The Good Questions Project: Understanding Energy Project Development in Indiana Phase 2 Final Report

prepared for:

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1.0 Contents

2.0 Executive Summary

The Indiana Office of Energy Development (OED) has contracted with a research group under the direction of Prof. Peter Schubert of the Richard G. Lugar Center for Renewable Energy, administratively housed within the Purdue School of Engineering and Technology on the campus of Indiana University-Purdue University Indianapolis (IUPUI) of Indiana, USA as of 17 January 2022 to conduct a two-phase study into the issues involved and the possible resolution thereof for energy projects being considered by Indiana counties. Called the "Good Questions Project", the aim is to help community members ask informed questions of developers, and to provide aid and assistance to county elected officials and county economic development professionals. A report for Phase 1 was submitted on 5 July 2022. This is the final report of Phase 2 of this two-phase project, and contains all new material.

Of the Phase 2 Good Questions Project deliverables, these four are required:

(a) **Mapping Tool** to illustrate county-by-county opportunities towards new energy project rollout, economics, harm to humans, impact on the environment, and considerations of social justice, equality, and diversity.

(b) **Guidance Tool** for siting per energy technology (this will be at a medium level of detail, as a full study would require more time), with white papers to help guide discussion germane to the intersection of technology and land site.

(c) **Best Practices** stories and data, including successes, projects that did not consummate, as well as epic failures. These can be useful to county assets in guiding their own destiny.

(d) A **Generic Survey** that can be used to update the information presented as circumstances and situations evolve over time in this dynamic field.

The project team consisted of 10 student researchers at IUPUI and IU-Bloomington, the Indiana Economic Development Association (IEDA), and The Polis Center at IUPUI. In addition to the deliverables enumerated above, the team completed three additional "deep dive" white papers and information cards on top-ranking questions from Hoosier citizens, bringing the grand total to nine. These 9 are among the 34 listed in a 3-page quick-answer fact sheet prepared as an aid to leaders. An additional aid to leaders, as well as to individual landowners, is a study of contractual terms and conditions to be negotiated with project developers.

Two agrivoltaic business cases are presented, combining traditional Hoosier agriculture with solar farms. Results are also presented on a new invention for low-cost detection of bat and bird strikes by wind turbines. These sensor systems can help answer difficult questions that are the subject of much debate. Early investigations are presented here into a "wind whistle" that can emulate the sound of wind turbine blades in the field, without needing to go there in person.

Several public outreach and fact-finding investigations are summarized, providing anecdotal support to the Generic Survey results. The issue of environmental justice was addressed by the team, with preliminary findings reported here. This report concludes with policy recommendations emerging from this body of work, plus next steps in a possible continuation of the Good Questions Project (GQP hereafter).

3.0 Introduction

The Research Team

Prof. Peter J. Schubert, Director, Richard G. Lugar Center for Renewable Energy
Mr. Lee Lewellen, President/CEO, Indiana Economic Development Association (IEDA)
Ms. Marianne Cardwell, Director of Geoinformatics, The Polis Center at IUPUI
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Mr. Shalem Poriah, Student, IUPUI – Energy Engineering
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Ms. Naznin Nahar Nipu, Graduate Student, IUPUI – Electrical and Computer Engineering
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Indiana has favorable power transmission infrastructure that makes it attractive for utility-scale energy projects. Wind energy grew rapidly in the last decade, and appears to be tapering off, while solar is just now beginning to grow rapidly. Fifteen years ago there was a "food versus fuel" debate regarding diversion of corn (maize) to ethanol for blending into gasoline. Today, about half (50%) of corn grown in Indiana goes to ethanol (Indiana Corn Marketing Council). The fervor of those old arguments has cooled as farmers realized the profits to be made. Regarding wind and solar, the debate rages across many Indiana counties, despite the favorable economic advantage potentially available to landowners and their communities.

Those opposing new energy projects may have many reasons, as reflected in the questions gathered, and answered, as part of the GQP. One consideration regarding corn versus solar is particularly ironic: farmers growing fuel for gasoline vehicles now perceive electric vehicles powered by solar panels as competition. Another very widespread feeling among citizens in rural areas is the cultural loss of farmland from food to energy. It is largely forgotten in the 2020's, but cropland in the US peaked in the 1930's, and has been declining ever since. Yet food is still plentiful and affordable. Our work revealed that land use changes for energy are only a small fraction of other loss of arable land. In the years between 2013 and 2021 almost three-fourths (68%) of lost agricultural land went to homes and neighborhoods. Most of the rest went to warehouses and factories (25%). Only about 5% of land use changes in this period went towards energy. This is within an overall loss of just 2%. Of the 21 million acres of Indiana farmland, about 0.4 million acres were no longer classified as agricultural during that 8 year period. These statistics illustrate how small this issue is, when put into context (5% of 2%, or **0.1%** to energy), but does little to assuage the perception of local residents watching a familiar field become a solar farm.

The aim of the GQP is to answer concerns and social media-spread disinformation with well-researched responses. This work aims to put each concern into context with other risks and harms that are already a part of our everyday lives. Armed with this information, communities can make informed decisions as to what is best for them.

4.0 Mapping Tool

GIS stands for Geographical Information System, and is a powerful method of analysis for any data that can be tied to a physical location. The range of place-related data is wide, and includes elevation, mineral deposits, satellite photographs, property lines, bridge locations, political boundaries, asthma incidence, local climate, and much more. For the GQP, it can identify the location of wind turbine towers, the fence around it, the access road, and the electric substation used to connect to the grid. For solar photovoltaics (PV), GIS can identify the fence line of the project, and the actual number of acres covered by solar panels. Working with The Polis Center at IUPUI (https://polis.iupui.edu/), under the direction of Marianne Cardwell, PMP, GISP, the GQP team has created a tool for studying new energy projects that is being hosted by the State of Indiana Geographic Information Office (GIO).

The following section describes the organization and purpose of the Mapping Tool, starting with anticipated use case scenarios. These four example describe how a variety of users can gain insight and obtain valuable data on energy projects from the Mapping Tool. Following this section are screen shots and explanations that describe the Mapping Tool, which cannot be embedded in this report.

4.1 Four Potential Use Cases for the Mapping Tool

Case 1. User has a parcel they'd like to build a renewable energy project on

In this case, the user has an empty parcel or set of parcels. The mapping tool can be used by the user to determine the amount of energy the desired area can generate. Using information generated from other renewable energy projects around the state, the mapping tool will estimate the amount of MW the renewable energy project would be, the number of jobs that the project would bring, and an estimated tax revenue. The next steps users will want to know are who to contact to develop the renewable energy project, local regulations, and if it would be more efficient to build a solar, wind, or biofuel project in that area. It will be helpful to include a list of renewable energy developers that work in Indiana, a link to state regulations for renewable energy projects (finding specific local regulations might be difficult and time consuming) and include different energy potentials for the parcel based on the renewable energy source.

Case 2. User has a renewable energy project they'd like to build but don't know where to build it

In this scenario, a user has an agreement with a renewable energy developer to build a project in their district. The user is then tasked with finding a location for the project. The user can compare different open parcels to find their energy potential. First, the mapping tool can be used to find how many acres similar projects take up so they know how many acres they would need to allocate to the project. Next, the user can use the mapping tool and select parcels or draw an area they would like to build the renewable energy project. The mapping tool should include instructions that inform users that renewable energy projects don't need to be on conjoined parcels. For example, a 10 MW solar project can have 5 MW on one parcel and 5 MW on a parcel that's a 10 minute drive away. The mapping tool can also tell the user how the parcel they would like to build the renewable energy project is being used. For example, if a user doesn't want to build a renewable energy project on farmland, they can turn on the farmland layer to ensure that the renewable energy project is built somewhere else

Case 3. User wants to compare money generated from agriculture to potential renewable energy projects

This is the situation where users can compare the economics of farming and renewable energy. The users will use the Purdue GIS layer, market data, and the data showing average crop yield to receive an estimate on how much money a farmer can generate from their crops, and in turn how much tax revenue they generate. The Good Questions Project team is collecting data on how much money a farmer can make if they turn their parcel (or part of their parcel) into a renewable energy project, as well as the expected 'rent' the farmer/owner of the land would earn from the renewable energy company. Additionally, the mapping tool will have data on how much space a solar/ wind farm takes up, so that farmers can know how much of their land would be dedicated to the renewable energy project and how much would be still farmable. Users will wonder if there is a way to put a renewable energy project on parcel, and the other task that the Polis Center is working on can help answer that question.

Case 4. Users want to know if they have a workforce well suited for renewable energy projects

Using information from the EPA's environmental justice map as well as a map of jobs in each area based on U.S. census data, the mapping tool can be used to give users a sense of how their district's workforce compares to the workforce needed for a renewable energy project. The mapping tool can show how many people live in the district, the type of workforce they have, how many eligible people they have to work, and the general income of their population. This can be used to identify what job training programs they need to bring to the district that would make the area optimal for a renewable energy project. Although sometimes renewable energy projects bring in most/ all of the workforce, it is often cheaper and part of the renewable energy company's agreement with the county to use the local workforce to build the project. Users will likely want to know the type of workforce needed and skills/ abilities needed to make their workforce optimal for a renewable energy project. The Good Questions Project can include links or find research that shows what skills are needed in a renewable energy project. Additionally, users will want to know how their district stacks up against others, and to do so they can click on other districts to compare.

4.2 Description of the Mapping Tool

Figure 1 shows the initial graphic of the "story map" from the arcGIS online software tool. A story map is similar to a very long webpage having zoomable maps stacked from top to bottom. Within and among these semi-interactive maps are floating textboxes that pop up and provide instructive details of the map contents. A user can proceed scrolling downward at their own pace. They can pan and zoom in to see more detail, or zoom out for more context. This provides an overall perspective on energy projects in Indiana with some high-level statistics. The image in fig. 1 comes from the US Energy Information Agency (EIA) and was filtered to show wind and solar projects. Each icon of a sun or a turbine indicates a "project", within which are many solar panels or wind turbine masts, respectively.

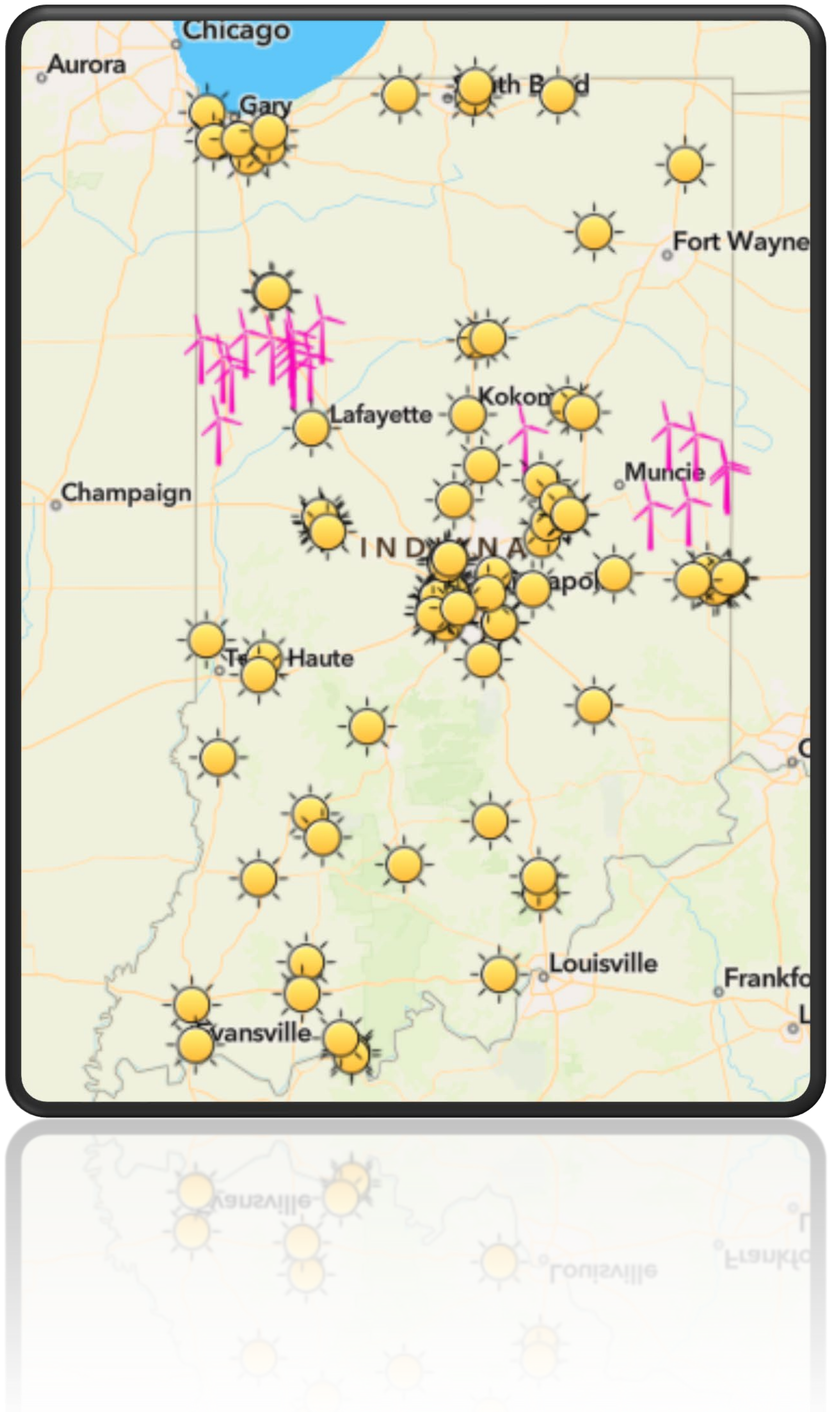


Figure 1. Location of wind and solar farms greater than 1 MW, from the US Energy Information Agency.

Figures 2 and 3 show two examples from the storymap, with a solar farm project on the grounds of the Indianapolis International Airport, and the Fowler Ridge wind farm. Users can easily see what portions of the project's footprint have the energy generation capability, and what portions are vacant land available for other purposes, such as farming around wind turbines.

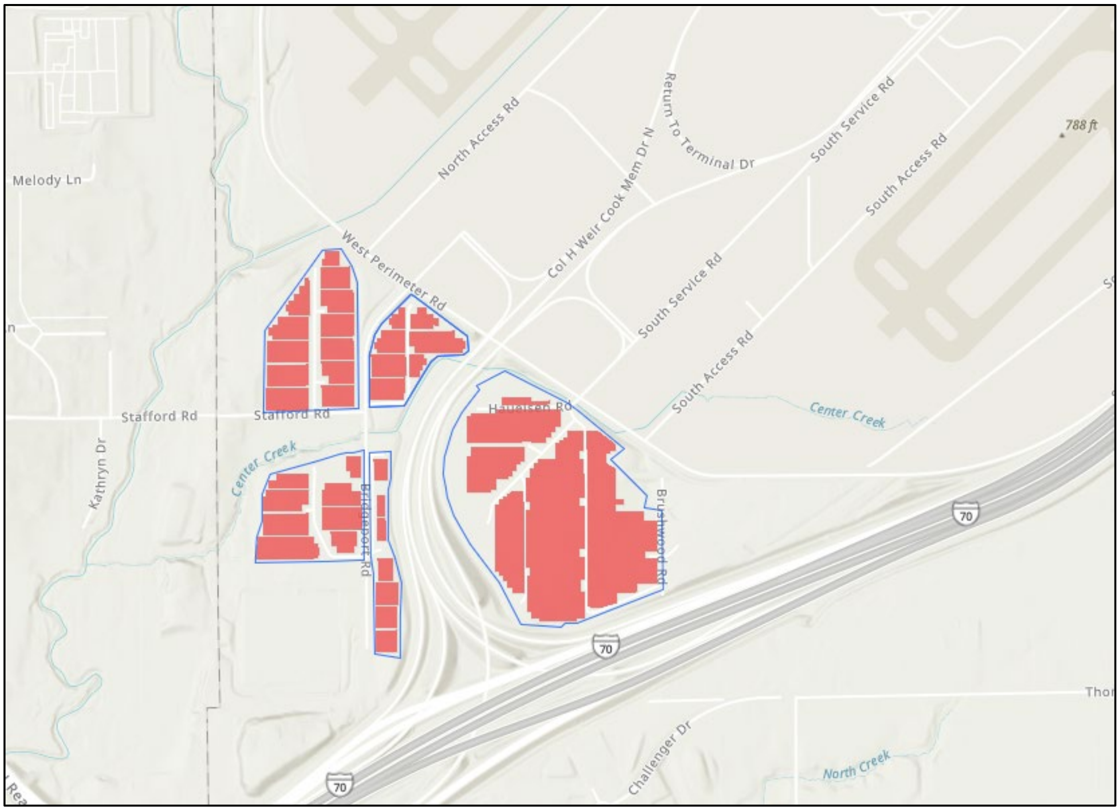


Figure 2. Indianapolis International Airport solar farm showing actual panel coverage (red) and facility boundary (blue lines).

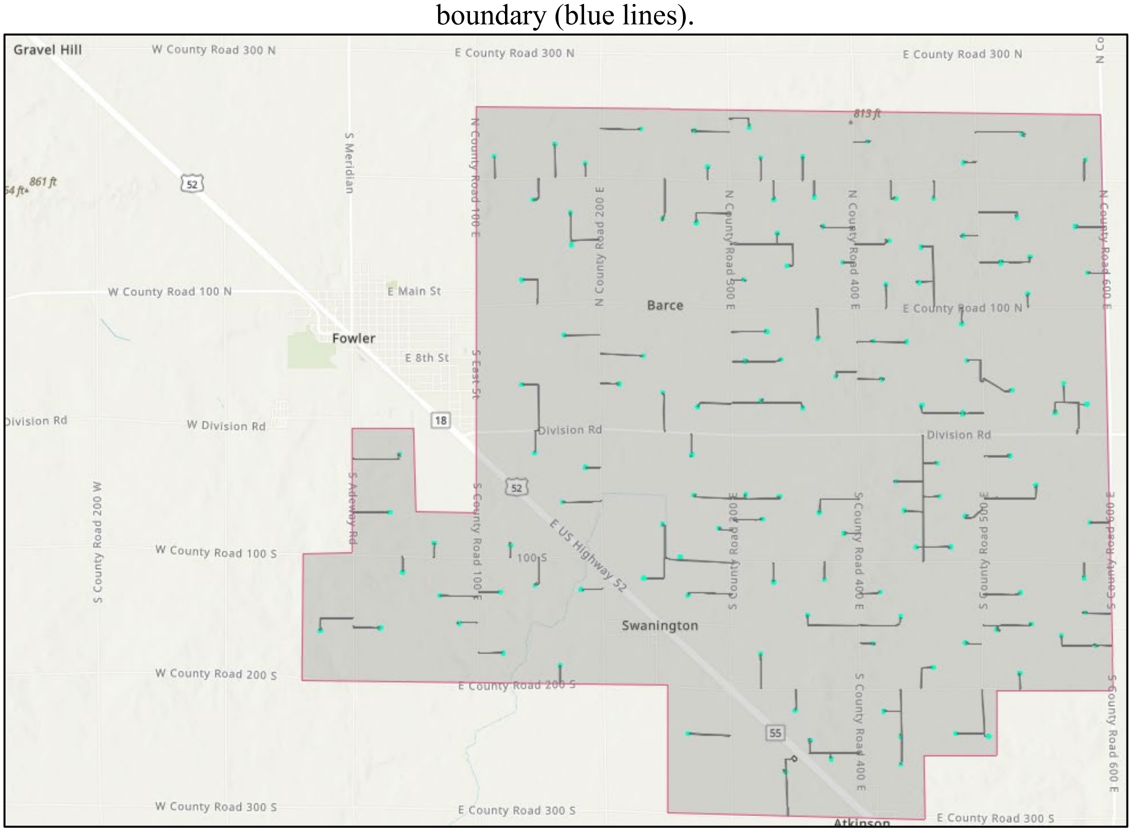


Figure 3. Fowler Ridge wind farm showing masts (cyan) and access roads (black).

Once the user reaches the bottom of the storymap, they reach an interactive capability that implements the four use cases listed in the prior subsection. This interactive section has great power to show various "layers" of data, and the user can turn each layer on or off to either display or hide, respectively. The image in figure 4 illustrates one aspect of use case number 4 from the prior section. This is a "heat map" showing the concentration of construction jobs across Indiana. A user can zoom in on an area of interest to find out how many workers may be available locally for the construction phase of an energy project. In most localities, it is highly desirable to create jobs locally. With the Mapping Tool one can assess, as one example, what fraction of the required installation workforce might reasonably be demanded to include citizens who already live and work in the community.

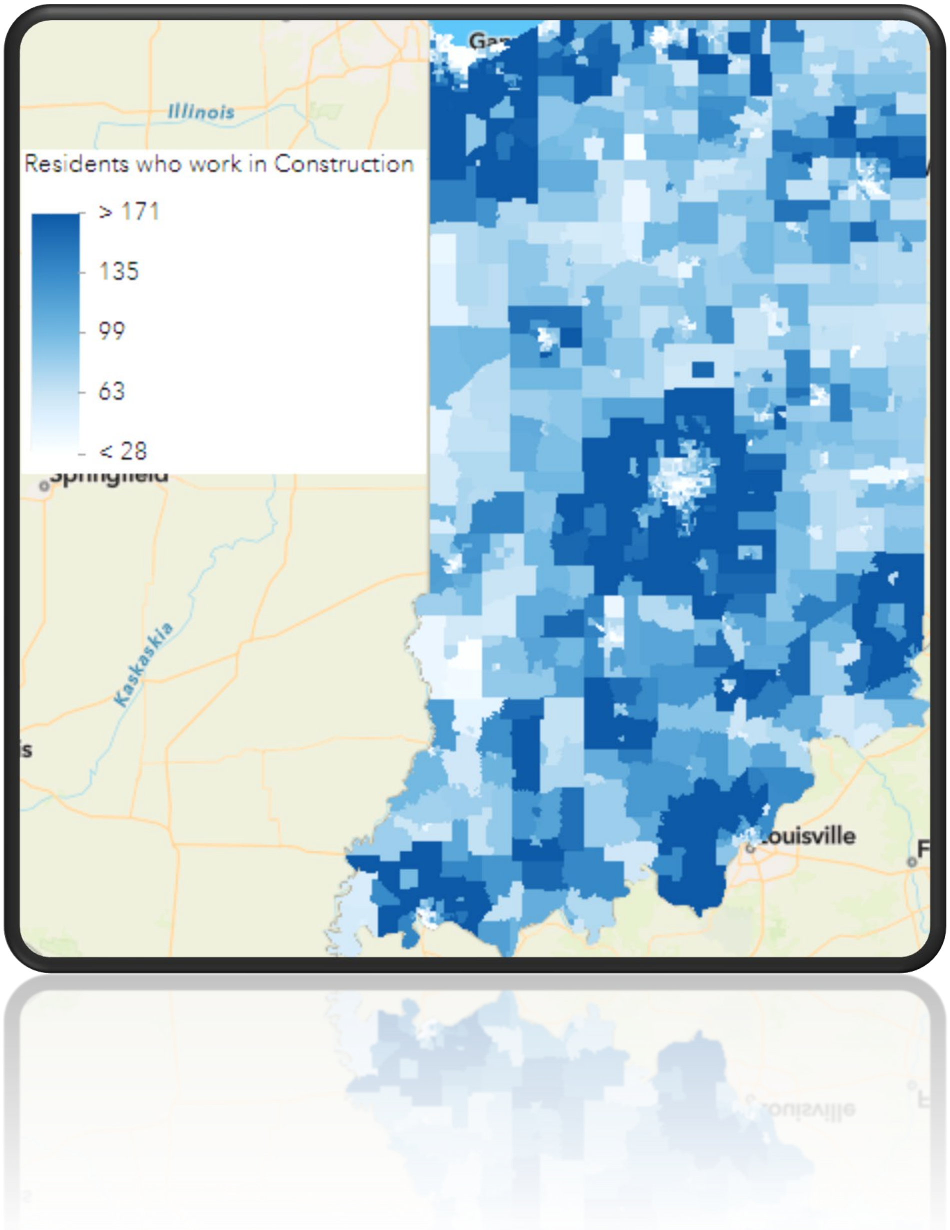


Figure 4. Map showing density of residents who work in construction, from "2019_Indiana_Lodes_by_Tract" database.

