per Kilowatt hour, which is a wide range that could represent the costs for residential areas versus corporations buying it for less.

Miscellaneous Expenses

The potential miscellaneous expenses added range from nothing to upwards of $2 million dollars. This allotment covers any unseen externalities with the production and capital costs of the plant, it covers the possibility of road bumps that could delay or raise the cost in the production of this solar farm. Examples of these miscellaneous expense could be labor regulations, land redevelopment, or even a rise in materials required after the beginning of the construction of the solar farm.

By adding this measure, we can add a variable to cover potential wiggle room of the production of the plant, as well as keeping the situation real. Having the environment of this simulation being as real and non-ideal allows people viewing the program to understand that it is not just a best-case scenario simulation but also encapsulates all possibilities and realistic pitfalls that large productions will have.

Discount Rate

When trying to figure out the net benefit of something like a solar farm, we will need to compare the overall costs of startup as well as the yearly generated revenue and costs that the solar farm will have. This means that we will need to be able to compare the difference between a one-time cost of the production of the solar farm from the annual gains made by the farm.

Using a discount rate will allow us to be able to take a period, in this case 10 years, and see what the value of the ten year's gains will be compared to the one-time building production cost. Following the idea that money today is the same value as money tomorrow, we will need to use a discount rate to understand the time value of money and the amount we will need to offset the production costs of the plant. The discount rate will be able to help our projections in setting a good and accurate estimate of the overall value after the ten-year period. Investopedia describes a discount rate as incredibly important since it "helps determine if the future cash flows from a project or investment will be worth more than the capital outlay needed to fund the project or investment in the present".

We will need to isolate a discount rate or at least build a range for which the value we generate can be changed to be at the same bar that the original cost was. In this set of simulations, I went with a very broad and wide encompassing range from anywhere between 2% and 9%. This allows for the simulations to cover a wide variety of potential economic environments, while a more well research estimate could lead to a higher level of accuracy.

However, with the current volatility of the economy and unknown future of the market, keeping a wide range between the discount rates felt the most reasonable.

Discount Rate Calculation (10 Years)			
	Year	0.02	0.09
	1	0.980392157	0.917431193
	2	0.961168781	0.841679993
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	8	0.853490371	0.50186628
	9	0.836755266	0.46042778
	10	0.8203483	0.422410807
		8.982585006	6.417657701

By using these discount rates, we can calculate the value of money made at the end of the period if it was converted to that amount in the beginning. This will be needed later when comparing the cost of production of the solar farm versus the first ten years of costs and value generated by the plant. This discount rate will be later seen referenced in the simulations section when calculating net benefit.

Environmental Assumptions

While the monetary assumptions are relatively straightforward with their explanations, we can also see the impact that a solar farm could have on the environment. Using clean energy sources as opposed to using the same amount of energy from harmful resources will have inherent value in the decision process for building a solar farm.

Although using clean energy should always be a focus and a goal to strive for, using it to justify the investments into these types of renewable resources without proper definition of its value could do more harm than good. Therefore, in this section regarding the environmental assumptions I will quantify how much value is placed in the clean use of each kilowatt hour of solar energy compared to the different current methods. By setting a monetary value to using clean energy over the alternatives, we can effectively measure the net benefit generated by this solar farm or other potential projects in the future without missing out on the hidden benefits of clean energy.

Environmental Costs (Coal, Oil, Natural Gas)

Aside from the normal costs of mining, producing, and distributing resources such as coal, oil, or natural gas there is the costs that are derived from the harm that each fuel source does to the environment. With the air pollution that is seen from these fuel sources, some amount of economic penalty should be seen when comparing their effectiveness against a clean energy source such as solar energy. This tends to be not as heavily focused on by many planners however since the value saved by clean energy is not directly monetary and cannot be gained by the user.

Protecting the environment is however an increasing concern within many city planners and politicians, as we have begun to see just how harsh of impacts the fuel we have been using has been on the environment and therefore place more value on these cleaner energy sources. This has led us to factor in a specific amount of value (set to a monetary value) to be considered with the output of solar energy made by solar farms.

Coal "Environmental" cost per (kwh)	$	0.17	$	0.27
Oil "Environmental" cost per (kwh)	$	0.08	$	0.19
Natural Gas "Environmental" cost per (kwh	$	0.01	$	0.02

For this set of simulations, I began with the estimates on the environmental costs of each fuel source that Indiana uses (coal, oil, natural gas, and renewable). These estimates were taken from Matt Kasper's article "The External Costs of Fossil Fuels;

Environmental and Health Value of Solar". This article was posted by the Energy and Policy Institute and allowed me to use a basic range that encapsulates the economic benefit that solar would be having as opposed to the other sources.

