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Ohio Energy Generation Optimization

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HONORS PROJECT

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Abstract

This honors project explores the optimization of energy generation within the state of Ohio to better the energy generation efficiency both environmentally and economically. The proposed solution is a 30-year plan from 2020 to 2050 to reduce the environmental impact caused by electricity generation in Ohio. This project shows guidelines and goals to reach by the end of every decade spanning from 2030 to 2050. This was done using an optimizing program called Multiple Objective Linear Programming (MOLP) and while not perfect it lays a foundation for changes that should come to Ohio's energy mix in the next 30 years.

I: Introduction

For my honors project I decided to optimize energy generation within the state of Ohio and my inspiration for this started when I was about 8 years old as my mother is a science teacher. With me being a business analytics and intelligence major, I wanted to see if it was feasible to actually become more environmentally efficient as well as economically efficient in the way that we generate electricity. My mother from a young age taught me to care for the environment and paired up with the local energy co-op back in my small town to make people's homes as efficient as possible in an effort to reduce environmental impact where she could easily do so. But I always thought that this was good, but it is avoiding the overarching problem that is the way that we generate electricity here in Ohio, so I set out on the honors project to change that. I set out to answer questions that I had about the ways that we generate power here in Ohio.

II: Research Questions

The questions that I would like to answer in this project are as follows:

1.) What is the most efficient way of generating electricity in Ohio with the least amount of environmental damage?

Wind

2.) What is the most efficient way of generating electricity economically?

Hydro or Nuclear

3.) What is a good middle ground between prioritizing economics and environmental that is feasible for the state of Ohio to achieve?

See the spreadsheet

4.) How are these results different from the current energy mix in Ohio?

See the spreadsheet

5.) What is a 30-year plan that will shift the energy generation mix in Ohio to the middle ground scenario?

See the spreadsheet

III: Literature Review

In this project, I used a program within excel called multiple objective linear programming or MOLP for short which I learned from Dr. Chris Rump. In this program, I can develop a spreadsheet that allows the program to tell me what feasible answer can be reached in the most efficient way possible for the case. This program can answer the first four questions that I have proposed, by creating a weighted average between what is economically best and what is

environmentally the best solution. To answer the last question, I will need the help of Dr. Nathan Hensley who taught me in his ENVS 1010 class to question how we can better the world environmentally. I would like to discuss a way of developing a plan that would shift Ohio from generating energy with coal and natural gas to a more sustainable option. I think that to answer these questions I will have to have the expertise of both individuals, and I believe that an answer to these questions is vital for the slowing or even stopping of climate change.

To start, I began by looking at databases at both the state and federal level to ensure that the numbers that I was using were accurate to modern day and in that I found that there were several ways of reducing our environmental impact, but all would require investment on behalf of the state as our current infrastructure is outdated with major amounts of both coal and natural gas production which are 2 of the greatest negatively environmentally impactful ways of generating energy.

IV: Methodology

My first step to my project was to collect the necessary data and build a spreadsheet around every major way that we generate energy in Ohio including solar, wind, nuclear, hydro, biomass, coal, and natural gas. Once I collected this data and organized it into a spreadsheet, I set different objectives for the MOLP to achieve a weighted average of the two objectives which are to be environmentally and economically efficient in the way that we generate electricity. One thing that this model will attempt to achieve is a balance of all environmental damage and not solely focus on CO2 emissions. Another thing that I want this model to consider is land usage because we are an agricultural state, I want to also consider the cost to build and maintain these structures to have a deep understanding of how these changes will economically impact Ohio.

Once these were generated, I developed a potential plan that Ohio could follow to achieve the new mix in the next 30 years that is financially feasible by 2050.