Figure 5 shows the interface to the interactive portion of the Mapping Tool where the user is given great power and control across the four use cases. Along the far left edge of the tool, in the blue menu ribbon are the “hamburger”, the “stack” and the “window”. The “stack” icon provides a pop-up menu listing the available layers, such as the construction jobs layer shown in the prior figure. Among the various use cases, users can rapidly and intuitively swap between demographics, incomes, existing land use, educational attainment, and more. The map can also be panned by click-and-drag to compare and contrast other locales .

By clicking on the icon that looks like either a toolbox/lunchbox/briefcase (indicated by the top red arrow), the geoprocessing tool menu is brought forward. Under the text “Proposed Site*” are clickable icons for various drawing tools. The most popular method is to use the polygon tool (image to right) allows the user to create a plot or region or layout for a potential energy project. The red waste-basket icon can be used to remove a selected region, and, for example, to try another plot in a different location. The Run button (indicated by the bottom red arrow) calls a series of functions to calculate statistics regarding the plot that the user has drawn. The result is presented in a pop-up window that includes ranges for the following:

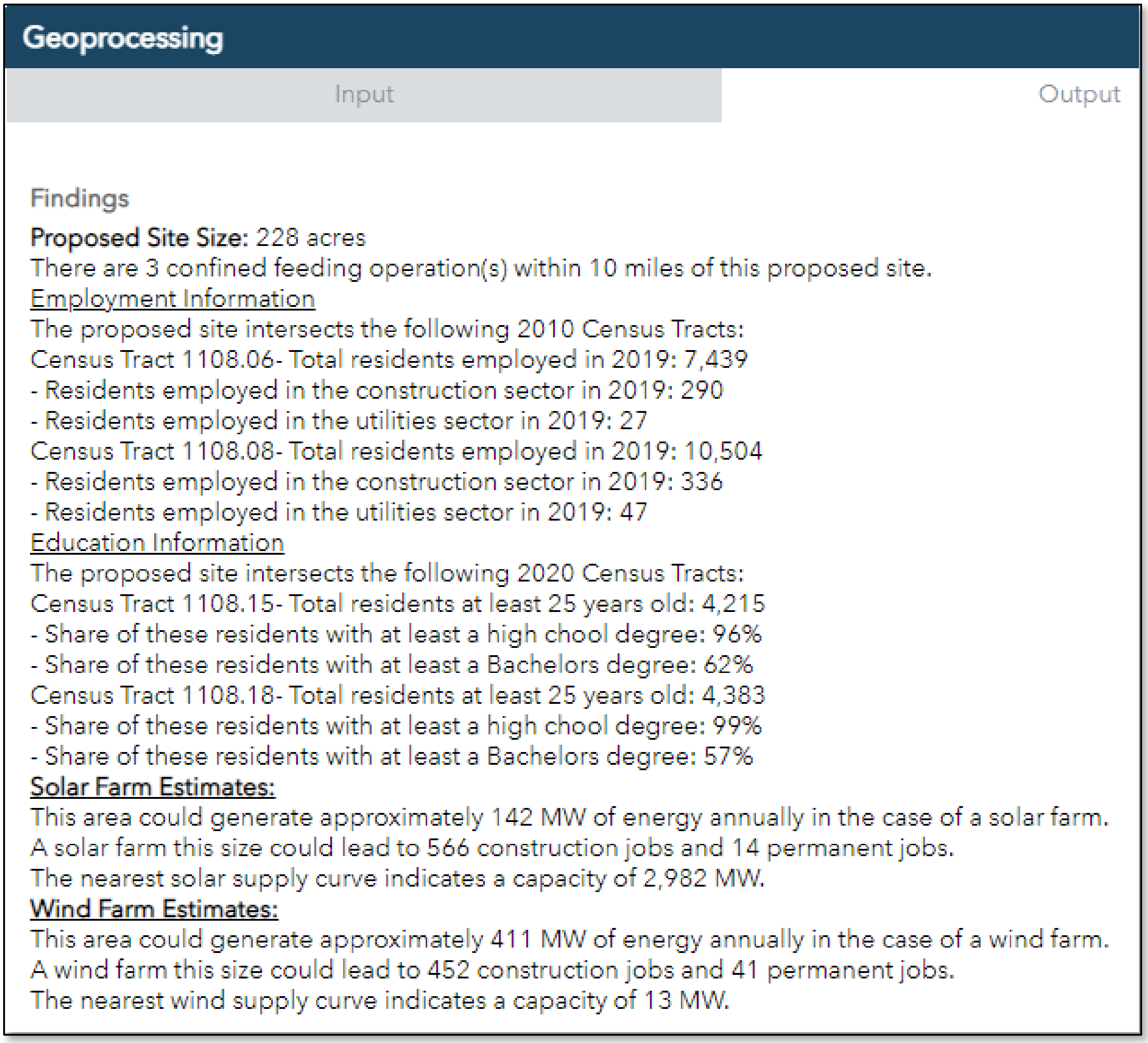
A. Megawatts (MW) of capacity for solar
B. MW of capacity for wind
C. Construction jobs
D. Expected annual revenues

Through the use of this interactive tool, a user of the Mapping Tool can answer the questions and “what-if” scenarios described in the four use cases. This capability can provide value to landowners, economic development professionals, and even project developers. As a non-limiting example, a farmer considering leasing a parcel of their land to an energy project can use the Mapping Tool to learn a range of revenues they might expect. Such information can be of considerable value in negotiating with project developers. For more considerations in more transparent negotiations, please also see Section 12.0 below.

It may be evident that the power of GIS is considerable. The Mapping Tool created during the GQP shows proof-of-concept for how these capabilities can be used during the consideration of energy projects in Indiana. The storymap functionality is relatively straightforward to create, however, there is the ability to code more complex analyses, although this would require more time and resources. Additional features that might be included in future versions of the Mapping Tool can include studies of historic land productivity and current land prices vis-à-vis earning potential for energy projects. Analysis by the GQP team, with input from IUPUI SPEA professor Jerome Dumortier identified that the site of the Mammoth Solar project, currently set to be the largest in the US, is located in two counties (Starke and Pulaski) that are among the lowest in Indiana for average bushels per acre of corn yield (https://www.nass.usda.gov/). It may be that the developer, Doral Renewables, considered this factor in their siting investigations. With an expanded Mapping Tool, target communities can perform similar analyses to answer questions such as “Why here?”. As another example, an expanded Mapping Tool might assess county tax rates, infrastructure condition, and income per capita to identify communities that might be receptive to a new project. A complementary capability conducted within the GQP is the Guidance Tool, presented in section 5.0, that considers factors that are not location-dependent in new project considerations.

Figure 5. Custom Mapping Tool interface showing toolbox (top red array), area drawing tool (middle red arrow), and run/calculate button to produce results (lower red arrow).

Figure 6 shows the output when the Run button is pressed in the prior figure. A new window pops up with the result of calculations based on the area selected by the user with the drawing tool. These calculations are based on averages from research into related project, but it must be understood that there is a range straddling this average, so that actual results could be greater or smaller. Also, as wind turbines are built taller, and solar panels are made more efficient, the power generation estimates could increase over time as technology advances.



Geoprocessing

Input | Output

Findings

Proposed Site Size: 228 acres
There are 3 confined feeding operation(s) within 10 miles of this proposed site.
Employment Information
The proposed site intersects the following 2010 Census Tracts:
Census Tract 1108.06- Total residents employed in 2019: 7,439
- Residents employed in the construction sector in 2019: 290
- Residents employed in the utilities sector in 2019: 27
Census Tract 1108.08- Total residents employed in 2019: 10,504
- Residents employed in the construction sector in 2019: 336
- Residents employed in the utilities sector in 2019: 47
Education Information
The proposed site intersects the following 2020 Census Tracts:
Census Tract 1108.15- Total residents at least 25 years old: 4,215
- Share of these residents with at least a high chool degree: 96%
- Share of these residents with at least a Bachelors degree: 62%
Census Tract 1108.18- Total residents at least 25 years old: 4,383
- Share of these residents with at least a high chool degree: 99%
- Share of these residents with at least a Bachelors degree: 57%
Solar Farm Estimates:
This area could generate approximately 142 MW of energy annually in the case of a solar farm.
A solar farm this size could lead to 566 construction jobs and 14 permanent jobs.
The nearest solar supply curve indicates a capacity of 2,982 MW.
Wind Farm Estimates:
This area could generate approximately 411 MW of energy annually in the case of a wind farm.
A wind farm this size could lead to 452 construction jobs and 41 permanent jobs.
The nearest wind supply curve indicates a capacity of 13 MW.

Figure 6. Output sample from the custom Mapping Tool interface showing demographics. The exact acreage selected, and estimates for annual average power, plus job creation, for either wind or solar.

Appendix 18.6 illustrates the methodology for energy project boundary identification conducted by The Polis Center at IUPUI. Wind farm boundaries were performed by eye, using parcel edges as a guide. Solar farms have fences, which was taken as the boundary. These solar farms are:

Figure 1. Indianapolis Airport Solar Farm
Figure 2. Indy Solar II, LLC
Figure 3. Riverstart Solar Park

The following wind farm projects are also shown in the Appendix.

Figure 5. Fowler Ridge I
Figure 6. Meadow Lake I
Figure 7. Meadow Lake IV
Figure 8. Wildcat I

5.0 Generic Survey

The Phase 1 survey was sent to economic development officials, elected leaders at the local and state level across all 92 counties in Indiana. Those results are summarized in the Phase 1 report (5 July 2022). In Phase 2 this survey was expanded slightly and send to a much wider audience intended to be representative of the general population, focused on 10 counties.

5.1 County Selection Process for Citizenry Survey

Introduction

There are 92 counties in Indiana and over 6.5 million residents; polling all of them to find opinions of all Hoosiers would be tedious and near impossible. Instead, the Good Questions project has paired counties that have renewable energy projects located within the county and counties that either have ordinances severely restricting, or outright banning, new renewable energy projects, or counties where a specific renewable energy project faced significant opposition. In order to minimize demographic, geographic, and climate differences, each pair of counties will be neighbors. Indiana has been divided into four different regions, and one pair has been selected from each region, except the Northeast which has two comparison pairs. This allows the Good Questions Project to get answers from people who support and people who oppose renewable energy projects from all over the state, providing a large enough sample size to draw accurate conclusions from the survey data.

Finding Counties with Opposition to Renewable Energy

In Indiana, there are many counties that have renewable energy projects big and small in them, so the first step of finding county pairs is to find counties which are on the record as having barriers to renewable energy production. For this, there are two websites. The first comes from a website run by Robert Brice. Brice is famously anti-wind energy, but his website simply states which county opposed the renewable energy project (the website is limited to wind and solar), when the opposition occurred, brief notes, and links to an article. Brice cites the following counties opposing wind farms: **Jasper (2018), Wells (2015), Rush (2016), Henry (multiple times), Fulton (2017), Rochester (2017), Montgomery (2019), Vermillion (2022), Tippecanoe (2019), Clinton (2019), Posey (2019), and St. Joseph (2002).** Additionally, **Howard** County (2021) and **Delaware** County (2022) have halted solar farms in recent years.

Additionally, the Sabin Center for Climate Change Law at Columbia University tracks renewable energy restrictions. This website is more thorough and is updated yearly. It included one to two sentences explaining the opposition to the renewable energy project. However, it also includes any restrictions, such as Hamilton County limiting wind turbine blade length to 300 feet or particularly long setbacks. They track the following counties as having laws or ordinances restricting renewable energy projects: **Allen (2018), Boone (2009), DeKalb (2018), Delaware (2022), Fulton (2017), Hamilton (2019), Jasper (2019), Kosciusko, Marshall (2013), Miami (2018), Montgomery (2019), Noble (2013), Pualski (2018), Rush (2016), Tippecanoe (2019), Tipton (2016), Wabash (2017), Wayne (2016), and Whitley (2016).** Additionally, they find that the following projects faced significant pushback, even if the project was approved. The following projects faced significant opposition (with county in parentheses)[1]: **Jordan Creek Wind Farm (Warren), Big Blue Ribbon Wind Farm (Henry), Prairie Breeze Wind Farm**

[1] Underlined projects are projects that were approved despite significant pushback

(Tipton), West Fork Wind Energy (Rush, Henry, Fayette[2]), Elkhart County Solar (Elkhart), Lone Oak (Madison), Gibson Solar (Gibson), and Meadow Forge (Delaware). The last source for finding oppositional counties was looking at the Lugar Center's list of Indiana based organizations and looking at corresponding Facebook pages. The most useful result of this methodology yielded an interesting comparison as it relates to the Mammoth Solar Project. This project splits Starke and Pulaski counties and interestingly support vs opposition also splits along county lines. Pualski County has a large Facebook page opposing the project, as well as a change.org petition with 462 signatures trying to cancel the project (a similar petition in Starke County has 49 signatures). Additionally, there is a large, active website urging citizens of Pulaski County to reject the project. Although the protests and op-eds have yet to result in significant changes, it still provides the Good Questions Project with a good opportunity to find out why people oppose the project and where the information they get comes from.

Approved Renewable Energy Projects

Finding approved renewable energy projects is a much easier task. To do so, data was downloaded from the EPA's Egrid dataset (https://www.epa.gov/egrid), which tracks total energy production from every power plant over 1 MW in the United States. Using data from 2020 in R studio and Microsoft Excel, a table was created showing the total energy production from different fuel sources in each county. Then non-fossil fuel sources were filtered out to show which counties should be surveyed for the Good Questions Project. There are 48 counties with renewable energy projects, making for ample opportunities. The counties covered will be listed in the following section.

5.2 Counties to Survey

Using information on which counties have barriers to renewable energy projects or have opposed them in the past, and which ones currently have renewable energy projects, the Good Questions project has selected the following five pairs to study:

Starke County and Pualski County

Perhaps the easiest comparison to draw are two counties that are sharing the same project. Neither county currently has a renewable energy project, but there are noticeable differences between county support for Mammoth Solar. Many energy professionals around Indiana have mentioned that Starke County has little opposition to the project, while Pulaski County has significant online presence dedicated to fighting the project. By studying these two counties, the Good Questions Project can find what the difference is between the two counties, whether it's where the information they get comes from, what areas they focus on with regards to the project, or another factor.

White County and Jasper County

Although this is right below Starke and Pualski counties, comparing White and Jasper counties would provide valuable insight. White County is the 'renewable energy capital' of Indiana, with the most wind production of any county provided by the Meadow Lakes Wind Farm, a staple of the drive from Indianapolis to Chicago. However, in 2018 Jasper County rejected a wind project despite seeing the benefits wind has brought to their southern neighbor and the next year stopped

[2] This project was halted in Rush and Henry Counties but is still up in the air in Fayette County.

expansion of wind turbines into the county. They also have a Facebook page dedicated to opposing wind turbines. Additionally, Jasper County has two (small) solar plants, so the Good Questions Project can find why those two were approved but a wind farm was rejected.

Wells County and Jay County

In the Eastern part of the state, Wells and Jay counties pair well. Wells County has a fossil fuel plant – natural gas- providing the Good Questions project with a county that currently has fossil fuel energy production. In 2015, they passed zoning regulations, freezing out future wind turbines in the county. Five years later, Jay County completed the Bitter Ridge Wind Farm. While Jasper County rejected wind turbines after seeing the successes of White County, the Wells-Jay relationship shows a county that built wind turbines after seeing a previous rejection in a neighboring county. This dynamic is something that the Good Questions Project can explore more with the survey.

Rush County and Hancock County

Further south, the Good Questions Project can compare Rush and Hancock counties. Interestingly, a solar project that will span both counties just began construction. This would seem to disqualify Rush as an 'opposition' county, but instead it makes it an interesting case study. Rush has a biofuel plant in the county but has rejected a wind farm in the past. Hancock, on the other hand, already has a solar project. So by surveying these two counties, the Good Questions Project can find the role of a successful neighboring project on attitudes towards renewable energy, how feelings towards renewable energy projects change over time, and why some people support a solar project vs a wind project. Additionally, this is the only county comparison where both counties are part of an REMC. Rush uses Rush-Selby Energy while Hancock County has their own REMC. This will allow the Good Questions Project to look at effect Rural Energy Cooperatives have on their constituents.

Posey County and Vanderburgh County

The Southwest portion of the state has a dearth of renewable energy projects, especially when compared to the rest of the state, but Vanderburgh County does have two solar projects in the county, although they are both relatively small. On the other hand, Posey County has placed stringent rules on wind turbines placed in the county. By studying these two counties, the Good Questions Project can try to find why there are so few renewable energy projects in that area, as well as further find the relationship between why some people support solar much more than wind.

A map of the counties surveyed is shown in figure 7 on the next page.

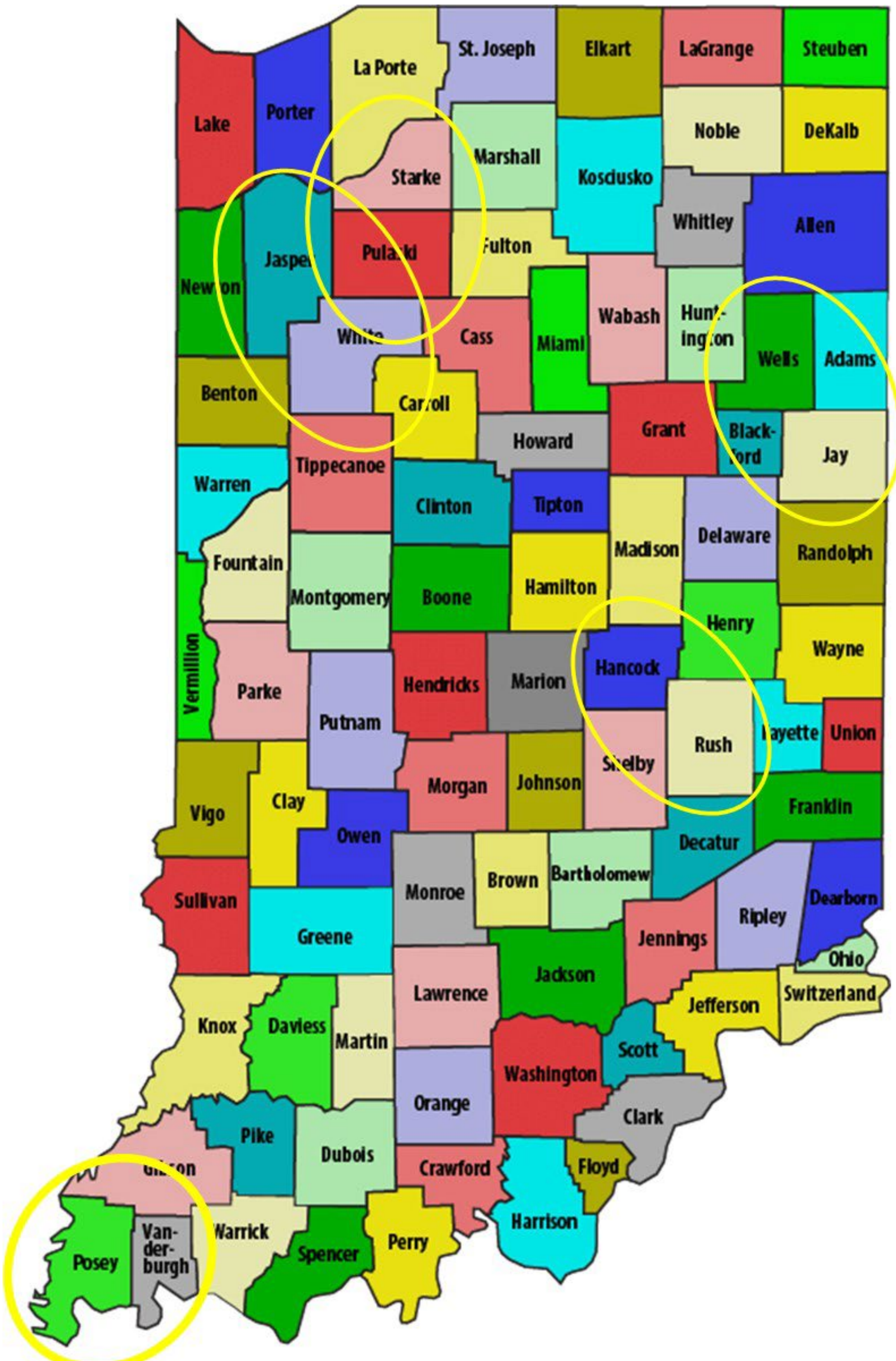


Figure 7. Five pairs of adjacent counties (10 total) selected based on divergent attitudes towards new renewable energy projects.

5.3 Survey Results

Questions asked in the survey are available in the Phase 1 report. Only minor adjustments were made to make the questions more clear. The survey itself is still live as of 8 December 2022, but may not be available at future dates. Any responses submitted now are not planned to be analyzed. The link to the survey itself is here:

https://iu.co1.qualtrics.com/jfe/form/SV_6m2okaAOL0iku1M

To reach as many citizens as possible, the Phase 2 generic survey was distributed to local leaders in the 10 counties with a request to forward to their constituents and organization members. These leaders included county commissioners, mayors, state representatives and senators, church pastors, and school superintendents. With gracious support from Mr. Jeff Cummins, Assoc Dir Policy Engagement with the Indiana Farm Bureau, the survey was also passed to Farm Bureau leaders in the 10 counties selected. The survey was first released in early September and concluded in late November 2022. A total of N=365 responses were received and analyzed.