Once the environmental costs were figured out, the next step would be to see how much of each fuel source would be taken away and replaced with clean energy. This led me to find how much of Indiana's fuel usage was derived from each source. According to the US Energy Information Administration, Indiana uses roughly 66% of its energy needs from coal, around 26% from natural gas, and less than 1% oil. The rest was shown to be alternative energy sources such as solar or wind, which in this scenario would be calculated to have no environmental cost. Finding these proportions allowed me to have a basis to calculate a weighted average of how much of an environmental benefit the city of Muncie would be offsetting with this added source of solar energy.

Percent of power currently:		Indiana
Coal	66.2%	6188
Natural Gas	25.7%	2400
Oil	0.3%	26
Other (environmental friendly)	7.8%	730
	100%	9344

Environmental Benefit of Solar

With these calculations done of the environmental costs of each fuel source and determining the overall saving solar would have in Indiana per kilowatt hour produced, we can build a better picture on the environmental value the solar farm could be producing.

By taking the estimated value of the environmental savings per kwh that the solar farm would create, we can then multiply that by the estimated production of energy that was projected each year, we can get an annual amount of value the solar farm would generate as people would be consuming clean energy as opposed to the harmful costs of the energy they would get with coal or other harmful alternatives.

Future Variables

While many of the variables in the assumptions tab are required for this calculation, I left several variables that currently did not lead to a specific calculation but would still be useful information to know when considering the undertaking of building a solar farm. These variables could also be seen as important for future use and modification to the program, as I specifically left it easy to be edited to meet other potential scenarios in the future, allowing other city planners or officials to use it with estimations and see their projections over 2000 simulations.

Population

Knowing the population of your town or city would be generally important, as knowing what your worker population might be could be vital when making a solar farm that may require more workers, if in less habitable conditions. This would also help aid in knowing how busy of a location you may have, if it were very dense in population then it would likely make the land more valuable and therefore be a higher cost to build a solar farm there.

Having population down could also be incredibly important for researchers who are more interested in other aspects of the simulations, if they wanted to see what limits the solar farm would have or how it could affect the population. The population can be used in a multitude of different test, seeing how much of the location’s energy needs can be met, what level of energy the population requires, or even if the building of this solar farm could have positive or negative impacts on the growth of the population stated.

Cost per person/energy per person

There is a section regarding the energy requirements per person, originally taking made up parameters and estimates of how much energy a city would use and dividing by the population of the area. This could be further developed to see how much of a cost people's energy requirements are having as well as how much of an environmental impact someone's energy requirements would have with the current energy source ratios. This could also show the savings that could be generated and the overall environmental change that would be happening per person or could show that there needs to be some better management on a city's energy usage.

City requirements

By adding city requirements of energy, similar to energy costs per person, a city planner or researcher could see the impact that a solar farm could have on their energy grid. This could show the potential changes to their ratios of energy they would be using, as well as show whether or not the solar farm might be able to power their city's energy needs alone, making the city closer to carbon neutral and giving it a sustainable competitive advantage over other nearby cities.

Setting these requirements could also lead users to understand the advancements in solar panels as well as see what level of production would be needed from their solar farm to reach their requirements. This could lead to city planners using the database to aid them in designing their next solar farm, selecting a location that could house enough panels to generate the level of output they need.

Required Modules

There is a section involving required modules, as well as the energy generated per module or set of solar panels. This would allow users to potentially change the database to show the current output of a solar farm as well as could alter the output if there were to be any advancements in the solar industry, as it is getting more and more efficient as time goes on. This could allow users to determine if they should upgrade their solar farms to have the newer models or when they might need to wait to replace their current panels and how the change could have an impact on their generated output.

Simulations

The next tab in the spreadsheet takes the previous assumptions discussed and displays them in 2000 simulations, where each assumption is taken as a random value between the upper and lower parameters. This allows for each simulation to be completely separate from one another, making the results of the 2000 simulations able to cover most of the types of outcomes that would be seen, giving the areas with the most outcomes in a specific area the most likely occurrence of the solar farm's success.

Goal of Simulation

The goal of these simulations was to determine what the net benefit would be if we take all of the value generated by the solar farm minus all of the initial and annual costs that the plant would incur.

The value generated by the solar farm would be calculated by taking the yearly generated kilowatt hours of energy multiplied by the price of residential energy (a basic price if they were to sell this energy, or what it would cost to buy it for their energy purposes) plus the environmental cost that they would save of the use of clean energy over the harmful alternatives (discussed in the environmental costs section). This would give us the yearly generated value that the Muncie solar farm would be producing, whether they want to use the energy themselves or sell it to the residential users to generate more profits.