One drawback to this methodology is that I am not privy to some information in the energy world as much of our energy generation is from private companies which can result in discrepancies in data which can make the model inaccurate. Another drawback is that I cannot look at every possible way of energy generation because there are always new technologies emerging in the energy sector to combat climate change and the technologies that exist improve every day meaning that the model should be ever changing which would be difficult to keep up with. Another issue is that some information that is publicly available has not been updated in many years which again leads to inaccurate data for the model to base its analysis. Another issue that I will not be looking at in this model is the impact on the job market which is a large debate in the world of energy generation, therefore this model will assume that for every coal miner that loses their job from a closed coal fired power plant there will be a job created as a wind turbine technician for example which is not necessarily true. There is simply not enough time, nor do I have the resources to research such a topic on top of everything else that is in the scope of this project. Another factor that is nearly impossible to predict is the political climate because it can change and depending upon who is in charge could change the goals in which we set. Another issue that we have with this model is that we may not reach the full potential of an investment because the model cannot understand timeline horizons of investments, so we assume in this model that it does not matter when in reality it does. Another issue is that the model assumes the same statistics over the next 30 years, but because the technology has not been created yet and we do not know where these statistics will go, nor do we know when they will improve, I will be

assuming that they stay stagnant for the next 30 years. On top of this environmental impact could lessen over time due to alternative construction methods.

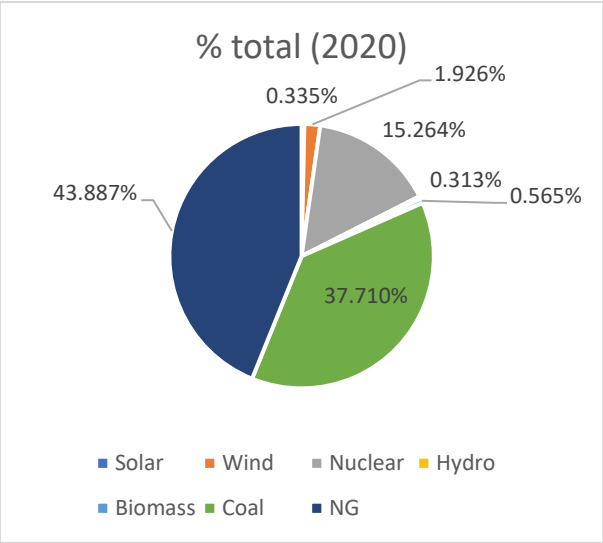
I also create a variable called the environmental impact factor or EIF in which I took several factors into consideration in order to create in order to get a wholistic view of how these ways of generating electricity impact the environment, not just CO_2. The major thing that I considered was cradle to grave life cycle which takes into consideration the impact of generating the method of electricity generation so what are the construction costs environmentally then what does it cost to deconstruct these methods environmentally speaking. Emissions that I took into consideration were CO_2 (Carbon Dioxide), CO (Carbon Monoxide), SO_2 (Sulphur Dioxide), NOx (Nitrogen Oxides), and the overall pollution which includes but is not limited to soot, lead, mercury, radioactive waste, etc. Another factor that I considered is how long it takes to break down an energy generation method like nuclear powerplants for example. The majority of the structure is concrete which is extremely good at resisting breakdown (this is why we use it), but where does that leave us when we tear down structures made primarily out of concrete. I also considered what resources were needed to create and run a specific type of energy generation and if those resources were rare.

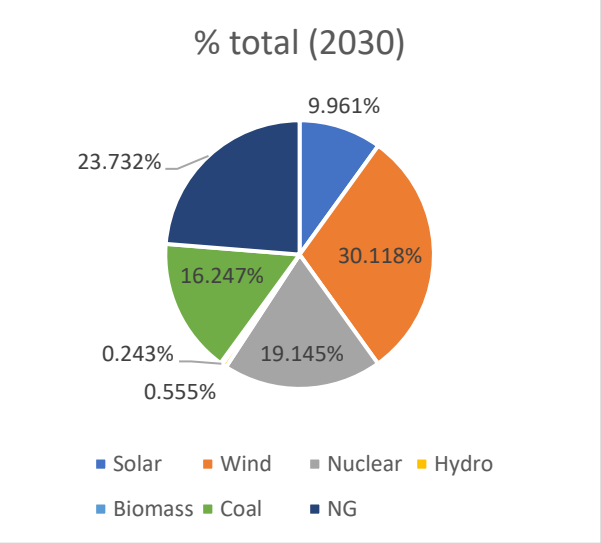
One thing that surprised me when looking at these factors was that about 20% of the worlds current CO_2 emissions are generated in the creation of concreate. Concreate is made up of four ingredients: large aggregate (stones), small aggregate (sand), water, and cement which is the compound that does the binding when mixed with water. This reaction is an exothermic reaction meaning that it lets off heat and in that reaction CO_2 is released, but there are ways of creating concreate that are still in development where the carbon emission is reduced or even eliminated. We also must take into consideration that steel production releases a lot of carbon into the