The first question in the survey asks respondents to self-identify with the county they work in and their role, selecting from the following list: county commissioner, economic development professional, energy professional, citizen, business owner, farmer, or other. The respondent is then guided through several series of questions to understand their attitude towards various energy projects, including: wind, solar, nuclear, coal, and natural gas. They are then asked their feelings towards electric vehicles, climate change, distributed energy resources, and whether they personally noticed in change in climate since they were children. In order to understand what sources of information people relied upon, they were asked to select one or more of: national newspaper, local newspaper, social media, word-of-mouth, energy professionals, and other.

Analysis of correlations between the five energy sources studied was interesting. Not surprisingly, there was a high correlation between attitudes towards wind and towards solar; also there was a high correlation between coal and natural gas. Feeling towards nuclear power tracked with feelings towards coal (see figure 8). A frequently-encountered argument is that baseload nuclear power can backstop intermittent (non-dispatchable) renewable sources, however, this was not evident in the survey results.

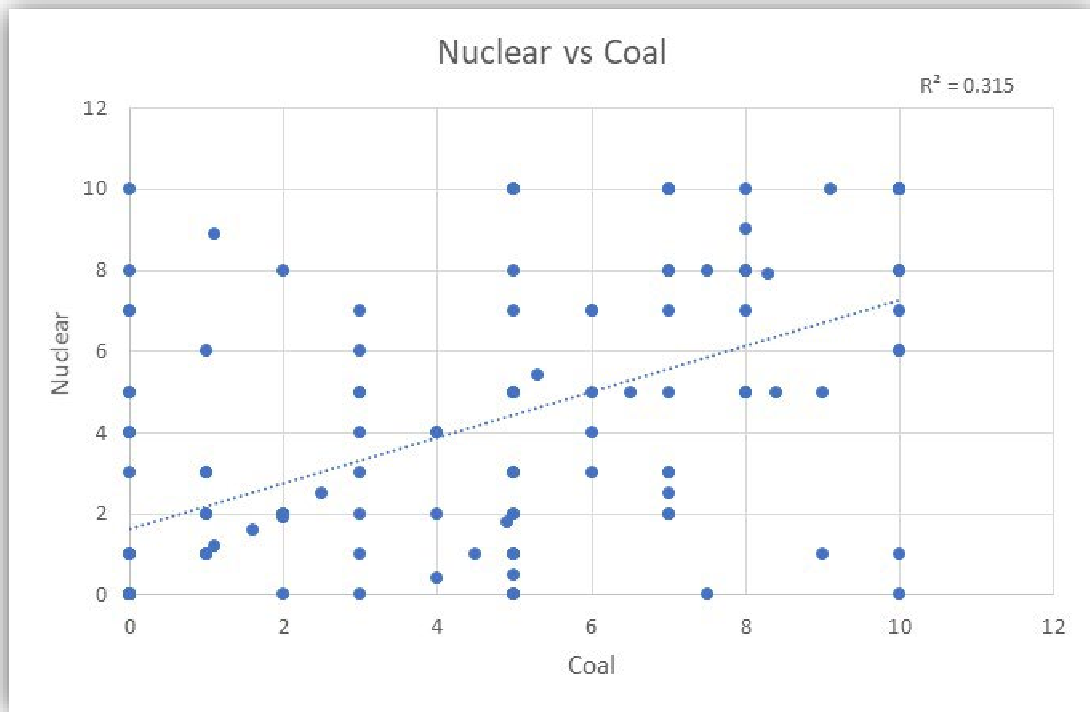


Figure 8. Correlation plot between nuclear and coal-fired electric power favorability.

Overall responses to the five energy sources shows solar and natural gas being significantly higher than wind, nuclear, and coal, as shown in figure 9. This figure is called a "box and whiskers" plot and the responses range from 0 to 10, with higher numbers being more favorable. There are four important features in a box-and-whiskers plot. First is the **range**, shown by short, horizontal bars showing the highest and lowest response. From the survey results all forms of energy received at least one zero and at least one ten. Second is the **average** (called the "mean"), indicated by an "x". The position of the "x" across the energy types clearly shows solar and natural gas being most favorable. The colored box represents the span between 25th and 75th **percentiles**. In the figure, these are quite tall, suggesting a wide spread of responses. Fourth is the **median**, that number having an equal number of responses higher and lower. In an standard distribution, median and average line up with each other, as seen in wind and natural gas. In the figure of overall responses, a median line above the "x" indicates the responses are "top heavy". In the case of solar, those in favor tend to be enthusiastic; while in the case of coal, which is "bottom heavy": those who do not like coal feel that way very strongly.

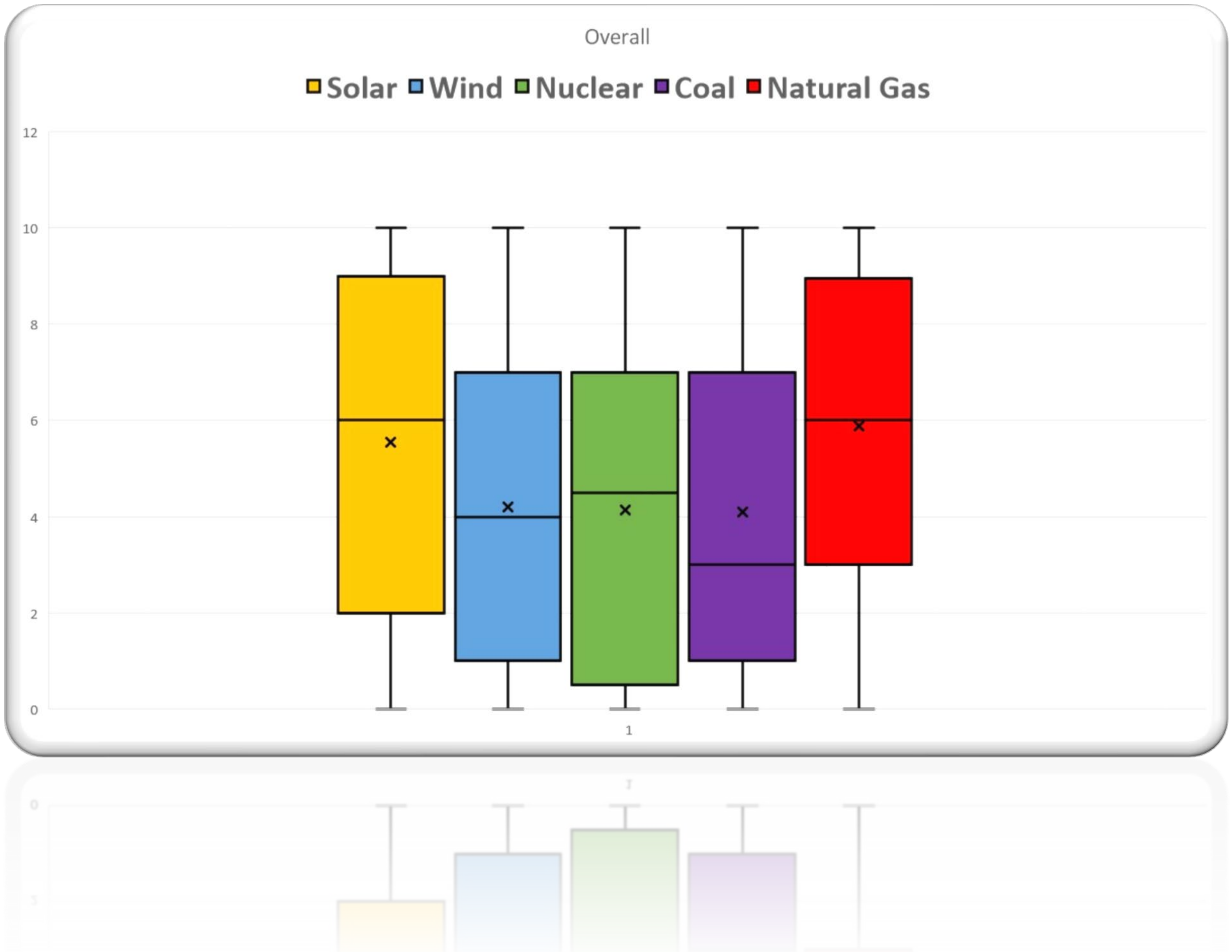


Figure 9. Overall generic survey results showing favorability ratings for five energy sources.

Delving deeper into these responses, those who self-identify as “citizens” follow the general trends of the overall result. Economic development planners have a very strong positive response to natural gas, followed closely by solar. Although the survey does not identify the reasons or motivations behind respondent choices, it might be surmised that the recent surge in natural gas generation plants in Indiana has caught the attention of these commerce-oriented professionals, and that they also see the upside to the emerging growth in solar. Farmers strongly favor natural gas over all other forms of energy. But the most interesting result is from those who identify as “business owners”, as shown in figure 10. Business owners favor coal and natural gas, and the median line for natural gas is significantly above the average, suggesting enthusiastic support of this energy source. A related question asked business owners to rank the importance of having their energy come from renewable (non-fossil fuel) source on a scale from 0 to 10. The average was 3 and the median was 2, with the 75% percentile at only 5. In trying to interpret these results, a plausible hypothesis is that business owners in these 10 counties are not much motivated by being “green”, but place maturity and reliability of electricity as their top priority.

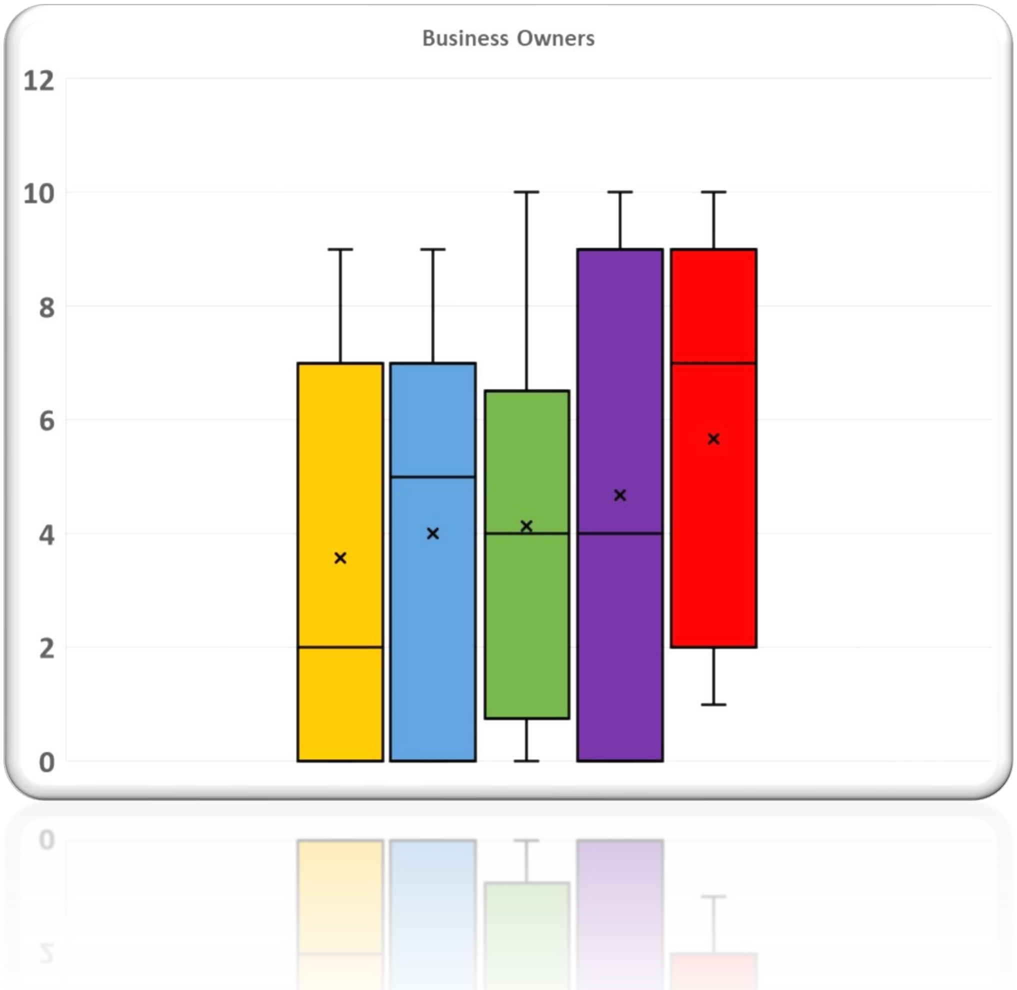


Figure 10. Business owners show very high favorability towards natural gas-derived electricity.

Survey respondents asked about interest in owning an electric vehicle (EV) showed a somewhat polarized response with the most-frequent response being “strongly disagree”. This was balanced by an approximately equal number answering “somewhat” or “strongly agree”. Given this result, it was surprising that none of the 365 surveys received selected “strongly disagree” when asked for their concern about climate change. This result is shown in figure 11. Supporting this is the response to whether respondents, as individuals, had personally noticed a change in climate since they were young. This question has two deficiencies in that respondents were not asked if they were native to Indiana, and did not ask their age. However, the results in figure 12 show that a majority indicated, yes, they had observed a difference since they were kids.

One economic question asked in the survey was how much the individual would pay to have solar panels on their roof. While only 9 of the 365 were willing to spend more than $5,000, the majority of responses were in the 0-100 dollar category. This is supported by the number of rooftop solar installations in Indiana, which hovers at about 600, or just 0.01% of the population.

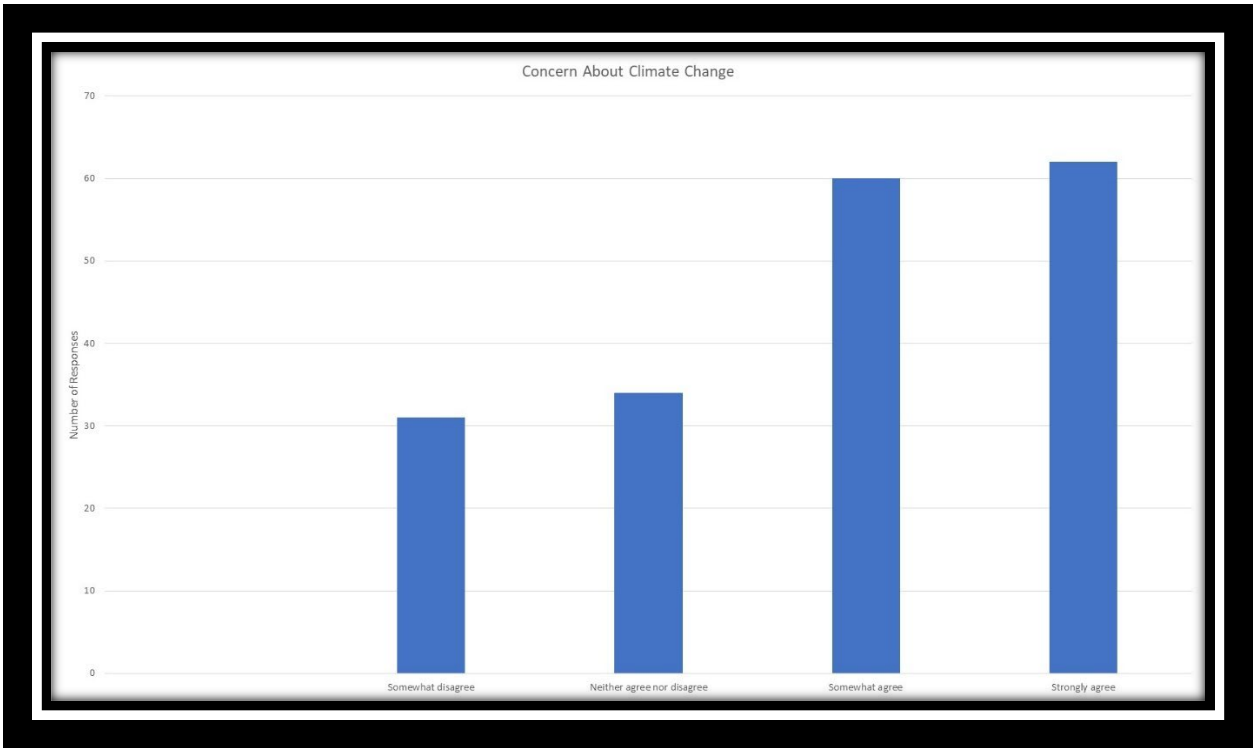


Figure 11. Overall responses to question of concern about climate change.

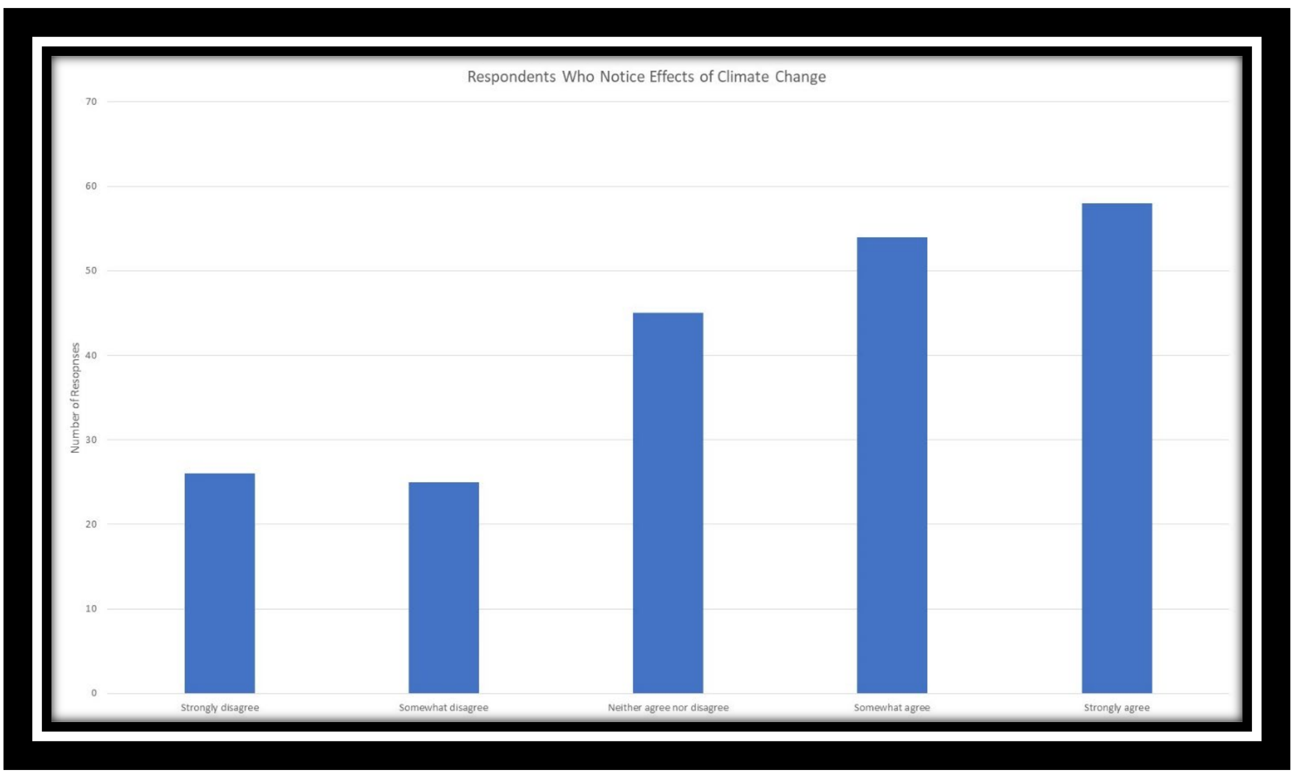


Figure 12. “Since you were a kid, have you noticed a change in the climate?”

The next analysis segment addresses the importance of various factors when considering solar farms or wind farms, these considerations being: tax revenue, job creation, home prices, aesthetic visual impact, energy prices, and heath impacts. The colored bars on each topic are low importance (blue, left), medium importance (pale red, center), and high importance (gray, right). Solar farms are considered in figure 13, showing a broad range of responses. Home prices and health impacts, both "kitchen table" interests have the most "high" ratings, while aesthetics and tax revenues received the most "low" ratings. Job creation had the strongest "medium" rating, along with a strong "high" rating, on a par with energy prices. Not one category was dismissed by the respondents. The key take-away is that many people care about many issues about solar.

Figure 14 presents results for important factors regarding wind turbines. While no factor was dismissed by respondents, job creation had both the fewest "high" ratings and the most number of "low" ratings. Respondents may realize that wind turbine installation is specialized work and probably does not draw as many local jobs as other energy projects. The strongest "medium" and "high" responses were on home prices. This topic has been studied by many groups, including the recent paper "Commercial Wind Energy Installations and Local Economic Development: Evidence from U.S. Counties," by Brunner and Schwegman, (*Energy Policy,* 165, 2022). This, and other sources included in the Phase 1 report indicate that property values are not affected by nearby wind farms. This topic is perhaps the best example of how misinformation has a notable impact on public perception. Of nearly equal significance are health impact concerns by respondents. The Phase 1 report on InfraSound addressed this particular concern. Plus, there are still people who remember high-profile politicians trying to link wind mills to cancer, despite there being no cause-and-effect to support such claims.

Figure 15 shows how respondents rated various sources of information relative to energy projects. As can be seen at a glance, energy professionals and national newspapers (e.g. New York Times, Washington Post, Wall Street Journal) are rated higher than word-of-mouth, social media, and local newspapers. One noteworthy trend across these information sources is that trust on the topic of natural gas out-ranks all other topics for every source, when considering either the average/mean or the median. Perhaps this is unsurprising because Indiana was historically an early leader in natural gas production. The former boom town of Gas City was named after this underground resource in 1892. Unfortunately for Indiana, the shallow deposits of this fossil fuel were limited, and the hey-day has long since passed. Also, as noted above, natural gas power plants have been installed at a rapid rate in Indiana over the last decade, and now exceed the share of energy production of coal. Furthermore, the fracking "revolution" in the US has kept prices lower and less volatile than 15 years ago, and has sheltered Hoosiers from the energy shock experienced in the European Union stemming from the war in Ukraine.

Word-of-mouth and social media show very similar profiles, and appear to be regarded as less reliable than newspapers and energy professionals. For those concerned about the influence of sites like Facebook, Instagram, and Twitter, it may be consoling to learn from these results that Hoosiers broadly recognize their relatively lower value of trustworthiness.

From text responses to the surveys, these other concerns were also expressed: (1) protecting farmland; (2) effect of wind turbines on wildlife; (3) decommissioning; and (4) maintenance. See section 5.4 below for examples.