The costs incurred by the solar plant would be calculated in two different ways, taking the annual costs as well as the initial investments required. The initial investments would be adding the values of the cost of capital of the building of the solar farm plus the miscellaneous expense category, covering any extra expenses that could potentially be incurred. The annual cost of the solar farm is the early discussed estimate that a farm of this size would have for maintenance as well as any upkeep required for the plant.

The calculation of the net benefit of the solar farm over ten years would be calculated by taking the annual benefit minus the annual costs, the difference then being multiplied by the earlier discussed discount rate to give it a comparable product to the initial costs of the plant. By taking this product and subtracting it by the cost of capital of the plant and miscellaneous expense, we can get an accurate net benefit that would show us how much of an actual benefit we would see in ten years after production.

This process would then be replicated 2000 times with each variable randomized between their minimum amount and maximum amount. This would give us an effective view of the different potential outcomes that could occur with a venture such as this and by seeing where the simulations end most often, we can find the more likely outcomes. This ultimately will show us the impact of Muncie's solar farm and whether it will be beneficial to take this investment or if the value generated is not enough.

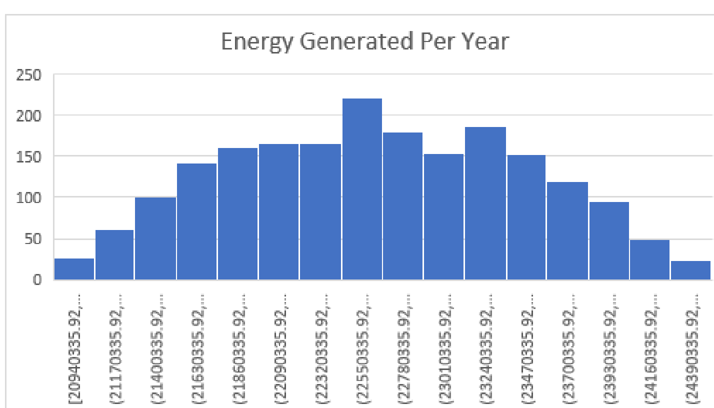
<u>Distribution Models Used</u>

While taking a random variable between the minimum and maximum is effective in getting a wide variety in the different ranges of outcomes, economists have found ways to shift the average of these variables to be more accurate. With each variable we can find a specific method that would suit it best to show the more likely result and therefore use a random variable that more favors that side. These are known as distribution models, which are ways that data can be commonly seen and observations we can make when data appears a specific way. The most common distribution model that many know is the bell curve, where the most likely outcome of a range tends to be in the center, where at either end sees the less likely outcomes.

Using this knowledge I have edited each variable in order to see the most likely distribution of each so that the results of these simulations are more likely and contain fewer externalities that could skew the results.

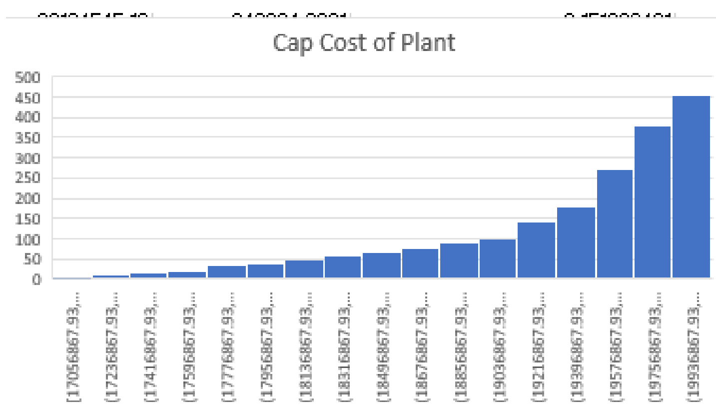
Normal

Normal (or bell-shaped) distribution is the most common distribution model seen by economists, and therefore were a majority of the variables seen in our simulation.