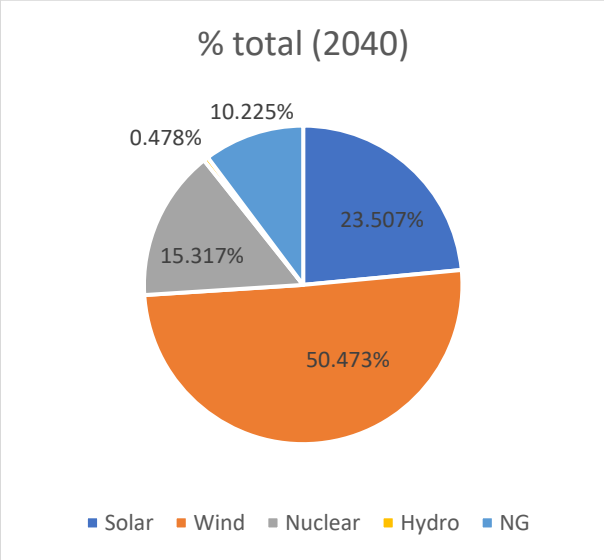
atmosphere but being that steel is an alloy made from iron and carbon it is impossible to create without carbon emissions so alternatives to steel would be helpful in reducing environmental impact as well. The greatest weakness that this model has is that we must assume that the new mix target will be hot every decade which may not be the case because we may not have been able to hit our new target every decade because there was not enough time.

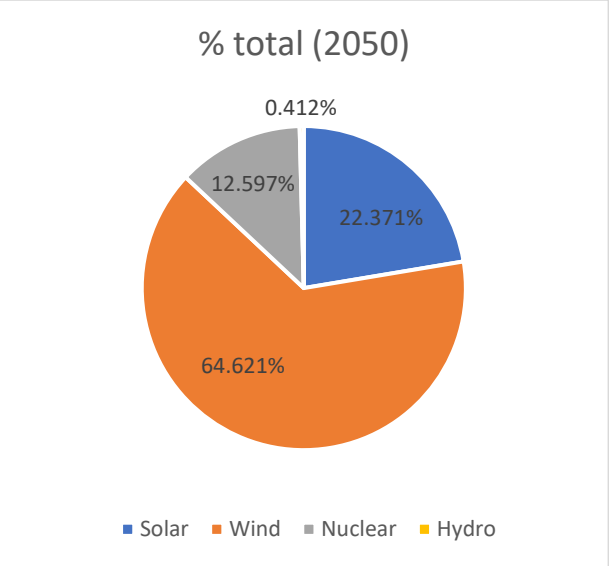
V: Results and Conclusions

The model I created favored green alternative energy in Ohio like wind and hydroelectric over solar as we are a cloudy state compared to many other states making our solar panels less efficient. My model kept the nuclear power plants Davis-Bessie and Perry open as these two power plants provide great amounts of energy to the state and in fact it added a nuclear power plant in order to lessen the environmental impact that coal and natural gas have on the environment. I anticipated that my model would eliminate coal and natural gas energy production and, on that account, I was correct because I set a limit on how much the model could eliminate it took 20 years to deconstruct all of the coal power plants and 30 years to deconstruct all of the natural gas powerplants. The results that I expected from the model were drastically different from our current energy mix and as stated before I expect it to take us 30 years to reach the optimized mix that will minimize our ecological footprint while not destroying the economy and I was correct in that assumption too. By the end of my 30-year model, it eliminated all production of coal, natural gas, and biomass and maximized production of wind energy every decade and this is likely because we are a windy state due to the flatness of Ohio. Here is how the energy mix should change according to my model over the next 30 years (see pie charts).