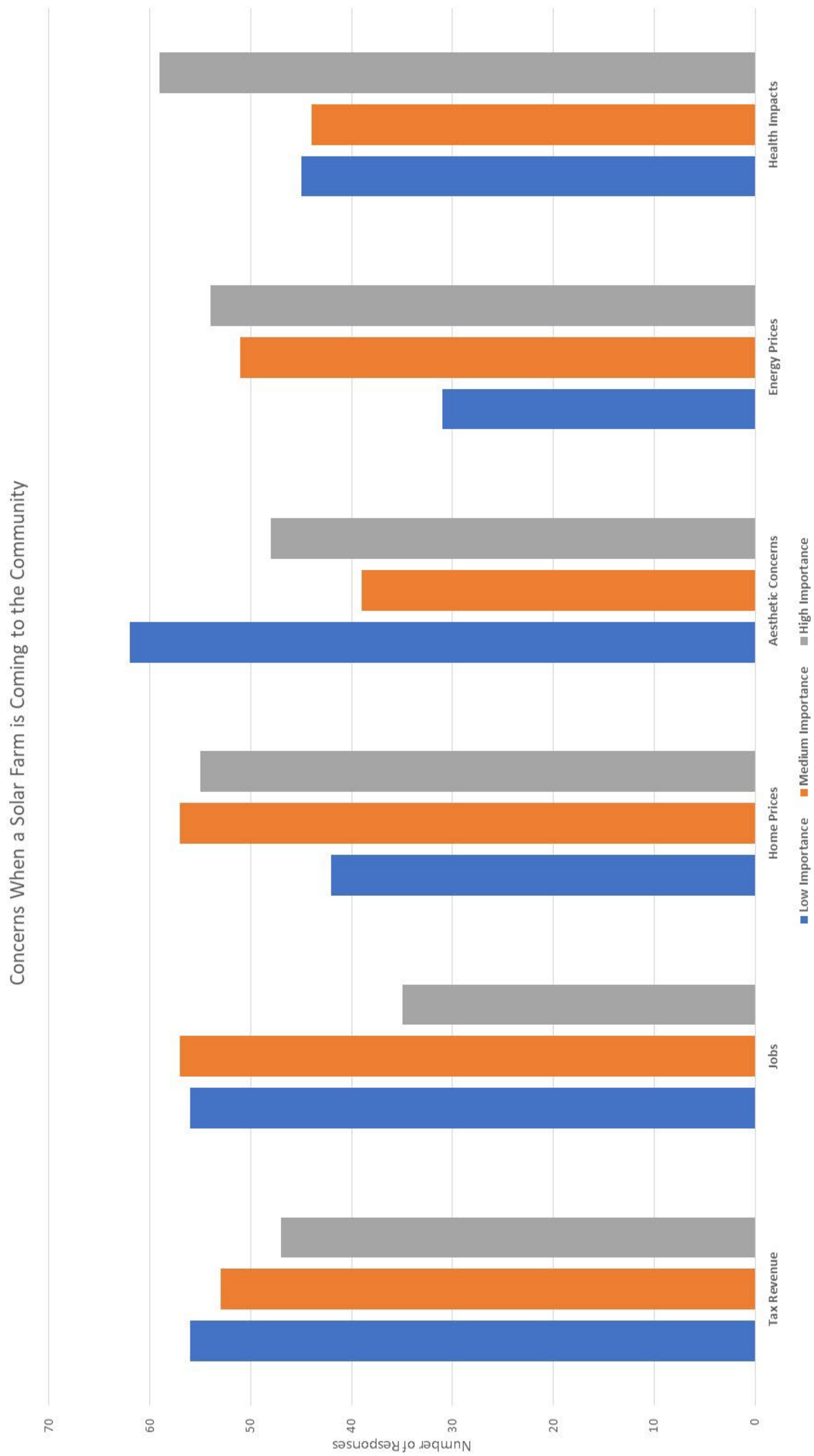


Figure 13. Importance ranking of six factors when considering solar farms.

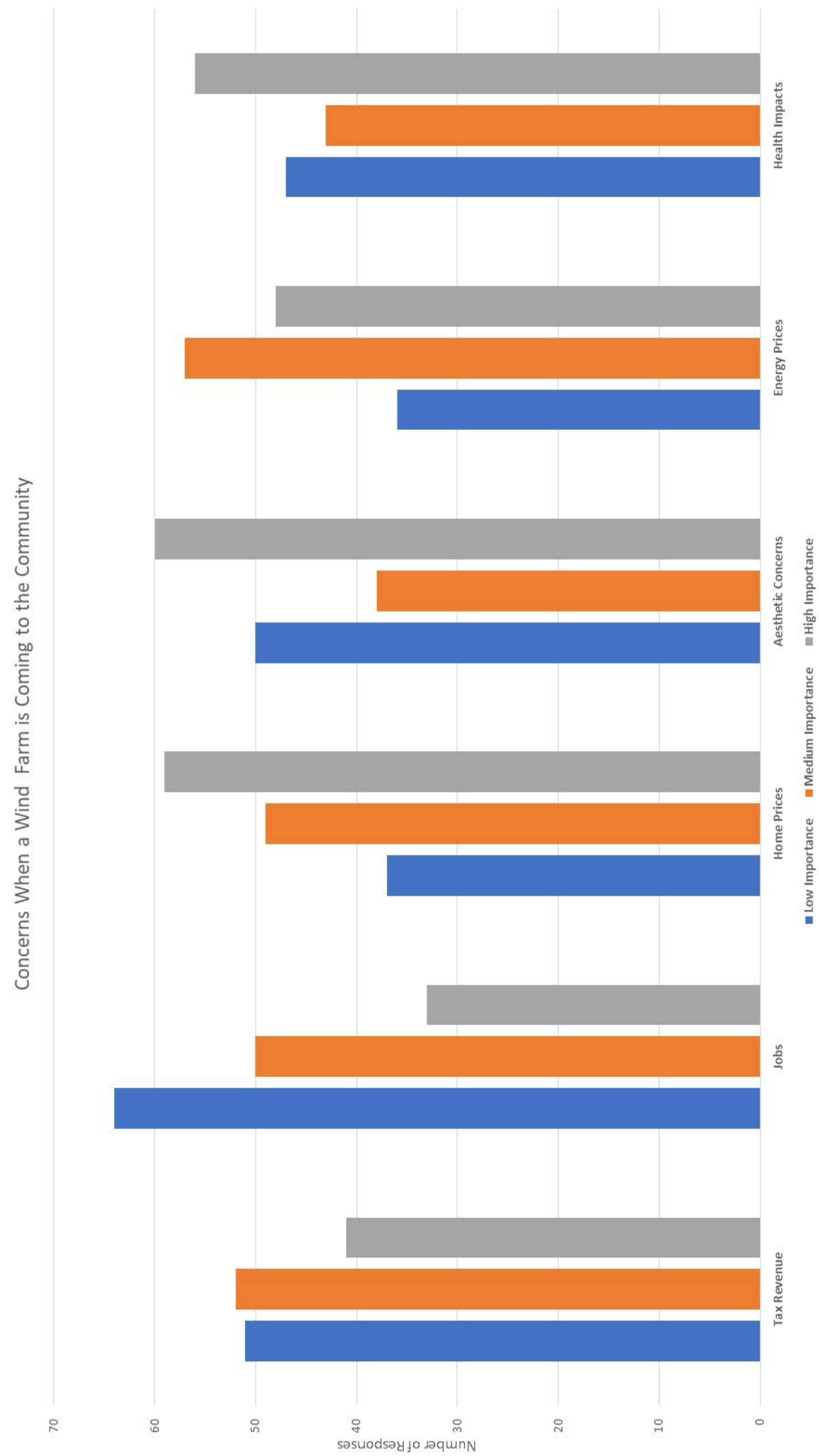


Figure 14. Importance ranking of six factors when considering wind farms.

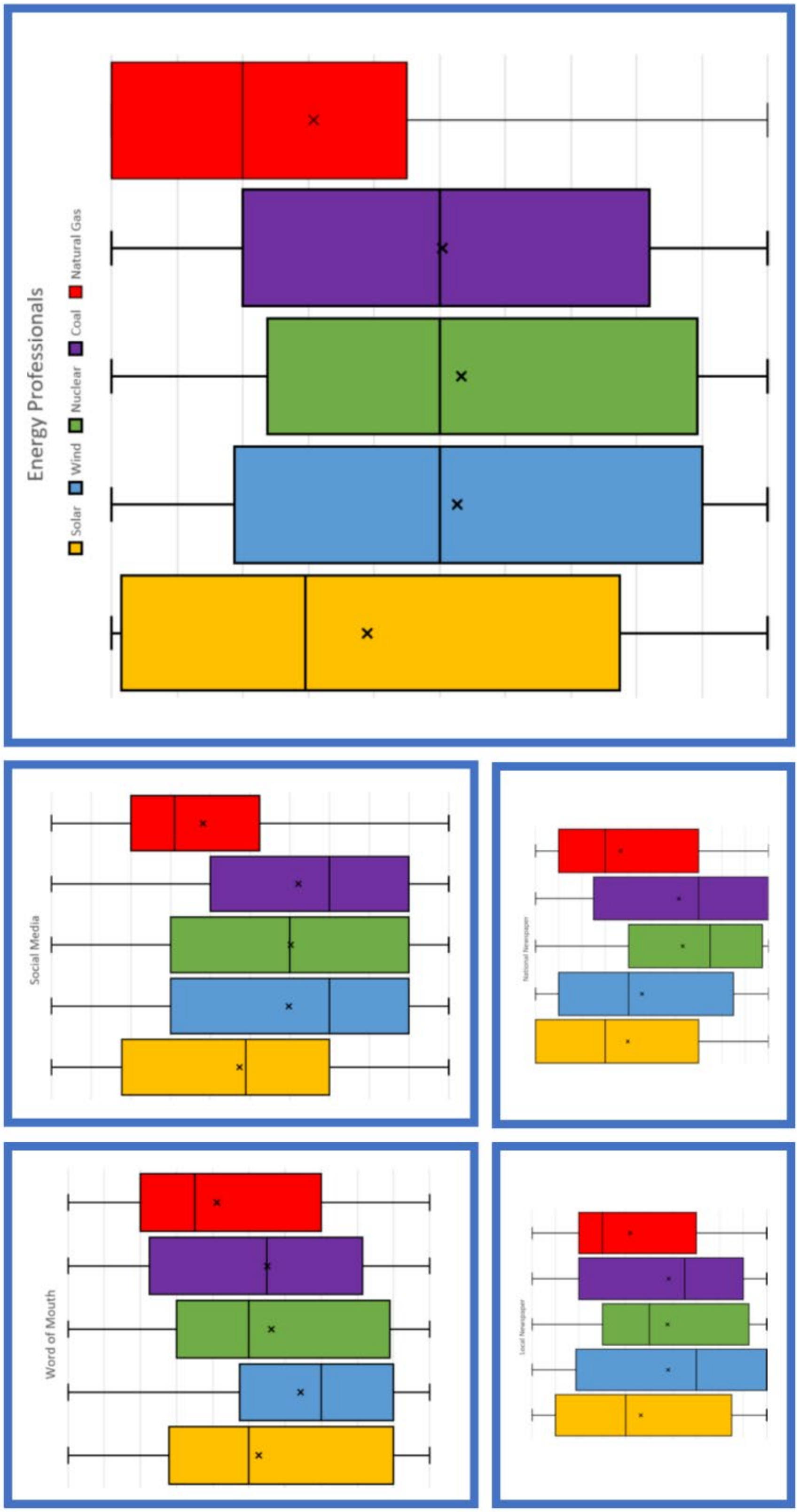


Figure 15. Trustworthiness of information sources, clockwise from top-left: word-of-mouth, social media, energy professionals (largest block), national newspaper, and local newspaper.

5.4 Individual Responses

The survey included a text-entry box for written comments. Below is a sample of about half of the text responses received, the others being trivial or duplicative. The GQP also created an e-mail address for questions regarding the survey (goodqs@iu.edu), but this only received a single substantive input, being very similar to the first quote below.

> I think it is wrong to take productive farm land out of production in order to install solar panels. I don't believe that the research has proven that solar (or wind) energy will save our planet, considering that it takes energy to construct the panels and wind turbines. Do the math!
>
> They are an eyesore and not very effective in generating electricity
>
> There are solar farms already in the works in our county. I was asked to sign up for it, but I don't see these solar farms as a positive for our county or the farmers who signed up, in the long run. What will be the impact of these in 30, 40, or 50 years? Foreign owners do not live in the area, so they do not have the love for this area like those of us who have lived a lifetime here. The county officials are being influenced by promised money, but I don't believe they are thinking long term.
>
> Why don't we just bring back the horse and carriage? That's about as "green" as you can get!
>
> Being involved in the negotiation process for solar projects, and seeing the declining tax revenue in our county, I know that we need tax revenue and revenue in general from other sources. Tax revenue from solar projects is one of the advantages from these projects, as they are assessed at a higher value than farm land.
>
> Our county can always use new sources of tax revenue.
>
> Not enough revenue producing projects in community.
>
> Knowing that we are building a solar farm, the economic development payments are also an important part of the project to the county.

6.0 Guidance Tool

6.1 Use Case Scenarios

The purpose of this section is to provide an overview of the guidance tool and possible scenarios for the Guidance Tool. Each **scenario** will present the purpose for needing guidance as well as the **solution** through using the Guidance Tool. Seven pairs of scenario-solution are presented.

Scenario 1

Knowledge of a specific community's reaction to a renewable energy project is desired. Without previous knowledge of a community's bias a developer wants to enter basic information about any specific community and determine if they will be receptive or not.

Solution 1

The receptivity calculator is ideal for this task. The user will have a series of inputs to satisfy. Each of these data points will be easily accessible information such as the number of coffee shops, number of churches, number of bars, county population, high school graduation rate, or various information that could be easily found through government websites or Wikipedia. Once known inputs have been answered the application will process the raw data through a regression algorithm and output an index indicating the potential reception any community might have towards a renewable energy project being developed in their area. (e.g. the index number may be anywhere between 0-100, with 0 being least receptive and 100 being most receptive)

Scenario 2

A comparison of two communities' known statistics in regards to renewable energy is desired. A potentially new resident of Indiana is interested in comparing different communities' stances on renewable energies.

Solution 2

The comparison function is ideal for accomplishing this task. The user will have different drop down menus to select from. One for counties of interest, one for renewable energy sources (solar, wind), and one for the specific area of interest (legislature, county standards, pros and cons). The user may then cycle through different options in the drop down bar to instantly see both communities' stances on a given area of interest side by side.

Scenario 3

Knowledge of one specific community's potential for renewable energy projects to be developed is desired. An economic development professional wants to attract a developer, and desires to understand the specific metrics that will make their community ideal for development.

Solution 3

Many of the functions of the application can be used in tandem to obtain desired results. The general information search function will provide information to the user about any given community. The user will have three different drop down bars to filter information about an individual community. One bar will allow the user to select the specific community, another drop down bar will allow the user to select between the different renewable energy sources, and a third drop down bar will have various information categories that once all three inputs have been satisfied the desired information will be displayed on screen. The user can then select different information categories to learn about all the different aspects of a given community. In addition to the search function the comparison function could be used to explore the areas where the user's community is a better location than others. Finally, the receptivity calculator can provide the user with a finite number to use leverage over other locations.

<u>Scenario 4</u>
Holistic knowledge of Indiana's response to renewable energy desired. A state-level official would like to know more about Indiana as a whole in regards to the development of a renewable energy project while constructing new policy or legislation.
<u>Solution 4</u>
The notes function would be the best tool for this task. While exploring other functions the user can tag any specific information and log it to a notepad. The user can then refer back to this for future reference and to have all applicable information in one location.

<u>Scenario 5</u>
A correlation between a community's attributes and misinformation is desired. An academic who has a research hypothesis and would like to support it with peer reviewed information.
<u>Solution 5</u>
This task can be accomplished through the use of a few of the application's functions. While researching a specific community the user can use the receptivity calculator to attempt to draw conclusions between their hypothesis and the index generated. In addition, through the use of the search and notes function the user can compile data from all across peer reviewed articles.

<u>Scenario 6</u>
A pastor or teacher who wants to educate themself as well as their students on renewable energy in their community as well as a whole.
<u>Solution 6</u>
This can be accomplished by using the Guidance Tool's search function. They can pull up any energy technology in any county to learn about it. Using this information, they can educate themselves as well as their respective congregation. These group leaders can then guide their students to download the app. With a tutorial on how to use it, each member can learn the knowledge they seek on their own time.

<u>Scenario 7</u>
A farmer has been visited because his or her land has a lot of wind energy potential. They are not sure and don't want to make a decision that they may regret. They would like to know how wind has worked out in other places in Indiana before deciding.
<u>Solution 7</u>
Using the guidance tool's comparison function, the farmer will be able to compare wind energy in several counties to their own. They can also see the legislation around it and the rules that must be followed when citing an energy technology. The Guidance Tool can then inform them how wind may positively and negatively affect his community.

6.2 Regression Analysis

The Guidance Tool complements the GIS-based Mapping Tool by incorporating input factors that are not as readily gleaned from maps. This includes responses to the Generic Survey results described in the previous section. Figure 16 lists the potential purview of the Guidance Tool.

	Guidance Tool Inputs (distinct from Mapping Tool)
1	View on Renewables, personally and in the community
2	Legal Regulations
3	Energy Standards, not found in legislature
4	View on EV's and owning one
5	Opinions on climate change
6	View on natural gas, coal
7	Interest in rooftop solar
8	How minority goups view renewables/energy
9	Complaints/Concerns against renewables
10	Pros & Cons of Energy Technology
11	How local festivals, traditions tie into renewables/energy
12	Influtential Figures, Casamir Pulaski, tie to renewables/energy
13	Influence of ethnicity on opinions towards renewables/energy
14	Renewables in school curriculum

Figure 16. List of input factors considered by the Guidance Tool.

A key function of a guidance tool is providing users the ability to make A-B comparisons between counties. The software user-interface design tool Bubble (https://bubble.io/) provides an intuitively simple method of creating an interactive web-based tool, and was used to create the Guidance Tool.

The most powerful aspect of the Guidance Tool comes from its connection to the Generic Survey. Through the statistical method known as multi-variate regression ("regression" hereafter) one can develop a mathematic relationship between input factors and survey responses. The regression is in the form of a polynomial equation between inputs (X) and output (Y) having a slope (m) and an intercept (b, the value of Y when X=0). The simplest regression is a linear equation having the form:

$$Y = b + mX$$

Regression analysis can be conducted using statistical software tools, or even Microsoft Excel™ using the Data Analysis add-in under the Data section of the menu ribbon. Regression finds a "least-squares" fit between the inputs and outputs to determine the minimum error in calculating m and b in the equation above. With more than one input (multi-variate) analysis, there are more than one X, each having their own m, although the fitting requires only a single value of b.

$$Y = b + m_1X_1 + m_2X_2 + \cdots$$

As part of regression analysis, which finds the "best fit" of the m's and the b, for each m it computes a metric of statistical probability called the p-value. The p-value is stronger when it is closer to 0.00, meaning the probability of making an error in using that value of m_i as a predictor gets smaller. The industry standard test for "statistical significance" is a p-value of 0.05 or smaller, meaning less than a 5% chance of being wrong, according to that particular variable. In addition to the m's, the b, and the p-value, regression analysis spits out one more important metric, the R-square value. The R-square value applies to the entire equation be estimating how much of the observed variation in the output variable Y can be explained by the input variables X_i. An R-square value close to 1.000 indicates that essentially all of the variability can be predicted, with very little variation not accounted for in the model. A perfect score is only possible for perfect predictability. Note, however, that a least-squares fit can "over-fit" and achieve a high value of R-square. This can happen when the number of input variables i, are very close to, but less than, the number of output variables Y in the data set. This reduces the number of "degrees of freedom" that can be used to estimate the error remaining, that often shows up in the intercept b. For example, in the GQP, nine input variables were used to predict aggregated responses from ten counties, providing only one degree of freedom to error, sometimes resulting in a R-square value near 1.000, but with poor (high) p-values on the m_i. Therefore, it is common practice to run a first regression analysis using as many variables as possible (9 in our case), then to run a second regression analysis having omitted those input variables with poor p-values. The result is that R-square comes down somewhat, but the p-values of the remaining variables shrink down, providing greater statistical significance. This practice requires some art, skill, and experience, because there is no perfect answer. An example output from regression analysis using nine demographic input variables (X) and the ranking of solar importance (Y, on a scale from 0-10) is shown in figure 17.

Figure 17 is a first regression using nine input (X) variables to predict a survey response (Y). The R-square value (in green) of 0.9998 is very high, although the degrees of freedom (df in pink) for the error is just 1, which suggests a risk of over-fitting. The coefficients m and the intercept b are highlighted in blue. The yellow highlights are the p-values, with stronger highlight in the two variables found to be statistically significant. Note shown is a second regression omitting the input variables having the worst (highest) p-values, which slightly reduced R-square, but dramatically reduced the p-value for several input variables, indicating a robust predictive equation. The equation from the second regression (R-square = 0.9965), using the reduced set of variables, is shown here, with several p-values below 0.01:

$$Y = 4.26 - 0.23 * (no. of\ churches) + 0.08 * (crime\ rate) - 0.0001 * (manufacturing\ jobs) + 0.20 * (no. of\ gas\ stations) + 1.07 * (no. of\ EV\ stations) + 0.66 * (no. of\ libraries) - 0.00003 * (employment)$$

SUMMARY OUTPUT				
Regression Statistics				
Multiple R	0.9999			
R Square	0.9998			
Adjusted R Square	0.9976			
Standard Error	0.0795			
Observations	11			
ANOVA				
	df	*SS*	*MS*	*F*
Regression	9	25.93550155	2.881722395	456.2120462
Residual	1	0.006316629	0.006316629	*Significance F*
Total	10	25.94181818		0.03631961
	Coefficients (m_i)	*Standard Error*	*t Stat*	*P-value*
Intercept (b)	7.2799	2.7658	2.6321	0.2311
HS grad rate	-0.0413	0.0236	-1.7487	0.3307
Churches	-0.1876	0.0230	-8.1702	0.0775
HIghschools	-0.1303	0.0789	-1.6525	0.3464
Crime rate	0.0819	0.0162	5.0437	0.1246
Manufacturing jobs	-0.0001	0.0000	-10.0415	0.0632
Gas stations	0.2185	0.0404	5.4042	0.1165
EV stations	1.0591	0.0287	36.8676	0.0173
Libraries	0.6119	0.0638	9.5963	0.0661
Employment	0.0000	0.0000	-18.1311	0.0351

Figure 17. Sample (first) regression analysis from Generic Survey for the Guidance Tool.

When such equations are included in the Guidance Tool, the output is restricted to be within the survey range of 0 to 10. This is done because it is possible for a user to provide input variables beyond the range available for the regression. For example, if the number of churches in a community was 200, that is so much higher than any of the counties surveyed that non-sensical output numbers (such as below 0 or above 10) could result from the equation. This is called extrapolation, and is to be avoided. What it means is that the regression equation is only valid when inputs are within the range of the original data set. Using a regression to predict responses for very different communities with vastly different input factors runs the risk of extrapolation with the confidence in results diminishing a the deviation from the input range increases. As a concrete example, one would not expect these equations to apply to a community within a science outpost in Antarctica.