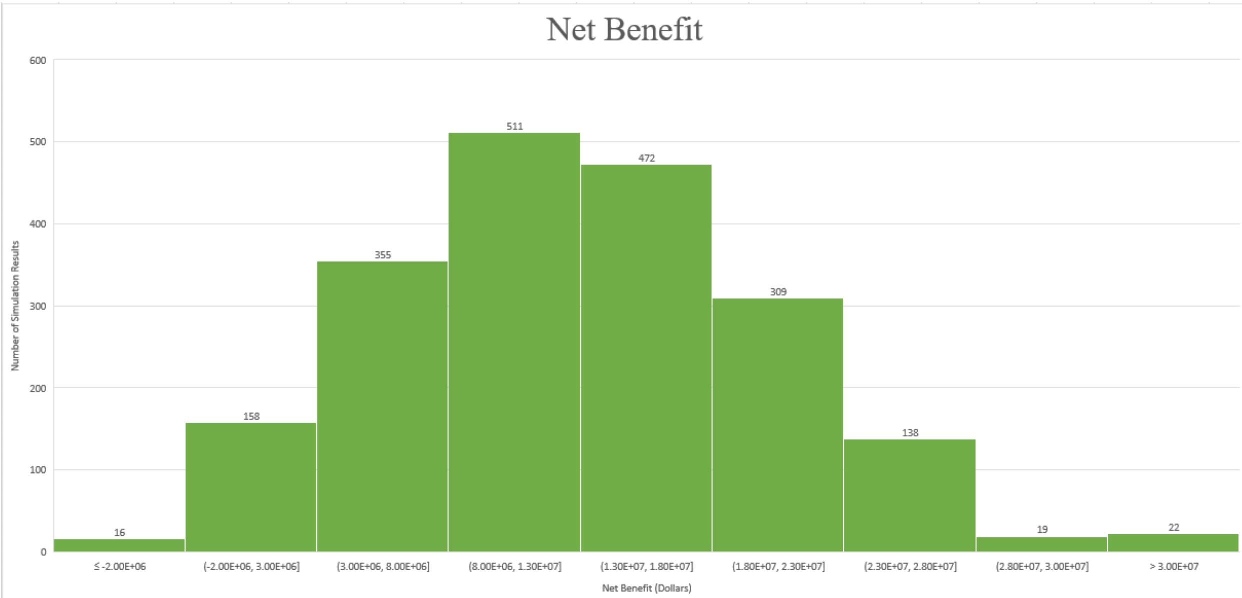
Variables such as the energy generated per year would likely favor a normal distribution. This would be because if there is a specifically sunny time period, it is often countered by a less sunny section. The sunlight captured by the solar farm would tend to stay towards the center of the estimation, therefore being a normal distribution. Other variables that would be normal distributions would be energy cost per kilowatt hour, revenue from energy sales, or the annual cost of the plant per year.

Beta



Beta distribution models are more complicated, as technically a beta distribution model could be similar to a normal distribution. Beta distribution is more of a general term that covers when a variable is heavily favored to one side or another, such as with the capital cost of the plant, since many estimates of how much a large building would cost is generally an underestimate, this would cover the fact that they are much more likely to find new places to spend their money in production instead of ways to save money or cut corners. Another variable that could be seen as beta distributions would be environmental cost saved per kilowatt, as it is likely that the value of this would be appreciated but not as heavily valued by the city as the actual monetary values they gain.

<u>Results</u>



The results of these 2000 simulations proved that the creation of this solar farm in the Muncie area would see a large net benefit after 10 years. The value generated by the solar farm is mostly seen in the 13-million-dollar to 18-million-dollar range. Almost all of the simulations showed a positive net benefit, with less than a percentage of them being a net deficit below 2 million dollars.

We can assume that with the upper and lower limits of the simulations having less than a percentage for each, many factors would have to go extremely well or embarrassingly poorly for these results to be seen, so these are likely externalities that can be ignored. Overall, the net benefit results show that this investment into a solar farm would likely be heavily beneficial to the people of Muncie and an effective decision by the Muncie officials that made the decision.

Conclusion

This spreadsheet can be further enhanced to cover different scenarios for other cities in the future. They could alter it to be more precise or cover the addition of multiple solar farms. An intriguing idea that this could definitely be used for would be to take the population factors discussed earlier and see how much of roofing solar panels would be needed in order to potentially have people be self sufficient in their energy requirements. This could lead to many cities reducing their need for harmful fuel sources, allowing us to get to a revised energy grid without needing a heavy overhaul. Instead using a value and incentive based gradual approach.

Making this spreadsheet and doing the simulations raised my appreciation for the valuable people producing, researching, and distributing new methods of safer energy production as well as the time and effort city planners take to ensure a new installation will be worth it to the environment and their community.

Muncie will likely see impressive results with the production of this solar farm, and hopefully will get many other cities in coal-heavy states to start to take notice to the efficiency of their energy usage. While the solution of our energy crisis is far off and unknown, making these types of advancements and investments will be the best way to ending our pumping out of air pollution, and can lead the world to a safer, brighter future.

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