If you wish to see the full model, here is a view of the technical details and the full results:

Ohio Energy MOLP Analysis.xlsx

Annotated Bibliography:

References

Berkman, Mark, and Dean Murphy. “Ohio Nuclear Power Plants’ Contribution to the State Economy .” *Nuclear Matters*, The Brattle Group, Apr. 2017, https://d3n8a8pro7vhmx.cloudfront.net/nuclearmatters/pages/211/attachments/original/1494337829/Ohio-Nuclear-Report-Brattle-21April2017_%281%29.pdf?1494337829#:~:text=Two%20nuclear%20power%20plants%2C%20each,as%20illustrated%20in%20Figure%201.

This article shows the breakdown of energy generation and consumption in the state of Ohio and shows the amount of energy generated by the 2 nuclear power plants. It also shows a cost breakdown on nuclear energy between the two plants. Another thing that this paper shows is the impact that nuclear energy has on the energy mix in Ohio and comparing how we would fill the gap if these 2 plants were not operational. They predict that the gap would be likely filled by natural gas because we would have to import power into the state which is generally made by way of natural gas in other states.

Blewett, Dan. “Wind Turbine Cost: Worth the Million-Dollar Price in 2022?” *Weather Guard Lightning Tech*, Weather Guard Lightning Tech, 20 Dec. 2021, https://weatherguardwind.com/how-much-does-wind-turbine-cost-worth-it/.

This website gives general information regarding the cost of installation and maintenance costs regarding wind turbines. The article starts as expressing concern for how expensive these wind projects can be and asks the question as to are they worth while? The answer that is revealed is

yes and they become more economically efficient the bigger the turbines become especially when we talk about the offshore turbines that can reach sizes of 15 MW.

Butler, Tom, et al. *The Energy Reader: Overdevelopment and the Delusion of Endless Growth*. Watershed Media, 2012.

This book has summaries of the energy returned on energy invested (EROEI) for all major ways of energy generation including all the major ways in Ohio. This determines efficiency and easy of generation which has changed over time and that is explained in the book, but EROEI can help determine the more efficient and easy ways to generate electricity in Ohio. Another thing that this book does well is that it shows what the limiting factor of every resource is and whether it is a viable alternative. This book is targeted at the US as a whole and not just Ohio so some of the energy generation methods outlined are not pertinent to the problem that I am trying to build a model around.

Comstock, Owen. "Construction Costs for Power Plants." *U.S. Energy Information Administration (EIA)*, 5 July 2017, https://www.eia.gov/todayinenergy/detail.php?id=31912.

This webpage gives construction costs for all of the major ways that we generate energy in Ohio and allows for a greater consensus on economical construction costs.

EIA. "U.S. Energy Information Administration - EIA - Independent Statistics and Analysis." *Ohio - Rankings - U.S. Energy Information Administration (EIA)*, Sept. 2021, https://www.eia.gov/state/rankings/?sid=OH#series/51.

This webpage shows the total energy generation in Ohio which we will have to maintain and grow as time goes on. This will give the target for total generation in Ohio. This also allows the user to make predictions as to who needs more power to import. As stated in another report, we currently Import about 5% of our power for the state of Ohio and if we wish to become independent and have control over the carbon footprint when we turn the lights on, then we need to take total energy production and consumption into account. That being said, this report shows that we in Ohio produce a lot of electricity compared to most of the US as we are ranked number 8 of 51 including DC. This website also allows the viewing of other statistics like CO2 emissions and prices of natural gas and electricity.

EIA. "Utility Scale Facility Net Generation from Biomass." *United States Energy Information Administration*, United States Energy Information Administration, 2021, https://www.eia.gov/electricity/annual/html/epa_03_19.html.

This table shows the biomass energy generation in all states and allows me to break down and trend of biomass energy production. According to the EIA, biomass energy production is down in the United States. This can likely be attributed to the fact that it still emits carbon like coal and natural gas because you have to burn trees in order to harvest their fuel for electricity. On top of this fact, we can use trees for so many other things like paper, tissues, ect. I think that this table is saying that biomass energy is not a viable solution to climate change and energy production, but that is up to my model to decide. Bottom line is that the transport and harvest of wood also emit greenhouse gases, so the biomass industry has no clear advantages over the non-renewable sector because we can still easily access non-renewables such as coal and natural gas.