Using the actual data from the Generic Survey, and the practices above, figure 18 presents the validation of the model against the data. With a least-squares fit, one does not expect perfect correlation. However, these results show a margin of error of +/-11%. Thus, using the Guidance Tool in similar communities can be expected to predict responses with reasonable accuracy.

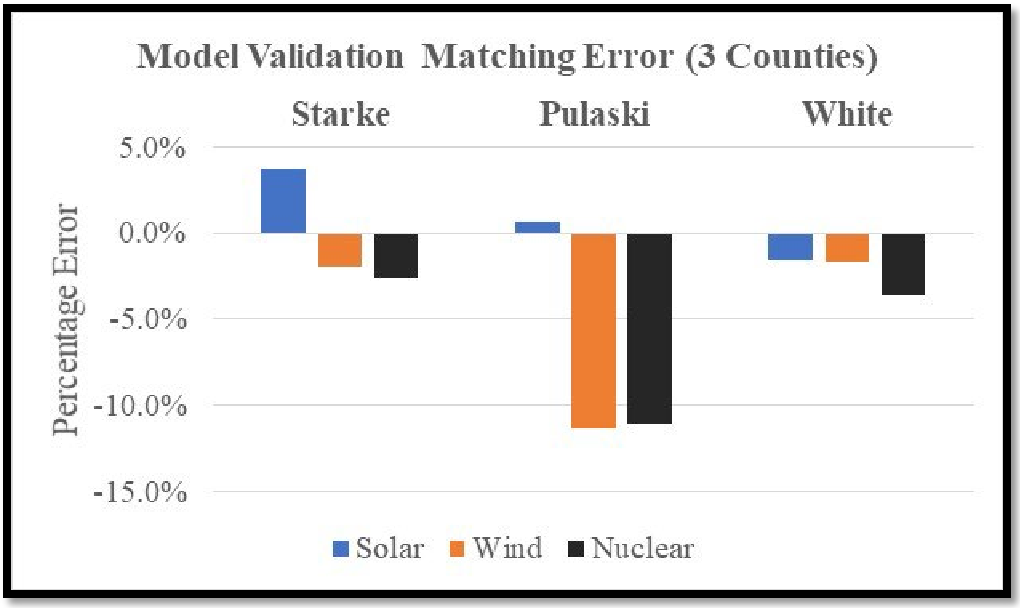


Figure 18. Validation results comparing regression model to survey results.

6.3 Guidance Tool Results

Figure 19 is a screenshot of the landing page of the Guidance Tool.

Figure 19. Splash screen for the Guidance Tool (created using Bubble).

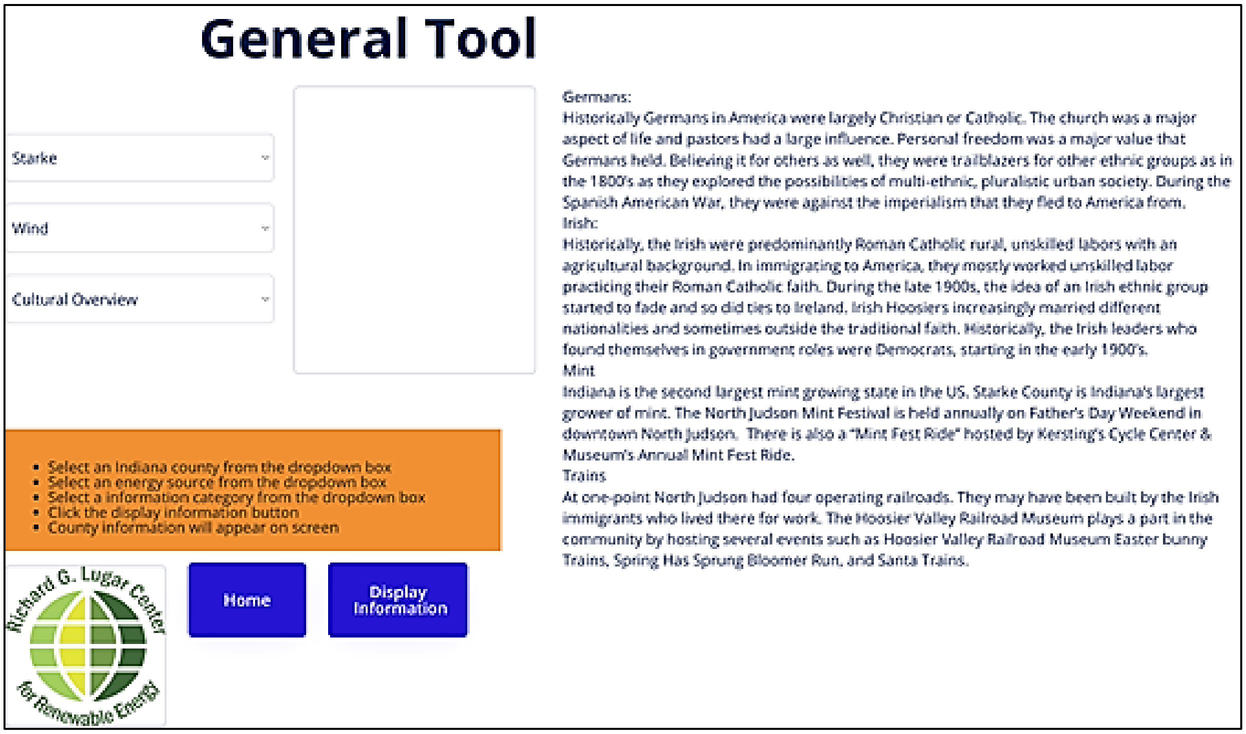


Figure 20. Sample response from the "General" function of the Guidance Tool listing background historical and cultural information about a county (instructions in orange).

Figure 20 displays one of three functions included in the Guidance Tool, called the General Tool. This addresses topics 11,12, and 13 of fig. 16. Although difficult to read in this screenshot, on a tablet or laptop the text on the right of fig. 20 is legible, and provides background on the history, legacies, and cultural influences in that community. As described in the Environmental Justice section below, having an understanding of the cultural milieu is vital in knowing how to address the citizens and to be sensitive to issues of importance.

Figures 21 and 22 show the other two functions. The Favorability Calculator is the regression linking the survey results to demographic information as described in fig. 17 and validated in fig. 18. Here, a user can input demographics for a new community in Indiana using the fields in the column to the right of the demographic variables such as population and high school graduation rate. Once the values are entered, the user can click on the blue buttons to obtain the numerical results for predicted favorability towards solar, wind, and nuclear energy projects. This is a very powerful aspect of this Guidance Tool, and may be unique, presented herein for the first time.

The County Comparison function shown in fig. 22 provides a side-by-side look on a given topic. The example shown presents the currently-available wind power in each of two counties (Pulaski and Jay). The user can select other comparisons (e.g. solar and nuclear), and the comparison data will auto-refresh. A user can select and copy the data from each comparison to use in a report or analysis.

These results show functions in the Guidance Tool that build upon and complement the Mapping Tool. This first prototype illustrates the power of such an approach - a foundation to build upon.

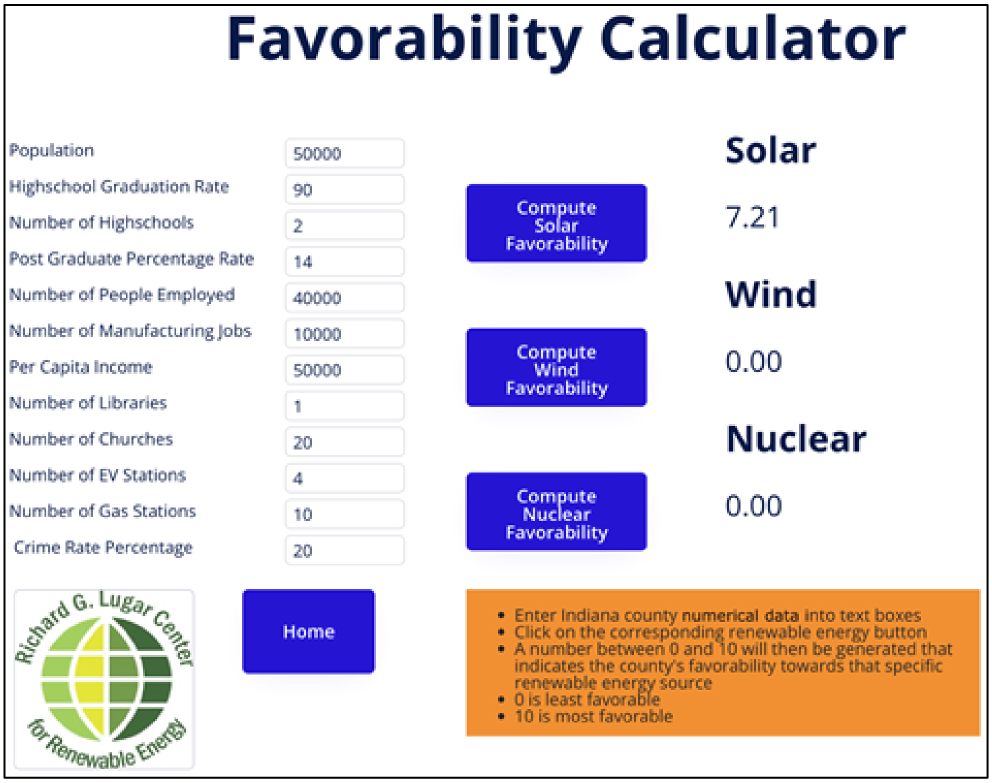


Figure 21. Favorability function of the Guidance Tool, based on regression of survey results as predicted by community demographics, entered in the left column by the user.

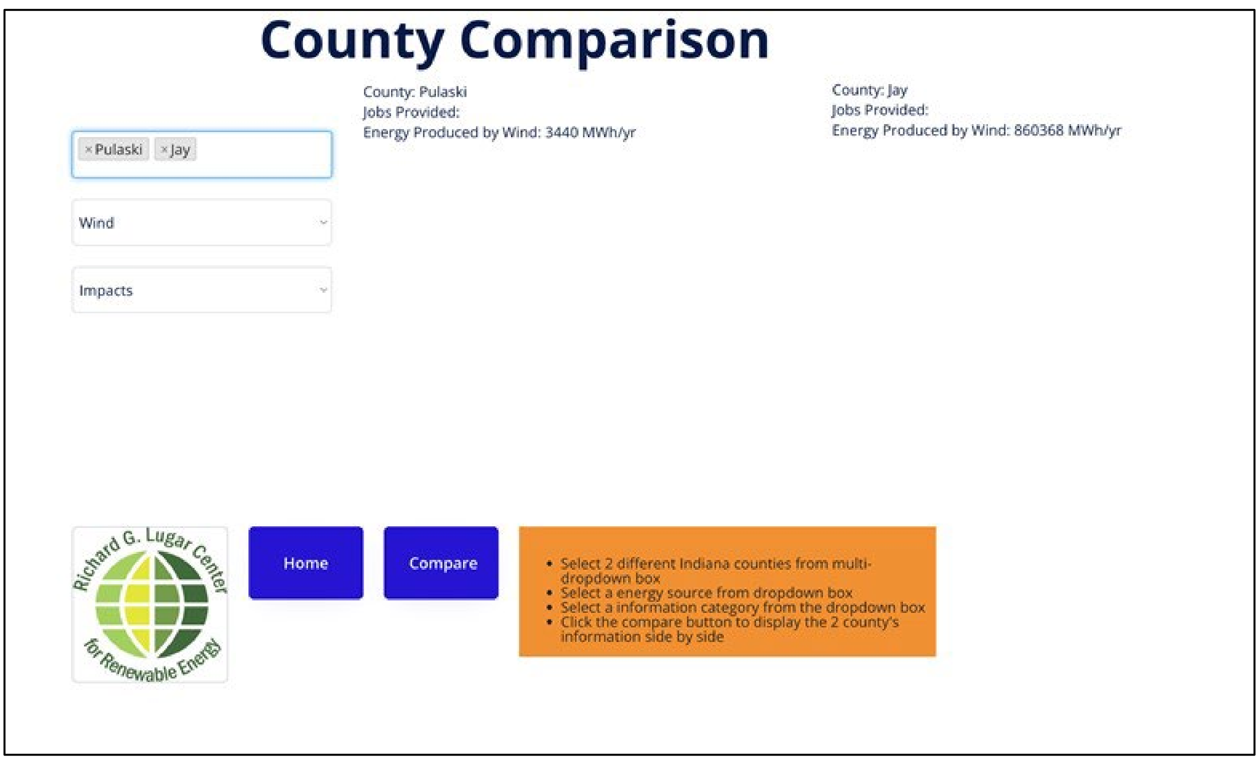


Figure 22. Comparison function of the Guidance Tool, allowing side-by-side comparisons per issue, with “Wind” shown. Users can cut-and-paste responses as desired.

7.0 Best Practices and Lessons Learned

7.1 Three-Page Quick-and-Dirty Fact Sheet

Citizens often have a long list of questions regarding new energy projects proposed for their communities. The GQP gathered more than 60 such questions from five sources and then ranked them with input from the OED and from EDP Renewables, a project developer based in Chicago. The 34 questions in the frequently-asked questions (FAQ) format on the next three pages is available as a PDF document that can be shared for viewing on a tablet, or printed for handouts. These are intentionally brief, so that people can quickly skim the document for a ready answer. The use case scenario behind this is a newly-elected official with limited prior exposure to energy issues who is suddenly barraged by citizen questions over a newly-proposed energy project. The FAQ may be considered a starting point, whereas the nine white papers and info cards go deeper into the more difficult questions where the answer is "maybe" or "it depends".

The FAQ has three sections, starting with questions of an economic nature, the focusing on solar and wind, as these are the most common such projects currently. The subsequent section includes the three new white papers from Phase 2. The first six white papers can be found in the Phase 1 report.

RENEWABLE ENERGY		
Question	**Keyword**	**Contents of a Good Response**
ECONOMIC		
Will jobs be created? How many?	**Employment**	The project should be able to: • Identify and describe the short-term, immediate jobs • Identify and describe the long-term jobs • Address the proportion of jobs provided locally
Are there income opportunities for the landowner?	**Leasing Payments**	**Yes**. Numbers vary based on location and the type of equipment used. On average, landowners who lease out the land under solar or wind can receive about $200 to $1600 per acre per year.
Will property values be affected?	**Property Values**	Research have shown that solar or wind farms tend to have either **no effect,** or a small **positive effect** on nearby property values.
Is a tax break/deduction available, and how does this work?	**Tax Deduction**	Yes. Both the landowners and developers can apply for a property tax deduction for a specified amount of time (a few months to few years). A tax professional can be consulted in this regard.
Does electricity produced and supplied to the grid lower utility bills? How do consumers use the sustainably generated electricity?	**Utility Bills**	**Sometimes**. Utility scale projects have no impact on the utility bills as the electricity is directly supplied to the grid. The utility company distributes this to the households at their set price. On the other hand, commercial and residential projects (i.e rooftop solar) can contribute to reduction of utility bills. The consumers are automatically using this electricity that the utility company has purchased from the developers/operators.
Is electricity generated from renewables more expensive?	**Utility Bills**	No. Even subject to fluctuations the price of renewable energy has been dropping and is quite competitive compared to other fuel options.
GENERAL		
What happens to the project when it reaches the end of life?	**Decommissioning**	As a part of the contract with the landowner, the project developer should provide a decommissioning bond as insurance. Should the developer not physically decommission the project after its useful life, this bond serves to pay for removal of equipment and any other steps needed to return the land to its original state, like removing concrete from wind turbine bases.
Will construction damage drainage or roads?	**Construction**	**Rarely.** Developers can easily work around existing structures and drainage systems as to not damage them. If drainage is damaged during construction, its often repaired by the developers.
Can the electrical grid remain stable with renewable energy penetration?	**Grid Stability**	**Yes.** It's true that a high percentage of renewable contribution to the grid can affect grid stability. However, modifications already being made to the existing grid system help to mitigate these effects.
Where is the locally generated solar power being used?	**Local Energy**	Power from a solar farm is routed to the power grid, the system that supplies the town/province with electricity. The power grid is owned/operated by the local utility companies. Electricity can travel 300 miles or more from a power plant, meaning the electricity generated could travel that far but it will take care of the closest needs first.
How much power is produced? How many homes can be provided for?	**Power Output**	Depending on size and technology one acre of land can be used to install 50-100 kW of wind and 200-250 kW of solar power. Considering the US average household electricity consumption of 882 kwh/month, around 20-25 acres of land can energize 1000 households.
Is Indiana a good place for renewable energy?	**Why Indiana?**	**Yes.** Indiana has always been a good state for wind turbine installations. Indiana is ranked 12th for wind power in the US. For solar, Indiana has 75% as much sunshine as the sunniest state in the US. In 2021, Indiana ranked 6th in the country for solar project developments.

SOLAR ENERGY		
Question	**Keyword**	**Answer**
GENERAL		
Will solar panels be damaged by weather events?	**Damage**	**Sometimes.** Most solar panels can withstand winds of 140-160 mph, and hail/debris falling up to 50 mph. Solar panel damage during weather events is rare with proper installation and maintenance.
Will traditional energy sources (gas, coal) still be used besides solar?	**Efficiency**	The major portion of the energy still comes from fossil fuels. Conventional fossil fuels are polluting and the use of renewable energy sources like solar is expanding due to reduced cost of producing electricity.
What will farmers do if they're not farming that land anymore?	**Employment**	A project will only take an agreed-upon amount of land, and this is rarely all the land. Other plots will still be left to farm, and many landowners use this to diversify their income.
Are solar panels noisy?	**Noise**	**No.** Inverters used in solar panels can generate a quiet low buzzing sound as they convert DC current to AC current. The noise generated is generally not audible over ambient noise (rustling wind, birds, traffic, etc.)
Will solar panels produce a bad glare?	**Glare**	**No.** PV modules use non-reflective glass and are designed to absorb sunlight, not reflect it. PV modules are less reflective than windows.
LAND USE & MANAGEMENT		
Will the solar farm take away from scenic country views?	**Aesthetics**	**It depends.** Many contracts require developers to leave a certain amount of land between an installation and a road/home, and may require a natural visual barrier (like a row of trees) to be planted.
Can farmland be restored back to agricultural use after solar farm decommission?	**Decommissioning**	**Yes.** Land can be converted back to agricultural use at the end of life of an installation. Giving the soil 20-25 years of rest, or switching to a low-height crop rotation, can also maintain or improve soil quality.
Can farmers raise livestock in a solar farm?	**Dual-Use, Sheep**	**Yes.** Sheep are commonly used for grazing vegetation control at solar facilities because they do not climb on or harm the modules. This can reduce mowing, herbicide, and other vegetation management needs.
Who owns the solar farm and who owns the land? Can utility companies take away the land from the landowners if they have rights to the solar farm?	**Land Rights**	The rights of the landowners and lessee is well defined in the leasing document. The lease is legally binding but does not give the lessee eminent domain rights to take the land after the lease period ends. Since the lease is complex, detail and lengthy, it is always wise to consult an attorney before signing the lease.
What happens to the tenant farmers of leased solar land?	**Leasing**	If the landowners choose to lease the land for the lifetime of the solar farm (20-30 years), operations and maintenance of the land shifts from the farmer to the solar company. Land leases typically generate more revenue than traditional crops, diversifies your income, and removes the risk of poor yield years.
Do solar farms have to be installed in high quality soil?	**Soil Quality**	**No.** Solar farms can be installed in rich or poor soil. They can be installed in non-farmable land, or in active farming sites. There is no "one size fits all" option.
How is vegetation managed under the panels?	**Vegetation**	With leased land, **the leasing party (i.e. utility company/developer) is usually responsible for upkeep**. Many options are available for weed control including herbicides, grazing animals, mowing, and weed control sheets. In non-farmable land, ground cover under the PV installations helps prevent erosion. Many native plant species and partial-sun crops (strawberries, melons, vegetables) can grow well under PV panels. In dry areas, some crops even grow better in the shade of PV than in an open field.
Are solar panels toxic?	**Toxicity**	**No.** Solar panels will not harm people, water, or soil . In fact, studies confirm that soil under PV panels holds more moisture than the surrounding soil PV cells do contain metals and some toxic compounds, but research shows though that industrial incineration temperatures (way higher than natural events) are required to release these compounds and pose any sort of significant risk.

WIND ENERGY		
Question	**Keyword**	**Answer**
GENERAL		
How long do the turbines last?	**Life Expectancy**	Blades and turbines last between **20-30 years** with proper operation and maintenance.
Why do turbines stop spinning, are they broken?	**Stopped Turbine**	Wind turbines stop when winds become too high for safe operation, when power demand is low, and for scheduled maintenance.
Will storms damage wind turbines?	**Storm Survival**	**Sometimes.** Turbines have a lock mechanism when wind speeds exceed about 55 mph. This reduces risk of damage in storms, like tornadoes.
SAFETY & PUBLIC HEALTH		
What is shadow flicker and can it be prevented?	**Aesthetics**	**Yes.** The shadow flicker from sun shining through rotating blades can be irritating to some people. Shadow flicker protection systems are available for turbine farms. This add-on technology tracks the sun and will shut down the blades when the sun is in a position to cast a shadow flicker on nearby homes.
Do wind turbines catch on fire?	**Fire Hazard**	**Rarely.** It's estimated that 0.05% of wind turbines will catch fire in their lifetime. This is less than the chances of a car catching fire, which is 0.07%.
How a wind turbine fire can be put out?	**Fire Safety**	Turbine fires can absolutely be extinguished. Fire suppression systems are available in the nacelle (a 'nacelle' is the large box at the top of the mast) to put out fires as soon as they happen.
Are wind turbines noisy?	**Noise**	**No.** Passing air across turbine blades does create a wind-whoosh noise. Newer turbine designs have managed to minimize this noise, and the sound becomes inaudible 1000 ft from the turbine, which is the recommended minimum distance between turbines and nearby dwellings.
Do wind turbines throw ice?	**Projectiles**	**Sometimes.** Ice can dislodge from wind turbines. Turbines sensing ice accumulation can be shut down autonomously or manually. Additional risk mitigation is in place by ensuring turbines are placed far enough away from inhabited dwellings and roadways.
ENVIRONMENTAL		
Are bat and bird populations affected?	**Wildlife**	A project should detail the environmental review processes and permits undertaken and received, and how impacts to wildlife has been avoided, reduced, and/or mitigated.

7.2 Case Studies

The goal of this document is to provide a detailed assessment and analysis of the methods, strategies, and tactics used by groups and individuals who have objected to new energy projects in their area.