Energy Information Administration. “U.S. Energy Information Administration - EIA - Independent Statistics and Analysis.” *Ohio - State Energy Profile Analysis - U.S. Energy Information Administration (EIA)*, United States Energy Information Administration, 15 July 2021, https://www.eia.gov/state/analysis.php?sid=OH.

This page has general information revolving around all general ways of generating energy in Ohio. It discusses how the energy industry has changed with time in Ohio where we have shifted from coal to natural gas but is still a top 10 consumer in both categories. In the oil category we are the largest producer of oil East of the Mississippi River, but Ohio still holds less than 1% of the US oil supply. We are in the top 10 states for consumption of oil as well with more than 80% of our consumption coming from transportation. After this the page continues to discuss how renewables are coming along to replace all these non-renewable options that we have bought into for so long.

Girouard, Coley. *The Numbers Are In and Renewables Are Winning On Price Alone*, 5 Dec. 2018, https://blog.aee.net/the-numbers-are-in-and-renewables-are-winning-on-price-alone.

This article opens up with a beautiful visualization of how costs are right now to produce energy comparing coal, wind, and solar panels which is important when considering what our next steps forward should be when considering what the environmental costs are and we find that coal is no longer as efficient as it once was as it is getting harder to find and other renewable alternatives are becoming competitive in price. As we move through the article, we also see a visualization of all of the ways that we create energy in a levelized cost analysis which is important because it factors in the cost of energy creation and initial investment spread out over the lifespan of the structure. From the chart, we can see that some of the renewables like wind, solar (industrial),

and nuclear are some of the most cost-efficient options on the market now and as the technology improves in the future.

"How Much Land Is Needed for Biomass Plants to Generate a Gigawatt Hour?" *Freeing Energy*, 2 May 2020, https://www.freeingenergy.com/math/biomass-bioelectricity-land-acres-m127/.

This website contains a spreadsheet of data collected revolving around land usage in the generation of biomass electricity. it concludes that biomass obviously requires a large amount of land to produce the amount of electricity that we need in Ohio. It takes a lot to do so sustainably meaning that we are only harvesting dead trees from the areas of harvest so much of the statistic in the land mass needed from production of electricity is still alive and growing because many of the trees in the area where harvest occurs are still alive to replant and replace the dead trees that have been taken away to generate electricity.

"Hydropower Development in Ohio." *RAPID Regulatory and Permitting Information Desktop Toolkit*, RAPID Regulatory and Permitting Information Desktop Toolkit, 2015, https://openei.org/wiki/RAPID/Hydropower/Ohio.

This website summarizes many key aspects and statistics about hydroelectricity generation in Ohio. One thing that this website does highlight well is all the background things that have to be done for anything to happen like permits and regulations. These are important when planning to change your energy generation mix because models can come up with unrealistic non-viable solutions, and it is important to notice these things to build that model around such restrictions. The most important thing stated in this article is that we can only double out hydroelectric power

output according to current regulations, and this gives us a maximum point for our model. This is only in the state of Ohio if we wanted more hydroelectricity it would have to come from out of state and be imported into the state via the power grid which presents issues on its own. We have little to no say in the power that we receive from across a state border so if we wish to have a say in these things, we must look inward rather than outward.

Jackson, Tom. “A Behind-the-Scenes Look at Davis-Besse.” *Sandusky Register OAK HARBOR - Inside the Turbine Hall at the Davis-Besse Nuclear Power Station, It's so Hot It Feels like Texas in August. It's so Loud, Visitors Are Handed Earplugs.*, Sandusky Register, 30 May 2019, https://sanduskyregister.com/news/94741/a-behind-the-scenes-look-at-davis-besse/.

This is a news report of land usage and energy generation of the 2 nuclear power plants in the state of Ohio, but mainly focusing on the one near Toledo, Davis Besse. This news report gives some background information on the plant that was started in 1977 under the Carter administration. This article was written during the time of the plants proposed shutdown which has since passed and is still operational today. The plant helps create many jobs which is not the main focus of my model but is something to consider because many people depend on the energy sector for jobs and their livelihoods cannot be brushed under the rug as a casualty of change. When considering a change in the energy mix we have to consider how it will effect the job market and if it's trend fits in with the current job market.

Lako, Paul. “Hydropower.” *Energy Technology System Analysis Programme*, Energy Technology Network, May 2010, https://iea-etsap.org/E-TechDS/PDF/E06-hydropower-GS-gct_ADfina_gs.pdf.

In this article, Lako discusses many aspects of costs revolving around hydroelectricity generation and the technology that is used to create electricity with water. After discussion of how a dam works, the article continues to state that the average cost of electricity generation is static over the years that the dam is active and can be active for over 100 years. The cost of 1 kwh can vary from 1 cent to 5 cents; however, the realization of that cost is heavy in the beginning of the creation of the plant because the dam can cost millions of not billions of dollars to create depending upon size not to factor in the time needed to build such a structure. The difficult part of investing in hydroelectricity is that they have a very high initial cost compared to alternative energies, however they tend to last for much longer. This however presents another issue and that is that when the plant dies, the removal of the dam can cause issues too and dams can disrupt ecosystems along the Ohio river where many of these dams would be placed.

Landmark Dividend LLC. "Solar Farm Land Lease Rates – How Much Money Can a Solar Farm Make?" *Landmark Dividend LLC*, 12 Sept. 2019, https://www.landmarkdividend.com/solar-farm-land-lease-rates-2/#:~:text=For%20a%20typical%20solar%20installation,acres%20or%20100%2C000%20square%20feet.

This website is posted by a business that buys solar farm leases that are currently generating rent for property owners or provide land financing for solar developers. This gives them insight as to how much land it takes solar panels to generate 1 MW of electricity as the loss of crop land can be important to factor in when talking about energy production in Ohio. Solar energy in Ohio is not considered to be the greatest investment due to lack of sunshine and overabundance of cloudy days when compared to places like Nevada and Arizona which receive much more direct

sunlight and less cloudy days. This is something to consider as well when building a model like this because we do not want to be taking resources from other states that would be better used in said other states. Solar panels are an example of a resource that could be better used in many other states, however that being said this website talks about land usage which can be used for other things in Ohio such as agriculture. We could still put the panels on our roofs which are useless spaces anyway.

Mitlyng, Viktoria. "Perry." *Nuclear Decommissioning Collaborative*, 2021, https://decommissioningcollaborative.org/perry/.

Gives basic information regarding the Perry nuclear power plant which is one of the two nuclear power plants in Ohio. The Perry nuclear power plant is near Cleveland, Ohio and was built in 1974 and has been in operation ever since its construction finished in 1986. Costing $7.4 billion over the course of 12 years, it is the larger of the two nuclear power plants. This plant generates millions of dollars in tax revenue for the state and local community as well as generating 1300 MW of electricity every year.

Schlissel, David, and Bruce Biewald. "Nuclear Power Plant Construction Costs ." *Nuclear Power Plant Construction Costs*, July 2008.

This article shows the cost of a new nuclear power plant if my model were to optimize the need for a new power plant that can be factored in. Many of the costs to building a new nuclear power plant are unknown because new designs are untested and have never been built before making both effectiveness and costs unknown. This poses the question as to why we would not just go with old, tested designs and the answer is that they are not as efficient in design as the new

designs are and if we are going to have a new plant, we want maximum efficiency and safely. While events like Chernobyl are concerns of old designs, we also do not know if these types of events are common in these new designs as they are untested. This enters in a new factor of risk and is something to consider in the model that I build.

SEIA. "Ohio Solar." *SEIA*, Solar Energy Industries Association, Sept. 2021, https://www.seia.org/state-solar-policy/ohio-solar.

This website gives statistics about Ohio solar energy generation and projections as to where they will go in the future. This website also gives insight as to the costs of setting up the units and how I can factor that into my model. The website also gives some insight as to where prices of solar panels have fallen from over the last 5 years, and this can be applied to the 10 year plan as well as prices will change which can have some effect on the model. The website also gives a prediction as to where they plan to see solar power in Ohio in the next 5 years which I can use as a benchmark in my plan, but I am unsure of how they made this prediction making it perhaps unreliable. One of the most valuable pieces of information on this page is the fact that solar panels are mostly installed by utility companies rather than individuals putting them on their residence or commercial companies installing them. This means that in my model I can assume that the state has more influence over solar installations than I had previously assumed.