The process for developing this document was qualitative research based. Researching peer-reviewed publications was the main source for enlightenment. Furthermore, interviews, case studies, and news articles relating to energy projects in Indiana were examined to then apply the academic studies to local occurrences. This allows for developing an overall understanding of why renewable energy projects might fail and apply that knowledge to a specific local community.

Local opposition groups tend to organize themselves online. For example, a Facebook group in Delaware county attends town hall meetings and garners signatures for petitions that support the group's ideals. Usually, through Facebook, these groups will create a page based on their arguments, and try to invite as many people to join as possible. In addition to Facebook, many groups create websites containing articles relevant to the group's concerns, and make petitions available for signature. Groups organize themselves before County commissions, and meetings, and then use these meetings as opportunities to voice their concerns.

Groups are also formed in person, usually beginning as a small meeting group that expands and reaches out to others to have a more significant impact. For example, a small group of eight came up with a strategy and an action plan and recruited others to the group through petitions, signs, the internet, and public hearings.

Reasons for Opposition

When an energy project is proposed, there are typically 5 reasons (or categories) for why a project may be opposed:

1. Aesthetic Concerns
2. Health Risks
3. Land Use
4. Lack of Control
5. Property Values

The five categories described were determined through case study analysis, and interviews with experts [1, 2, 3]. As projects evolve, the reasoning behind the opposition is subject to evolve as well.

1. Aesthetic concerns relate to the visibility of an energy project and the perception that is unpleasant to look at. Aesthetic concerns are more typical of energy projects like wind and solar farms, which are much more visible to local communities than other energy projects [1]. The surveys released in this study suggest that aesthetic concerns are the most common concerns voiced by citizens who oppose both wind and solar projects. Many of the aesthetic concerns relating to wind turbines have technological solutions in the market.

2. Health risks are a very difficult issue to address because they are often based on misinformation [2]. It is difficult to propose a solution to a potential health risk that is not actually based on any scientific fact and thus poses a challenge for energy projects. While some health risks are real, many of the risks addressed by the opposition are either outdated or simply not factual. Health risks based on fact or scientific research are typically easier to address because they are a factual basis upon which to develop a solution.
3. Land use is a complex category to address because the reasoning behind this argument tends to be subjective. For example, Tippecanoe County is considered one of the best areas in the state for wind farms and wind energy. However, many local citizens do not feel this way and believe wind farms to be an improper use of the county's land [4]. The impact and influence that an energy project may have on the grid is not an argument often used by local opposition, though it has been posed as a concern by more committed individuals [1].
4. Lack of control is felt when the citizens are made to feel as though they do not have open communication, or appropriate input in what is being built in their county. This occurs when county officials and energy companies make plans and negotiate leases for energy projects without holding public forums, posting notices, and allowing citizens to voice their concerns. It is also a likely occurrence when the concerns of the citizens are not addressed, and the community feels ignored. Opposition motivated by lack of control often causes a city versus community dynamic; in which the citizens feel opposed to the city officials rather than the energy project itself.
5. A common argument against wind and solar farms is the potential of projects negatively impacting property values in the area. Lawrence Berkeley National Laboratory committed research to this possibility and found no evidence of energy projects having a significant impact on property value [5].

Opposition Strategies

The local opposition focuses on 3 main strategies when opposing an energy project:

1. Information of questionable scientific veracity (Unsubstantiated Information) - unsupported information about health risks, property value, etc.
2. Zoning Ordinance Regulation - make ordinances so restrictive that energy projects cannot be built.
3. Mobilization of Opposition Supporters - if enough people are shown to oppose, then the county will impose moratoriums, or restrictions.

The strategies used depend primarily on the specific project and the location. Solar projects tend to receive more feedback about land use, while turbines tend to receive more arguments about the unpleasant aesthetics they create. This is not universal and the complaints or issues with energy projects are subject to change.

1. Unsubstantiated information is used as a tool for sowing fear, or distrust, undermining the trust that citizens have in their local officials, and delegitimizing energy companies, and projects. Misinformation is either entirely false or intentionally dated information that is presented as fact and used to increase opposition. It is not uncommon for opposition groups to change their misinformation strategy to increase effectiveness. For example, the director of a wind turbine opposition group stated in an interview that they chose to

switch from arguing environmental issues to arguing wildlife issues because they could not gain traction with their former strategy.

2. The most common route for halting renewable energy projects in Indiana is for counties to change zoning ordinances to such an extreme that companies become unable to build the project and meet the specifications of the local zoning ordinances. Common restrictions include large setbacks from neighboring properties and limits on turbine size. Many counties have implemented restrictions on the megawatts produced by any given energy project. Ordinances are usually changed as a result of local opposition and often result in the lease holders' inability to execute the project plans [3].
3. The largest factor in whether or not local opposition is successful is the number of people that can be recruited to the cause. Opposition groups tend to start small, develop an action plan, and then recruit as many people within the community to their cause as possible [2]. Simple logic would suggest that a county official is more likely to listen to a group of 500 protestors than a group of 5. Opposition groups are known to sometimes use misinformation and nightmare scenarios to convince people of their cause, have them sign petitions, and then present those petitions to local officials with hundreds of signatures.

In extreme cases, when opposition to a project appears to reach critical mass, a moratorium or ban can be proposed and put to a vote. If the vote passes the proposal, then no projects relating to the ban's specifications may be built. Delaware county passed such a moratorium on solar as a result of active local opposition to a solar farm lease in the county [6].

Opposition Case Studies

The following case studies provide insight into the events leading up to the failure of specific energy projects. In over 30 Indiana counties, commissioners have passed ordinances that ban or restrict industrial wind/solar [7]. While almost every large corporation in the state wants an increase in renewable energy projects, locals may be opposed.

Boone County (The Brickyard Solar Project)

In 2021 an energy project called The Brickyard Solar Project was proposed by a subsidiary of NextEra Energy Resources, LLC [8]. The proposed facility would have been a 200-megawatt photovoltaic solar farm of about 386 acres of fenced-in land in Marion township and about 785 fenced-in acres in Union Township [9]. NextEra estimated about 200 jobs produced from the project during construction, and upwards of $50 million in revenue within the next 30 years [9]. Despite the financial benefits to the county, many residents expressed concern over the aesthetic elements of the farm. Many residents viewed the project as visually displeasing and believed it would hurt property values [9]. Many Zionsville residents (a town within the county) say that they cannot be convinced that a solar farm won't affect their property values [9]. In the end, the county planning commission and board of zoning appeals eventually denied NextEra's variance requests, and the project was blocked.

Delaware County (Delaware County Solar Crisis)

In November 2021, Delaware County announced that it would be building two solar farms. Concerns over property values and the visual aspects of the solar farm led some in the community to oppose the solar farms. Opposed citizens decided to form a group to influence the county commissioners to draft a new ordinance [11]. The opposition's plan involved creating a Facebook page [6]. The locals are wary of the visual aspect of the farms, the possible damage to property values, and the use of farmland, and they expressed concern for young farmers [11]. The young farmers in the area that are not participating in the solar expansion will be at a disadvantage [11]. Ultimately, solar development was put on a moratorium in Delaware County while the county commissioners work to draft a new solar ordinance that satisfies local needs [6].

Montgomery County

In 2019, Apex Clean Energy signed an agreement with the Northern Indiana Public Service Company to build a 150-wind turbine farm called Roaming Bison Wind [12]. Local citizens responded quickly in opposition to the farm and began organizing groups. The main complaints were the effect on the community, turbine noise, and potential health risks. Eventually, an opposition group was formed and claimed the projects would be too close to homes and present a health risk [13]. The concerns from county residents caused county commissioners to draft a plan for the future of Montgomery County's rural areas where residents were specifically opposed to wind power installation [12]. County commissioners used this plan as a baseline for updating the county zoning ordinance; large turbines would only be allowed through special exemptions, and multiple other restrictions were included that make the installation of commercial wind turbines unlikely.

Henry County (Big Blue River Wind Farm)

Henry County denied the application from Big Blue River Wind Farm to build turbines in their county. Local residents, along with a large number of the County Planning Committee members, ultimately opposed the construction. The opposition centered around the negative visual aspects of the proposed wind farm, and the idea that it would hurt the community image and lower property values [15]. The planning commission was initially tied 4 – 4 when voting on the application in September 2019. However, the officials reviewed their findings and officially denied the application [16]. Big Blue River Wind Farm then decided to sue the county (December 9th, 2019), in the form of a judicial review request, because they believed that the petitioners took too long to come forward and that Henry County courts did not have authority over this matter [16]. The Big Blue River Wind Farm decided to officially drop the judicial review request in May of 2020 [16].

Gibson and Posey Counties

In September, 2020, E.ON Climate & Renewables was forced to abandon its two-year project to build a 200-megawatt wind farm as a direct result of local opposition and updated zoning ordinances [18]. What is particularly interesting about this failed project are the reasons behind the local opposition, which differ from the more common complaints and concerns regarding wind farms. Local citizens were worried about the wind farm's effect on the Doppler radar tower located in nearby Owensville [18]. Some studies suggest spinning turbines and the debris that can be put into motion by them can create motion on the radar and cause false reports of tornados, while also making it harder to track a legitimate storm. There are other citizens whose concerns pertain to the potential benefits of the wind farm versus the aesthetic impact the farm will have on the community [19]. Many citizens are simply concerned with "getting more information" because they don't know enough about it. One concerned citizen questioned whether or not the project would bring energy savings or tax breaks, “Or is it just another eyesore that we have to look at?” asked the citizen [19].

Tippecanoe County

In April of 2019, planners across Greater Lafayette proposed an ordinance that would effectively ban commercial turbines in the county. The ordinance was advocated for by nearly two dozen residents of the southern part of the county [20]. The main argument from the local opposition was that wind farms belong in counties that are already established and are not growing as fast as Tippecanoe. The Area Plan Commission voted 11-4 in favor of the ban, with the final vote on May 6 passing the ban [20]. The ordinance prohibits turbines taller than 140 feet, which completely shuts out commercial turbines that range from 300 to 600 feet [21]. This is not the first time that Tippecanoe has made it difficult for large turbines. In 2007 the county passed restrictions that demanded setbacks of 750 feet from neighboring properties, and at least 1,200 feet from dwellings [21]. The county still claims that it is not opposed to renewable energy sources, but that its decision is a matter of location, the rights of neighboring property owners, and undesirable land use [20].

Scott County

In 2012, citizens of Scott County in Indiana opposed a plan to build a biomass incinerator in their community and their efforts resulted in the halting of the project. The problem for Scott County began when the county called a public hearing to discuss zoning exceptions and a development plan with just ten days’ notice. The company, Liberty Green Renewables (LGR) wanted to build the incinerator on city-owned property, within city limits, near schools, a sizable population, and a reservoir that supplies the area with drinking water [22]. A group of eight locals called a meeting to discuss the proposed biomass project [22]. The group began to do research into biomass, LGR, and the mayor’s approach to the project. Their research revealed that the mayor had held meetings with LGR for several years before introducing the project proposal to the community [23]. The group even researched the records of the mayor’s meetings, and discovered that groundwork for the incinerator had been discussed as early as June 2009 [23]. The citizens decided to approach the county commissioners with their research. The county commissioners passed a clean-air ordinance similar to the one drafted in Crawford County, which is also fighting a biomass proposal from LGR. The group then decided to have its members run for local office, and a local person with “deep pockets” funded the campaigns with political ads on TV [22]. At January and February 2010 public hearings, more than 700 people protested the biomass proposal. By February 15th, 2011, more than 2,000 people had signed petitions against the biomass plant [22]. In May 2012, the commissioners denied LGR a permit.

City of Jasper

In July of 2010, the Jasper mayor mentioned publicly that the city council and utility service board were considering a proposal by Twisted Oak, to convert an old coal plant into a biomass plant [24]. Jasper citizens obtained help from groups who had recently researched, opposed, and defeated biomass proposals in their counties. At a formal public meeting on October 10th, 2010, 16 members of the community spoke out against the biomass proposal, citing health and environmental concerns, as well as the effects of the plant on property values and quality of life [24].

The concerns regarding the plant were of a broad spectrum. Several people mentioned birth defects, cancer, and respiratory issues from the burning of biomass. Among other concerns were dioxins released from burning biomass, air pollution, fine particles, and proximity to neighborhoods [24]. The local community felt that the local government was not concerned with the citizen's feelings regarding the biomass plant, which sowed distrust. Public officials claimed to be listening to the citizens but their actions were consistently opposite of what the majority of citizens desired. As air quality in Jasper is already an issue, the biomass plant and its potential to further damage air quality was very unpopular. Opposition was quick and widespread. Local newspapers published over 30 articles opposing the plant, people posted over 700 signs in their yards, and a petition opposing biomass managed 500 signatures in just a few hours [24]. Even still, public officials continued the process of leasing the plant to Twisted Oak.

The executives who negotiated the lease allegedly did so in illegal executive sessions. The Indiana Open Door Law, "allows officials to hold closed-door executive sessions only in certain cases, including certain situations where the city is negotiating the sale or lease of property.[24]" However, the argument is that the information discussed in said sessions did not fall within the accepted parameters set out by the law. Therefore, a lawsuit was filed alleging that the city council violated Indiana's Open Door Law [24]. The lease was signed by the former mayor on December 29th, 2011 [24]. The trial was in December and the judge ruled in favor of the city, and an appeal was filed. The appeal states that the City held 12-15 private meetings in a direct attempt to avoid the Open Door Law [24].

A case study by Notre Dame analyzed the issues related to biomass production, and the problems that may arise in the thermal processing of *Miscanthus x giganteus* [25]. Common arguments against the cultivation and use of *Miscanthus* include decreases in groundwater availability and the effect of drought on the crop's yield.

Bartholomew County

In March of 2022, a nonprofit group began seeking a moratorium on the leasing of farm land for solar farms in Bartholomew County [26]. The group is attempting to stop the construction of large-scale energy projects until the community can discuss its impact [26]. The group has been active in the community and has a website where the risks of solar farms and the concerns of the group are outlined [27]. In addition, the website has a clickable option to sign a petition against the leases for solar projects. The site allows you to connect with the group, get answers to FAQs, and view important dates like City Halls [27].

Root Cause Analysis

The cause of opposition is layered and differs depending on the motivation. While one person may oppose a project because they truly believe potentially unsubstantiated information, another person may oppose a project for financial issues. Either may use information of questionable scientific veracity as a strategy for convincing others not to support a project. A person may even oppose a project for personal, political, or social issues [3].

For example, a farmer in northern Indiana stated that he believed that one family chose to oppose an energy project in his county simply because a rival family had chosen to support it and stood to make a lot of money from its construction (zoom call 31 March 2022). While this may appear anecdotal, a Henry County official shared a similar story of two families in his community.

Additionally, companies that are based on fossil fuels may invest a lot of money in misinformation campaigns, and research groups centered around discrediting energy projects. A quote from an article written for the Bloomington Alternative stated that a "deep-pocketed individual" paid for the lawsuit against the city, in addition to political TV ads to elect new commissioners [22]. It is often necessary for these groups to have funding from energy companies competing with renewables, or from individuals with financial ties to the fossil fuels industry in a process called "astroturfing". It is also possible that renewable energy developers will use front groups.

A cause of opposition specifically referred to in our interviews is a lack of communication between local governments and the citizens they govern. Making plans for an energy project without holding the necessary public forums and understanding the desires of the community often leads to some form of opposition. Citizens want to believe they have some say in what is built within their community and are quick to oppose projects when they feel they have been misled or left in the dark.

An interesting piece of information is that there is little to no evidence that opposition to energy projects is based on political affiliation. There is no assumption that an area will be "easier" to build an energy project on because it is either Democratic or Republican [2]. While much of rural Indiana is Republican, many of the commissioners from Republican counties reported fairly high local support for renewables.

Assessment of Intentions

Those who oppose energy projects will often go to great lengths to meet their goals. A doctor moved their entire practice to another county as a result of a failed opposition attempt [22]. A minister in Scott County moved their family to San Francisco after failed attempts to force the county to change ordinances concerning wind turbines [22]. Some people who oppose energy projects have been shown to back up their beliefs with action.

Opposition groups differ in their intentions as it concerns what they want to be done with energy projects. There are some counties in which opposition has called for a moratorium only to revisit the project later and offer approval. However, it is most common for these situations to result in a moratorium, or ban; most successful opposition campaigns result in the project ending or being halted for a prolonged period. The data suggests that people with questions, or curiosity, do not often participate in active opposition groups [3].

The lengths to which the opposition will go to achieve their goals seem to depend on whether or not there is a large amount of funding. In Scott County, the opposition group had enough funding to run for political office, and eventually replace the county officials it was unhappy with [22]. In Jasper County, funding allowed the opposition to publish over 30 articles in the local paper, post 700+ yard signs, and maintain a 500-signature petition [23]. A private company then filed a lawsuit against the city. Clearly, some of the activity between supporters and detractors has a financial component.

Results

This section will suggest moments in a project's life cycle that are important to its success. At the outset of a project, as in when leases are being pursued, it is important to provide information to the public about what types of projects the county is considering [2]. This gives citizens a chance to do their own research, and to feel included in the process. Before negotiating and finalizing a lease contract, it would be beneficial to hold a public forum to better understand the concerns of the community. This would help the county officials and the company leasing the land to understand what obstacles they may face with a given project and develop an action plan prior to experiencing any opposition.

It is best for the county to have a clear plan to handle opposition before it becomes organized [2]. This allows the county to express their views and opinions before opposing groups are formed and mob mentality takes over. Having the ability to address concerns before they cause people to respond emotionally provides a higher likelihood of generating positive dialog. The earlier a county can begin addressing concerns and misinformation, the more likely they are to develop positive momentum [2].

It is important for the county to make the citizens feel heard. Gibson and Posey County saw a project halted due to a large number of small opposition groups. Instead of working with these groups and hearing them out, the county discredited them [18]. Citizens have moved out of their counties because they felt the local government wasn't listening [23]. If opposition brings up a concern that can be addressed without compromising the project, then it would be detrimental to the future of the project not to address it.

The importance of avoiding an adversarial relationship between community and county government cannot be overstressed. Once the opposition takes on an "us versus them" mentality, there is very little chance of compromise [2]. Research suggests that such a relationship stems from the community feeling a lack of control. The data has made it clear that allowing the community to feel as though it has some control over the project can create a sense of pride/place identity, and be of great importance to the success of a project.

Mitigation

The previous section addresses the opportunities that provide the most leverage for success when dealing with opposition, this section pertains to the specific strategies for handling oppositional tactics.

Once a project is undergoing Zone Ordinance Regulation, the opposition has already made its point and the halting of the project is on the horizon. It is unreasonable to expect to convince every opposer of the project's validity, and there will always be at least one opposer who is unwilling to hear another point of view.

When addressing information of questionable scientific veracity, it is important to avoid language that triggers conflict. It is unwise to use words such as "wrong", "false", "misinformation", etc. It is helpful to address such information calmly, with a respectful tone, with examples and analogies, and with a suggestion of differing thoughts. For example, "I understand why you may believe that, but have you ever considered looking at this." However, it is not uncommon for people to decide whether or not they are willing to change their minds before a discussion.

Often, people go into contentious discussions with their minds already made up. It is much more likely for a person to change their own mind, than for someone else to change it for them. Therefore, it is suggested that information be made available to communities at the outset of an energy project. This way, citizens have the opportunity to use factual information to build their opinions before anyone else has the opportunity to tell them what to think.

White papers are the most critical aspect of this strategy. If a collection of white papers could be compiled so that a citizen could never raise a question without having a concrete answer available, and all common misinformation is addressed, the solution would become a matter of distributing the information as quickly and broadly as possible.

Demonstrations are another tactic in educating without attempting to "change one's mind". A hands on experience can allow the user to learn for themselves rather than being told facts. Furthermore, not everyone learns the same way so delivering the information via visual, auditory, read/write, and kinesthetic styles can increase the number of people that absorb what is being presented. Demonstrations and exhibits inherently present information in these different styles and should be a serious consideration for education.

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8.0 White Papers and Info Cards

The full list of white paper topics from both Phase 1 and Phase 2 of the GQP is shown in figure 23. These topics were judged to lie between the two extremes of obviously bogus versus easy-to-address. These are considered the most difficult questions identified as part of this project, and deserved detailed study by the research team. Each white paper includes peer-reviewed reference citations and considers as many angles on the issue as could be identified. An important aspect of each white paper is to put these issues into context with other issue that are already part of our everyday lives. Utility-scale wind and solar projects definitely change our environment, however, they are not bringing unmitigated disaster as many nay-sayers proclaim. The white papers and info cards from Phase 2 work (2,7,8,9) are included in Appendix sections herein.

Good Questions Project White Paper Inventory

No.	Topic	By	Info Card
1	Infra Sound and Wind Turbine	Khoury	Available
2	Property values near Solar	Nipu	Available
3	WCR and Miscanthus	Parvex	Available
4	Wind Turbines and Bats	Parvex	Available
5	Frequency of Solar PV fires	Poriah	Available
6	Solar Panel Recycling	Levy	Available
7	Weather From Solar Farms	Veerapandian	*Results indicate a non-issue here*
8	Grid Balancing with Renewables	Jacobs	Available
9	Leachate from Solar Panels	Koch	Available

Figure 23. Inventory of White Papers and Info Cards from Phase 1 and Phase 2.

9.0 Agrivoltaics

The new term “agrivoltaics” is a portmanteau of agriculture and photovoltaics, and indicates land used for two purposes: farming and solar power. High volume row crops are not suitable because of the huge equipment that needs to navigate across the land. However, low-lying fruits and vegetables can be grown in the spaces between, and even under, the solar panels. There is no equivalent word for wind because the masts and access roads consume only about 5% of arable land within the project boundary, so the traditional corn-soy-Florida rotation can continue with minimal disruption.

Animal husbandry is also possible within a solar farm boundary. Cattle and goats are poor choices. Cows rub vigorously against the sun-tracking panels and vex their mechanisms. Goats eat anything they can chew, which includes electrical conduit. Worse, they love to stand on high ground, and will jump up on solar panels, scratching the surface, leaving dirty hoofprints, and shadowing the valuable semiconductor inside. Sheep are the ideal choice. They only need a nice cover crop (e.g. clover) to contentedly graze in and around the panels without causing trouble. Rabbits are another reasonable choice. One can also envision solar panels suspended above outdoor fish ponds, providing welcome shade to bass, catfish, bluegill, and perch. Having solar panels above can also protect fishes from the dive-bombing of eagles, hawks, and kestrels.

Figure 24. Aerial view of an Indiana fish farm.

Two agrivoltaic project proposals were developed during Phase 2 of the GQP. The first envisions watermelon combined with photovoltaics (PV), and dubbed the “Sun Melon”. Melons are popular in south-central Indiana, especially along the Illinois border. Several towns there have historically held Watermelon Festivals in mid-August. The GQP team learned of a business plan competition in Vincennes, but the deadline had passed and the organizers would not accept a late entry for 2022. However, the business plan, financial pro forma, and pitch deck are included herein as an Appendix. The results look very favorable because watermelon yield is affected very little, and the PV portion of the farm produces revenue without labor or fuel. The combination is better than either alone, lending strong support to the idea of agrivoltaics.

For diversity, the second agrivoltaic project presented in the Appendix is to raise rabbits in the shade of solar panels, and to invite school children on field trips to learn about bunnies and sunshine. This concept is called the “Sillycone Bunny Ranch”. There may only ever be one, but it serves as an example of innovation and entrepreneurship in this new dual-use business model.

10.0 Public Outreach

GQP project members participated in three public events during Phase 2. The first two were part of the Indiana Rural Energy Tour organized by the OED. These included a first visit to the Randolph County Fairgrounds plus a bus tour of Cardinal Ethanol, followed by a trip to greater White County with a tour of the Waste No Energy Anaerobic Digester, tour of wind farms and a lunch presentation at Reynolds Elementary School (seen in figure 25). Dr. Schubert also attended a public meeting of the Plan Commission of Noble County, held in Albion jointly with the County Commissioners, regarding ordinances relating to solar farm development.

Figure 25. Dr. Schubert presenting as IUPUI students S. Poriah and N. Parvex wait their turn.

As word of the GQP has spread, there has been an increase in speaking invitations of Dr. Schubert. In October, he spoke on the potential health impact of solar farms to the North-East Chapter of the Indiana Environmental Health Association (https://www.iehaind.org/). During the week of November 28th, Schubert spoke to the board of directors for the Indiana Corn Growers Association, the Indiana Soybean Alliance, and the Energy Roundtable event of the Indiana Farm Bureau.

11.0 Wind Whistle

During the self-guided tour through wind farms in White County, members of the GQP team stopped close to several wind turbines. Using the video feature of a smartphone, two of the students held a conversation at various distances from the mast. This was an informal validation of the findings of the Infra-Sound white paper, and also to provide first-hand experience of the sound itself. The day was warm and mostly sunny with a steady breeze. The corn was high, still green, and the rustling of the leaves in the wind was louder than the turbine blades until about 50 paces away from the mast. The Android app "Spectroid" recorded a noise level of -66 dB at this distance, which is very similar to the findings of the Infra-Sound paper.

Up close the "whoosh" of the three turbine blades rose and fell within about 1 second ("one-Mississippi"), and repeated about every 2.2 seconds. The sound was not unpleasant, but neither was it musical. Nevertheless, the team set out to create a portable "wind whistle" that could bring an approximation of the sound to a larger audience. Students S. Poriah and G. Koch were tasked with creating a hand-held musical device that sounds similar. A distinctive feature of wind turbine noise is a component that rises in frequency as it passes. This suggested a slide whistle.

Poriah and Kock designed and had 3-D printed a modified slide whistle. When played, after some practice, the sound is at least reminiscent of an actual wind turbine blade passing overhead. There is room for improvement of the wind whistle, but at this stage the GQP team has at least demonstrated proof-of-concept.

Wind Whistle Body
The body of the wind whistle was modeled using the computer-aided design (CAD) tool called NX. A symmetrical half of the actual wind whistle was modeled and then both halves were 3D printed and affixed to make the prototype. Masking tape was used to cover gaps.

Wind Whistle Plunger
The plunger was also CAD modeled using NX software. It is 3D printed and made of the same material as the body. The ball end of the plunger was not big enough to properly seal out the tube so too much excess air was escaping. This was solved by wrapping masking tape over soft paper so that the plunger would fill out the tube better. The body and plunger, used like a slide whistle, are shown in the figure below.

How to play:
The wind flute is very simple in design and use. The main spherical body of the instrument is where the user will blow into. There is a rectangular mouthpiece for this. The plunger will then be used to adjust the frequency of the produced sound. Pushing the plunger further into the tool will produce a higher frequency while pulling the plunger out makes a lower frequency sound. To imitate a wind turbine, push and pull the plunger while blowing into the flute. Smoothly pushing and pulling the plunger as you blow will produce the airy whooshing sound of the wind turbine.

Figure 26. Wind whistle body (left) and slide-style plunger (left) 3-D printed.

Spectrograph Pictures

The spectrograph pictures in figure 27 were obtained from the Spectroid app on the Google Play Store. A video of a wind turbine was played on a laptop while the Spectroid app would record the sound of the wind turbine blades by using a smartphone. The spectrograph shows the sound of two blades whooshing through the air. For the Wind Whistle, it was played twice, once for each time. These match reasonably well, and establish proof-of-concept for the Wind Whistle.

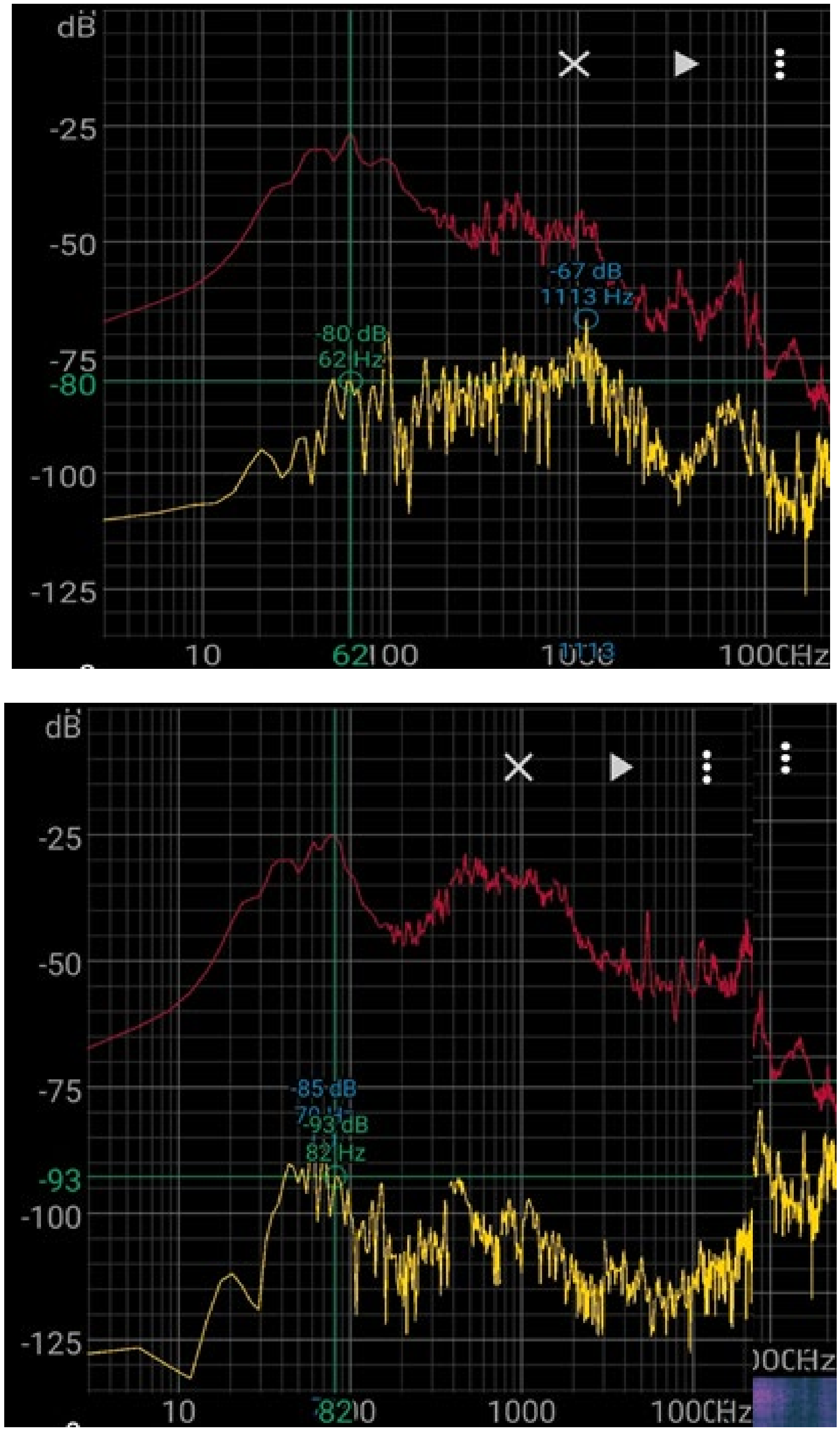

Figure 27. Spectrographs for actual wind turbine (top) and Wind Whistle (bottom). Note the red plot of maximums (yellow is instantaneous) for amplitude and shape.

12.0 Bird- and Bat-Strike Sensor Project

One of the most challenging issues identified is wind turbines killing bats and birds, topic 4 listed above. The white paper on this subject is included in the Phase 1 report. Yes, spinning turbine blades kill flying animals, but so do multi-story buildings with clear or lightly-tinted windows, and class 8 trucks on highways. Wind turbines can sometimes reduce the need for coal-fired power plants, and this reduction in emissions has great leverage in reducing avian deaths.

Nevertheless, this is an emotional issue, and it is hamstrung by the difficulty in obtaining good data. Anecdotal evidence in wide circulation are many, and most stories are gruesome. Hard evidence is difficult to find because the carcasses may be removed by scavengers (e.g. coyotes, vultures) almost immediately. The GQP project identified a gap in the data needed to address the magnitude of this problem. Most academic studies used predictive models, however, these are unconvincing to opponents of wind technology.

The GQP team determined that there is a significant need for a non-invasive, low-cost sensor system for detecting bird- and bat-strikes. As requirements, the team envisioned a self-powered (or remotely powered) sensor mounted inside the hollow shell of each wind turbine blade. Vibration sensors or accelerometers detect an impact, and discriminate against hail or heavy rain by the frequency spectrum, and report out the metrics from the hit and the date and time. This data is delivered wirelessly to a receiver in the nacelle or a ground-mounted relay station to gather hard evidence of each and every incident.

The GQP principal investigator, Dr. Schubert, has 43 patents to his name, and invented a Bat-Kill Sensor system. This has been disclosed to the technology transfer office of the IU system, called the Innovation and Commercialization Office (ICO). Schubert then commissioned a capstone design team from the Department of Mechanical and Energy Engineering at IUPUI to build and test a proof-of-concept prototype. The team consists of five energy engineering seniors, led by Mr. Antwan Khouri, who worked on Phase 1 of the GQP and prepared the white paper on wind turbine noise ("infrasound").

The student team built a three-blade mock wind turbine using white PVC plumbing pipe as surrogates for the blades. At the hub is a motor from an old vacuum cleaner, with enough power to sustain a steady rotation rate even under impact from a surrogate animal body (no live animals were used in any part of this study). The team included two types of sensors, a microprocessor to analyze the frequency data, and a wireless link to relay the data out for counting. The cost of such as system is expected to be less than $100, so that it may conceivably be required by participating localities interested in this subject, without undue economic hardship on the part of the developer. These could be used in all new wind turbines. But, even with a subset, the data gained would be of inestimable value in defining the exact probability of such unfortunate events. This issue varies widely with location, but a universal sensor could produce the hard evidence everyone wants.

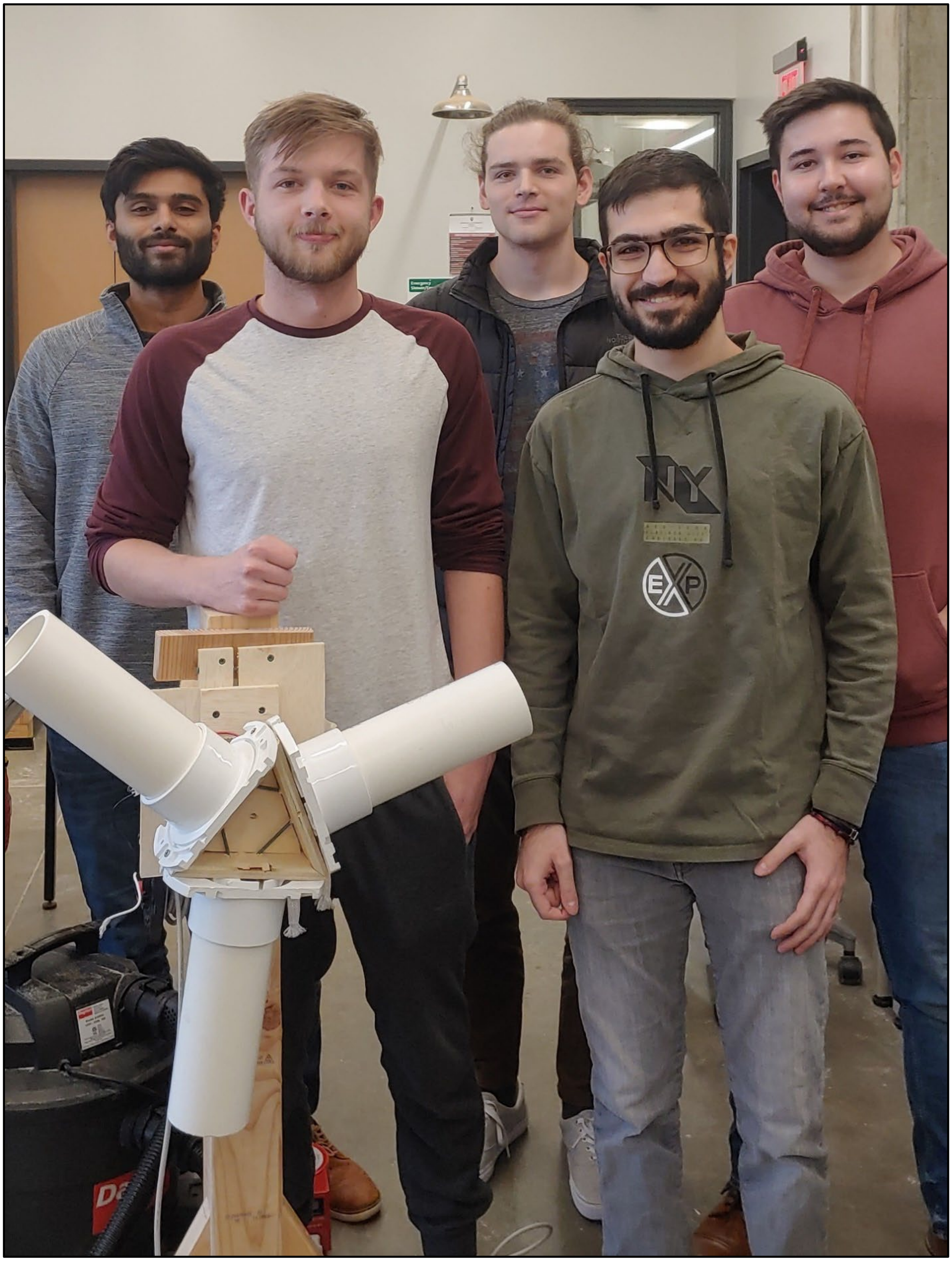

Figure 28. Bat Strike Sensor team of IUPUI energy engineers with their test apparatus. Pictured from left to right are N. Patel, W. Highland, A. Vozniuk, A. Khouri, and J. Wright.

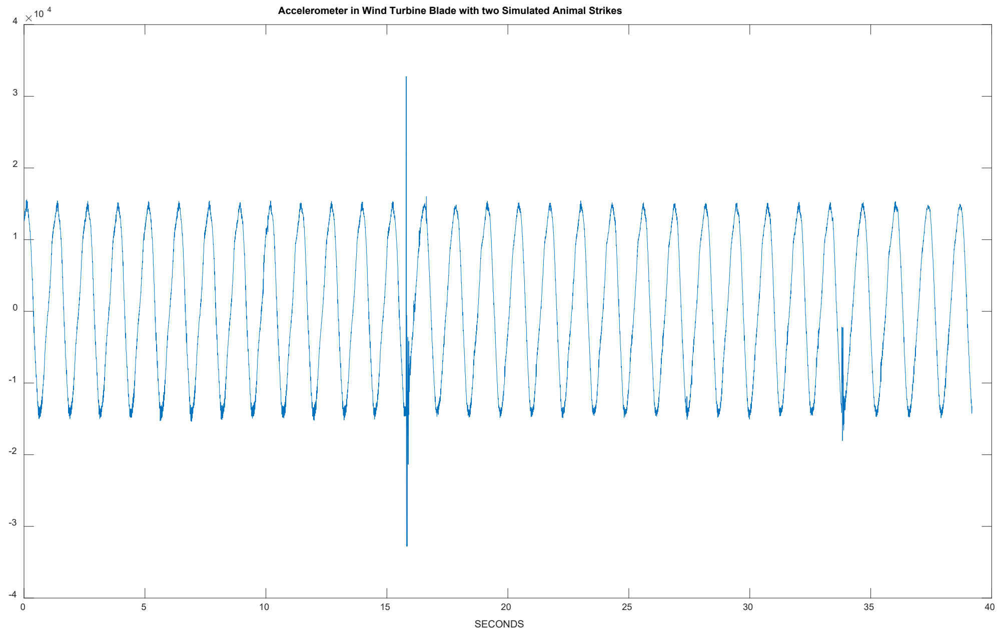

Figure 29. X-axis accelerometer showing sinusoidal direction change of gravity plus two simulated animal strikes at 16 and at 34 seconds.

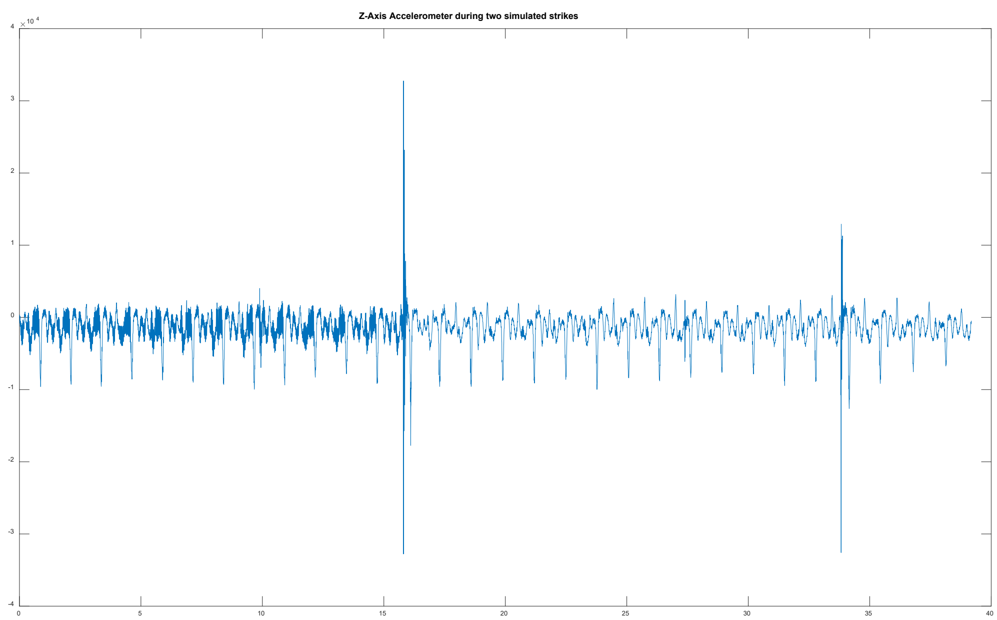

Figure 30. Z-axis accelerometer with small-amplitude signal from off-center wobble of the apparatus shown in fig. 28, plus simulated strikes at 16 and 34 seconds.

This data proves the technical feasibility for a low-cost wireless sensor to discriminate bird and bat strikes. This sensor system can be installed inside the hollow wind turbine blades such that turbine performance and reliability is not affected. These sensors can also detect wobble.

13.0 Energy Project Negotiation Terms & Conditions

The Indiana Code includes two laws resulting from the passage of Senate Bill 411 in the spring of 2022 which create voluntary regulation standards for utility-scale implmentation of solar and wind developments. IC 8-1-41 [1] and IC 8-1-42 [2] address default standards for “wind power devices” and “commercial solar energy systems,” respectively. This guidance is provided for local zoning ordinances in the unincorporated areas within a county, and includes the following categories for standards.

The list for wind energy projects in IC 8-1-41 has seven categories:

- setbacks and maximum height
- shadow flicker
- signal interference
- sound level limitations
- wind turbine light mitigation technology;
- drainage repair and
- decommissioning

The list for solar farm projects in IC 8-1-42 has nine categories:

- setbacks, height, and buffers
- ground cover
- fencing
- underground cables and aboveground infrastructure
- glare minimization
- signal interference
- sound level limitations
- drainage repair
- decommissioning, abandonment, and "force majeure event"

Section 20 of IC 8-1-42 defines “force majeure events” as fire, flood, tornado or other “natural disasters of acts of God”, plus war, civil strife, terrorist attack or other unforeseen event over which the project owner has no control. Both laws include many important details to be considered, at the county level, in developing an ordinance. Links to the two laws are provided in references [1] and [2] below.

For individual property owners, there are additional considerations, gathered by C. Martin of the Purdue Extension. A link to this report is found in reference [4] below. In the lengthy process of developing an energy project, developers generally require a large number of parcels of land and must negotiate with all the landowners. This is typically done one-on-one with a Non-Disclosure Agreement (NDA) so that the landowner does not share the results of their negotiation with neighbors. This approach presumably provides an advantage to the developer, because otherwise, everyone would demand the same, high, compensation. Although the GQP does not include a legal element, and the Lugar Center for Renewable Energy is not offering legal advice, this section includes lists of the topics that should be considered in such negotiations. We have blended considerations for landowners considering a lease with considerations for communities developing ordinances or conducting business development activities.

13.1 Considerations for a Wind Energy Ordinance

There are several components to a comprehensive county wind energy ordinance. They often include, but are not limited to [3,4]:

- A required distance for setbacks or distance of the wind towers from buildings or residential property. This will depend upon the scale and the speed of the wind turbines within a proposed development. Please see sample ordinances in Table 1 below.
- A method for determining compensation to landowners and farmers due to crop or property damage resulting from transportation and/or construction.
- Transportation of large equipment and turbine components during construction may require the development company to include road expansions and repairs to roads, bridges and culverts damaged by the construction phase.
- A requirement that developers maintain adequate drainage in farm fields or other land affected by construction due to damage or interference with drainage infrastructure.
- A contractual arrangement describing how payments will be allocated to landowners from wind energy developers for use of the land for wind energy development.
- An evaluation and understanding of current infrastructure and construction needs before the development process begins.
- Noise standards for utility-scale wind turbines to properly integrate turbines with residential property.
- Decommissioning arrangements for the structures that will come into play once the wind turbines are no longer usable.
- Security and safety inspection measures to protect the area surrounding turbines and other infrastructure involving transmission, etc. to protect landowners and others using the property.
- Indemnification provisions should also be considered for individuals and businesses. These provisions should define which party agrees to pay for liabilities associated with the project.