Simet, Anna. "Global Costs of Biomass Power." *Biomass Magazine*, Biomass Magazine, 20 Nov. 2012, http://biomassmagazine.com/articles/8344/global-costs-of-biomass-power.

This article gives in-depth information revolving around biomass energy around the globe not just on economic costs but also environmental. In the article, they expressed concerns of there

not being enough energy produced with biomass versus coal which is the dominate way that we create electricity in Ohio. Later in the report, the author admits that there is still much CO2 emissions with biomass energy because you are still burning something to generate electricity which makes it much less environmentally friendly compared to other renewables. Many renewables like wind and solar have virtually no carbon output to generate electricity. Other than the manufacturing and set-up of these renewables there are no carbon emissions associated with their generation of electricity unlike biomass production. That being said, the author predicts that biomass will take place of coal in the short run as a way of taking over the power generation until the switch to better alternative energies is made.

Solar Reviews. "Solar Panel Cost Ohio: Local Prices & Online Estimator." *Solar Reviews*, 3 Jan. 2022, https://www.solarreviews.com/solar-panel-cost/ohio.

This website gives insight as to the cost of solar panels broken down over the lifespan of the solar panel and what Ohio has spent on solar panels. This website offers some insight as to what the cost of installing solar panels on a commercial building or residential building would be. After going through the cost of the systems available, the website explains how having solar will affect prices of electricity over the next 25 years which is crucial to my model as I am trying come up with a 10-year plan. They state that the price of electricity will average 19.9 cents per kwh versus the 12.24 cents average now. After this analysis, it is stated that the levelized cost of a solar panel is 6.5 cents per kwh over the span of its life which is assumed to be 25 years. Now, with that the solar panel prices continue to fall, and electricity prices continue to rise meaning that solar panels are becoming a more worthwhile investment as time goes on and is something to consider in my model.

U.S. Energy Information Administration. “U.S. Energy Information Administration - EIA - Independent Statistics and Analysis.” *Electricity Data Browser*, U.S. Energy Information Administration, 2021, https://www.eia.gov/beta/electricity/data/browser/#/topic/0?agg=2,0,1&fuel=006vu&geo=00002&sec=g&freq=A&start=2001&end=2020&chartindexed=0&ctype=linechart<ype=pin&columnendpoints=2&tab=overview&maptype=0&rse=0&pin=.

This data explorer allows the user to generate searches for energy production and consumption in any state or combination of states in the US. I have used it to filter out Ohio data relevant to the model that I am building revolving around energy generation in Ohio.

United States Environmental Protection Agency. “About the U.S. Electricity System and Its Impact on the Environment.” *United States Environmental Protection Agency*, United States Environmental Protection Agency, 14 July 2n.d., https://www.epa.gov/energy/about-us-electricity-system-and-its-impact-environment.

This webpage contains general information about the electrical grid in the US and how it impacts the environment as well as how each sector influences energy generation. This article also discusses the delivery of electricity in the US which is via high voltage transmission lines that must be "stepped up" and "stepped down" for the electricity that they carry to be usable. Later the article talks about who uses electricity and they show that residents and commercial buildings are the largest consumers compared to industry which uses only 25% of the energy we consume. This highlights another issue in our society and that is that we need to focus on efficiency in the commercial and residential settings by switching to better bulbs like LEDs and better insulation to reduce our carbon footprint. This article also points out the environmental impacts of energy

generation such as pollution and greenhouse gas emissions which can be reduced via renewable energy sources.

United States Geological Survey. “USWTDB Viewer.” *Eerscmap.usgs.gov*, United States Wind Turbine Database, Nov. 2021, https://eerscmap.usgs.gov/uswtdb/viewer/#7.63/40.839/-82.782.

This website is a viewer for all recorded commercial wind projects in the US and can be used to filter down to specific locations. It also gives total capacities of what projects are displayed on the map. In Ohio we can see that there are 503 wind turbines with a total of a 1111 MW capacity which offers insight as to where they are most effective too as there is a map of where they are as well. It seems from the data that most turbines are in West Northwest Ohio showing that this is the windiest part of the state giving the turbines the highest chance of generating electricity at any given time.