13.2 Considerations for Solar Energy Ordinances for Communities

While there are few solar energy specific ordinances, an obvious list of considerations that need to be addressed has appeared. The ordinance may address these as well as other provisions [4]:

- Site plans to identify location of the panels, electric and communication lines and site characteristics
- Setback requirements from property lines and structures
- Visibility from neighboring property
- Ground cover and buffers
- Decommissioning plans in the event the solar farm is no longer used for energy production
- Indemnification provisions

• Evaluation of infrastructure requirements (especially for sites that propose to generate electricity as they will need an appropriate connection to the grid for that purpose)

A sample survey of one such consideration is presented in Table 1. This is the setback for wind energy systems, which means the distance from the base of the tower/mast to other property lines or developments. A common distance is 1.1 times the height of the tower/mast. This is similar to, but distinct from, section 10 of IC 8-1-41, which recommends a 1.1 multiplier on the blade tip high, as measured from the ground to the tip of the blade. The law does not explicitly state whether the blade tip is in the highest or lowest position in its circle of travel, although the presumption is the larger distance. In five of the seven counties assessed for Table 1, they use the tower/mast dimension, which is less ambiguous, but also a smaller number than the highest blade tip height. This may be evidence that some counties will borrow code from other peer counties in developing their ordinance language.

Counties	Setback for Wind Energy Systems
Adams	600 feet or 1.5 times height of the tower
Blackford	350 feet or 1.1 times height of the tower
Hancock	1.1 times height of the tower
Jasper	1.1 times height of the tower
Rush	2640 feet from the center of the tower
Starke	1000 feet or 1.1 times height of the tower
White	1.1 times height of the tower

Table 1: Setback for wind energy systems in select Indiana counties.

REFERENCES

[1] https://iga.in.gov/legislative/laws/2022/ic/titles/008/#8-1-41

[2] https://iga.in.gov/legislative/laws/2022/ic/titles/008/#8-1-42

[3] M. Costanti, et al., "*Wind Energy Guide for County Commissioners*", U.S. Department of Energy https://www.nrel.gov/docs/fy07osti/40403.pdf

[4] C. Martin, *"Renewable Energy Integration for Sustainable Communities"*, https://cdext.purdue.edu/wp-content/uploads/2021/08/Guidebook_Renewable-Energy-Integration.pdf

14.0 Environmental Justice

While much of the GQP remit involves farmland used for utility-scale wind and solar, other energy projects such as biomass conversion or waste-to-energy (WTE) facilities may be located in or near cities. While many wind and solar sites are considered "greenfield", meaning this is their first industrial development, urban sites tend to be "brownfield" suggesting there may be residual effects of a prior use for the land. In some instances, urban energy sites may emit substances into the air, land, or water. Neighborhoods nearby such facilities may be exposed to greater risk. Those peri-urban communities having residents who are educated and affluent rarely are affected, largely because they can effectively organize and use the legal system to protect their interests. Less-advantaged communities can be an easy target for project developers.

The GQP team identified several organizations created as grassroots citizens organization to address potential energy projects in their community. Such groups are being actively sought out by the Biden Administration as part of their Justice40 initiative, which states, in part: (https://www.whitehouse.gov/environmentaljustice/justice40/)

> For the first time in our nation's history, the Federal Government has made it a goal that 40 percent of the overall benefits of certain Federal investments flow to disadvantaged communities that are marginalized, underserved, and overburdened by pollution. President Biden made this historic commitment when he signed Executive Order 14008 within days of taking office.

To understand how to approach and address grassroots organizations within such communities, the GQP team interviewed Prof. Jason Kelly, chair of the History department at IUPUI. He warned against a common practice of well-meaning visitors wanting to do good who "drop in by helicopter, then leave."

Prof. Kelly emphasized the importance of meeting community leaders, especially "BIPOC" neighborhoods, meaning Black, Indigenous, and People of Color. Kelly shared with the team that some brownfield projects are done on top of other brownfield projects, and that often the communities are not asked. He explained that nominal community leaders may certainly represent at least some of their constituency, but that there can be underlying tensions, or "hot-button" issues within. It is important therefore, to speak with a range of community leaders. Having an insider on the project team is another important practice to bring in "lived experience".

Disadvantaged communities often want to know if there will be jobs created that they can expect to work at. Knowing who benefits is important to people, knowing where the profits or savings will flow. The impact to home prices is paramount, as nearby energy projects can lower property values nearby, sometimes trapping people economically, or even driving them to experience homelessness. Already, a new wave of funding opportunity announcements from the US Department of Energy is including Justice40 considerations to large-scale grant offerings.

15.0 Policy Recommendations

The primary policy recommendation is to make public many of the findings of the Good Questions Project (GQP). In particular, the 3-page fact sheet can be useful for the economic development professionals in every county, and could be distributed through the IEDA. Having this document handy could avoid a great deal of the consternation experienced by Indiana communities when an energy project is being considered. Must of this consternation comes from deliberate or ignorant spread of misinformation through social media. In many communities there is simply no subject matter expert available to refute the wildest claims and conspiracy theories. This situation allows negative information to fester, unchallenged, until the project developer is ready to begin moving forward. They often find hostile communities, simply because of the one-sidedness of misinformation and disinformation. This first-mover advantage for objectors can be mitigated, at least in part, if every county in Indiana holds this valuable resource. The 3-page fact sheet can be backstopped by the nine white papers and the eight info cards, depending on how detailed of a response is demanded by interlocutors.

Agrivoltaics appears to be a promising approach, but is relatively rare in Indiana. Many farmers learn "over the fence" by watching what their neighbors try. The business case for the Sun Melon (watermelons grown under and around solar panels) is compelling, and may even be attractive to a rural bank. Should the OED sponsor several experimental agrivoltaic projects to retire the risk and prove the economics, there could be a groundswell of interest generated. One of the most deep-seated emotions revealed by the GQP is the desire for farmland to remain farmland. Agrivoltaics can accomplish this, and, if more widely adopted, could ameliorate a source of angst among Hoosiers. In another 10-15 years, the current furor over wind and solar will probably mellow, as has the food-versus-fuel debate from 15 years back. Agrivoltaics can bring this sooner and with less drama.

A continuation and expansion of the Indiana Rural Energy Tour would be time and effort well spent. Tours of existing energy project are welcomed, and provide opportunities for networking and "over the fence" learning even beyond immediate neighbors. The expanded Tour could include raising awareness of agrivoltaic funding opportunities, and sharing of lessons learned from satisfied landowners. A summary of the GQP findings could spark awareness that the State now has answers to the most important questions they have, and knowledge of this would spread by word-of-mouth across the State. This could be thought of as inoculation against misinformation.

16.0 Outlook for Phase 3 of the GQP

There is presently no contract for the GQP to continue. However, if it were to continue, several important advances made during Phase 2 can be brought to fruition. Also, the GQP team uncovered a number of gaps related to new energy projects that may be worthy of further research and development.

1. Build a bus or trailer with hands-on learning about new energy projects. Drive this to sites as part of the expanded Indiana Rural Energy Tour.
2. Expand the Mapping Tool for greater functionality in considering multiple aspects of an energy project. The current "storymap" version includes job creation and energy production based on land area, which is just the start. GIS brings a wealth of information and connections that can be used in siting considerations. It is even conceivable that the Mapping Tool could be augmented with artificial intelligence and machine learning (AI/ML) to optimize a query based on user input. For example, a user might specify what would be an ideal situation for them, and the Mapping Tool could use optimization methods to select the best (and second best, etc.) sites within a given radius.
3. Develop the Guidance Tool into a publicly-available resource. Probably, large energy developers already have this capability, or internal experts who can create this information. If community leaders, and individuals, also have access, this creates a "level playing field" for project negotiations. Also, a community might use the Guidance Tool to assess where they might make themselves more attractive to an energy project developer. Of course, other communities could do the opposite, as they wish, but by making this information and capability widely available, the informed citizenry can act more confidently in support of their interests.
4. Expand the Generic Survey. The Phase 2 survey covered 11% of the state. It used a minimum of external resources sometimes used in conducting surveys, such as advertisements, direct mail, and in-person announcements at community events. An expanded survey can draw from the insights generated from the results presented herein to augment the questions. A larger survey would also include counties with larger cities within them, and elucidate issues related to environmental justice.
5. The GQP team did not uncover any similar projects in other states. This may be a unique project that fills certain needs not covered by more traditional studies. Another possible Phase 3 project would be publication of the methods developed and presentation of the results. This could lead to additional funding from federal agencies, or even from other States wanting to learn about their own citizens and where they get their information regarding energy projects. Continued GQP research could cement the OED and the Lugar Center for Renewable Energy as pioneers on the vanguard of energy issues. With new technologies coming, such as hydrogen, small modular nuclear, and more, the need for such work will continue to grow.

17.0 Glossary and Acronyms

Acronyms and Abbreviations

1. CRP - Conservation Reserve Program, run by USDA's Farm Service Agency (FSA)
2. CSR – Indiana University Center for Survey Research
3. DOE – US Department of Energy (https://www.energy.gov/)
4. EPA – US Environmental Protection Agency (https://www.epa.gov/)
5. EMF – ElectroMagnetic Field (also EMI for EM Interference)
6. FB - Facebook
7. FMEA – Failure Mode and Effects Analysis
8. GIS – Global Information System
9. GQP – Good Questions Project
10. IACC – Indiana Association of County Commissioners
11. IDEM – Indiana Department of Environmental Management
12. IEDA - Indiana Economic Development Association
13. IUB – Indiana University - Bloomington
14. IUPUI – Indiana University-Purdue University Indianapolis
15. IOED – Indiana Office of Energy Development
16. kW – kilowatt or 1,000 Watts (measure of power, sometimes MW for 1,000,000 Watts)
17. kWh – kilowatt hour (measure of energy, equal to running a hair dryer for 1 hour)
18. LCRE – Lugar Center for Renewable Energy (www.lugarenergycenter.org)
19. LCOE – Levelized Cost of Energy (measured in $/kWh over the lifetime of an asset)
20. MSW – Municipal Solid Waste (garbage or trash collected from a population center)
21. NIMBY – "Not In My Back Yard"
22. O&M – Operations and Maintenance – costs associated with running a facility
23. OSHA – Occupational Safety and Health Administration
24. PV – Photovoltaic (scientific term for solar panel)
25. ROI – Return on Investment
26. SME – Subject Matter Expert (also Small- and Medium-sized Entitites)
27. SMR – Small Modular Reactor (nuclear)
28. SPEA – School of Public and Environmental Affairs
29. TBD – To Be Determined
30. USDA – United States Department of Agriculture (https://www.usda.gov/)
31. WCR – Western corn rootworm

Frequently-used Terms

Agent Provocateur - a secret agent hired to incite suspected persons to some illegal action, outbreak, etc., that will make them liable to punishment (https://www.dictionary.com/).

Astroturfing - the deceptive practice of presenting an orchestrated marketing or public relations campaign in the guise of unsolicited comments from members of the public (https://www.dictionary.com/).

Biomass – any renewable, or endlessly replenishable carbon-based resource, such as utility trim (of trees), agricultural residues, landscape trimmings, forest slash, and even MSW.

Capacity Factor – the ratio of electrical energy output actually generated divided by the maximum possible output if the asset ran 100% of the time. Wind turbines may be in the 30-45% range, solar in the 25-35% range, and a nuclear power plant may be 90%.

Capital Expense – sometimes abbreviated CAPEX, this is the total up-front cost to build, install, and activate a large, expensive project.

Energy – a static quantity, measured in kWh or Joules, that has the potential to do work, or the amount of work that has been done. In equation form: Energy = Power * time.

Externality – an economist's term to describe those harms or loss of value/productivity due to uncosted consequences of doing business. When government regulation requires avoidance, reduction, remediation, or recompense, that become factored into business financial decision-making, these are no longer externalities.

Greenwash - disinformation distributed by an organization so as to present an environmentally responsible public-facing image.

Insolation – the technical term for how much sunlight falls on a given piece of land, often measured in kWh per square meter, sometimes also called "irradiance" or "exposure".

Intermittent – referring to the uncontrollable loss of availability of wind and solar resources; more accurately called "non-dispatchable", because it cannot be turned on at will.

Power – a dynamic quantity, measured in kW, for how fast work is being done. In equation form: Power = Energy/time.

18.0 Appendices

18.1 APPENDIX A – White Paper on Property Values near Solar Farms

Impact of Solar Farms on Nearby Property Values

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Good Questions Project

30 September 2022

Executive Summary

Impacts on property values near solar farms has raised a matter of great concern between renewable energy developers and property owners. Rapid increase of solar installation project has parallelly increased the importance of understanding whether the impacts are positive or negative. The concerns of negative impacts involve replacement of green lands with commercial purposes, visibility of solar farms from public property, noise associated with the technical parts, life threatening equipment used in farms and many more. Most of these concerns have developed due to lack of information and proper guidance. However, most of the studies reported on this indicate no negative correlation between solar farms and neighboring property values. Unfortunately, public are not aware of such studies and start to believe the myths. To break their misunderstandings, renewable energy agencies, property developers, community leaders and voluntary groups can play a vital role by presenting the true facts in appropriate manner.

Introduction

The Good Questions Project, developed by the Richard G. Lugar Center for Renewable Energy at IUPUI in collaboration with the Indiana Economic Development Association (IEDA), is a venture aimed at answering communities' questions about renewable energy. The purpose of the project is to investigate local concerns and outline facts about the implementation and use of renewable energy systems.

This report will focus on the actual impacts on property values established from previous studies and public misperceptions towards property values near solar farms. The report will also identify how the misconception forms and what measures can be taken to enlighten people with the true facts. The goal is to make people aware of the actual scenario when a solar project is installed in an area.

The U.S is expecting to add 46.1 GW of utility scale electricity to the power grid in 2022, where almost half of the capacity (21.5 GW) will come from solar alone [1]. Already 4.6 GW (DC) solar has been installed in second quarter of 2022 which in total result in 130.9 GW (DC) solar that is capable to power 23 million American homes [2].

Undoubtedly, this rapid growth of solar has in parallel raised concerns among the general public. One of the concerns is the impact on property values when a solar farm is installed near their home. Although past studies have proved that there is little or no impact of solar on property values, still there are some people who are being misguided on this point. In general, public are encouraging the implementation of solar however, when it comes to their proximity, they start to show the NIMBY (Not In My Backyard) attitude. Such approaches come from various concerns among which some are valid, and others are misinformation. In this study, we tried to find out the sources of those misinformation and how to debunk them.

Type and Values of Solar Farmlands

According to the Research from the National Renewable Energy Laboratory, the utility scale solar alone can power the entire U.S. by utilizing 0.6% of land for solar installation [3]. Depending upon technology and solar insolation at the project site, solar installations require approximately 5 to 10 acres of land per megawatt (MW) of capacity [4]. As a result, it is difficult to establish utility-scale solar in purely urban areas. So, most of the solar projects have been installed in suburban and rural areas due to the land availability.

Solar can be done in agricultural lands, residential areas, industrial areas, wildlife movement path, idle farms, etc. Depending on the land type, impact of solar farms on property values can vary. For example, unused and unimproved lands are most preferable for solar installation. Leasing a piece of land to solar farms generates a steady income for the landowner during the entire project lifetime while keeping the parcel at the disposal of the family. According to a survey conducted by Lawrence Berkeley National Laboratory, average expected project life for utility scale solar farms is approximately 32.5 years in 2019 [5]. The same survey also revealed that land lease cost for solar farms can vary between $1,000 to $8,000 for 1 MW (DC). If we assume that it requires 5 acres of land for installing a solar farm of 1 MW capacity, the landowner can make between $200 to $1,600 per acre per year. On the contrary, if the land is used for corn production, it will return an approximate net profit of about $95 per acre [6]. Moreover, once the project period is over, the owner gets back the property which has rested and been maintained by the solar farm.

According to a study conducted by Cornell University in 2018, co-locating utility-scale solar with grazing sheep results in a net positive benefit for farmers, in the form of labor hours (2.5 times fewer labor hours than traditional vegetation management) and additional income [7]. Previously used land may also affect property values, such as, installing solar near forests will negatively affect property value whereas installing solar near a brownfield or capped landfill may result in increased land value due to the development and repurposing of the land [8]. Taxes paid by the solar farms into the community from the sale of solar electricity increases the wealth of the community. Another benefit is the property tax exemptions that landowners can avail in 36 states of the U.S. While valuating their property for tax purposes, owners can exclude the price of the solar system if they have an operational solar system on their land. For instance, the state of Indiana and New Jersey have exempted 100% of the property taxes for lands used for solar farms [9]. Nevada has allowed the businesses to apply for a tax deduction of up to 55% for 20 years for generation capacity over 10 MW [9]. Again, while installing a solar farm, the surrounding areas of the project are also being partially developed. For example, an access road is generally constructed or an existing road may be widened for the convenience of carrying equipment for the project. As a result, infrastructure improvements occur due to solar which can be a reason for increased value of nearby properties.

<u>Relevant Studies Assessing Impacts on Property Values Near Solar Farms</u>

It is true that installation of utility-scale is critical to reduce dependency on fossil fuels and to generate electricity locally. However, rapid growth of utility-scale solar farms has introduced cause for concern. A common misconception has grown among neighboring property owners that installation of these farms in their neighborhood can adversely affect their property values. This phenomenon has drawn the attention of property developers, solar industry, policy makers, and especially academicians. A few studies have been conducted to assess how these installations affect the price and the market demand of the neighboring properties.

The Department of Environmental and Natural Resources Economics at University of Rhode Island applied the widely accepted hedonic regression method to quantify impacts on property values from nearby solar arrays. The researchers observed almost 400,000 real estate transactions in Massachusetts and Rhode Island between 2005 and 2019 before and after the construction of solar farms [10]. The study reported that residential properties within one mile of the solar farm went down by 1.7% upon the completion of the construction of the farm. It however showed that such depreciation is only observed in solar farms in semi-urban or urban areas in the proximity of high density living community. Utility-scale solar is unlikely to be built in urban green areas as they require large areas in the vicinity of high-tension transmission lines which is rare in urban areas. Rural properties were not at all affected in this study due to installation of solar in the neighborhood.

University of Texas at Austin published another study report where researchers applied geospatial analysis to analyze median household income and conducted a survey among residential property assessors (appraisers) who had no prior experience of quantifying the impact of solar installations on nearby properties [8]. Majority of the respondents believed that proximity to solar farms has either no negative impact (66%) or positive impact (11%). Most utility-scale solar installations require a large land area which generally means that these installations are built in areas with lower average income.

CohnReznick LLP is a valuation assessing firm that conducted a study on six existing solar farms and the property value trends of the adjacent land [11]. It was found that majority of the lands adjacent to the solar farms are used for agriculture. Neighboring residential properties experienced growth in price ranging from 0.1% to 7.46% with an average increase of 1.3%. In the similar manner, no negative impact was reported on the price of agricultural properties. This study eventually summarized no consistent correlation between price drop of properties and solar installation.

Examining property value in states across the United States demonstrates that large-scale solar arrays often have no measurable impact on the value of adjacent properties. In the Great Lakes region, studies conducted in different sites in Illinois and Indiana show that installation of solar farms resulted in an escalated value of the properties ranging from 1 to 2 percent [12, 13, 14].

Factors Affecting Public Perception

Most studies reported to-date found no evident relationship between a decline in property values and neighboring solar farms. Respondents in different surveys who advocated the notion that solar farms would reduce the adjacent property value mostly failed to present solid reasons behind their viewpoint. Some common concerns regarding property values adjacent to the solar farms include visibility (glare, glint) of the solar installation, squeaky noise from the mechanical parts, humming from the electrical boxes, damage to subsurface drainage tiles, chemicals leaching into the soil, water drainage, and fires.

In a survey done by the Idaho National Laboratory found that 23% of the people from the southwest US believed that the visibility of solar installations would increase property values, whereas 43% believed it would decrease the value [15]. Solar installations are typically surrounded by fences for protection purposes. On top of that, aesthetic green landscaping (e.g. arborvitae) can significantly reduce visual disturbance. Many believe solar farms produce noise and attract traffic that will hamper the calmness of the nearby residential areas. However, the truth is, motors and inverters used in solar projects might create some noise but that is not audible from outside the project site. As solar projects need little maintenance, it mostly operates under small manpower bringing very little new traffic. Another point of misinformation is that installation of solar panels degrades soil and leaves land unusable for farming. In reality, solar can improve the quality of over-used soil when installed with deep-rooted grasses and plantings that attract pollinators [16].

Again, some believe living near a solar farm can increase the risk of cancer.. Cadmium, often found in solar panel, is a carcinogen, however, only increases the chance of cancer if eaten and digested [17]. Silicon dust, which can be generated if solar cells are pulverized, can cause lung-related ailments. But it does not get into the human lung if someone breathes near an intact solar panel. Rather, Gillings School of Global Public Health at the University of North Carolina claimed that solar panels and solar farms can contribute to reduce the number of lung cancer patients as they minimize the dependency over other electricity generating sources that contribute to air pollution causing lung cancer [18]

Sources of misinformation

As most of the concerned factors are not valid, they can be defined as misinformation which may come through various propagandas. For instance, many business organizations may not welcome the growth of solar due to their vested business interest. Supporters of a specific political group may be biased by the negative statements of solar made by politicians. Again, some housing developers may oppose green energy, as it may bring price competition over the lands for their business interest.

To address the misinformation caused by different groups, it is important to identify the sources from where they are being spread. The first and foremost source can be identified as social media, such as Facebook, Twitter, Instagram, etc. People share news in social media without knowing the truth which in result help to pass the false information to millions within seconds. Manipulation of images or videos is a popular technique to get publicity. For instance, a green land that turned into a solar farm can be pictured as "Solar Destroying Greenery". Besides, word of mouth can also be dangerous when people believe them without applying their judgmental abilities.

In all these cases, people are sometimes unable to differentiate misinformation from facts. The reasons behind this inability are lack of critical thinking skills, age of the decision makers, emotional and sentimental persuasion, etc.

Possible Approaches for Eradicating Misconception

When a solar project is about to be installed in an area, some property owners come forward with NIMBY attitude as they have heard or seen negative statements about solar. If we do not verify the sources of those information, we will end up depriving ourselves from the blessings of green energy. To establish true facts about solar among people can be done by following some steps.

There are many studies done previously which proved zero impact on property values near solar farms. If those factsheets are distributed among society, people will have an idea on whether their property value is adversely affected by solar or not. Inoculation theory can be applied to those who lack education or are not aware of the benefits of green energy. They can be trained through videos describing common manipulation techniques, and this will help them to identify misinformation from facts. However, this manipulation technique recognition can be boosted by an average of 5% only [20].

Another approach is to use the source of misinformation as a platform of debunking. For example, advertisements in Facebook pop-up very frequent while using the app and they are also popular in convincing users to try their products. Using the Facebook platform, if solar can be advertised in solar prospect areas through videos containing true facts can be helpful in eradicating the ongoing myths. However, this strategy has some limitations as well. If the proponents of solar energy run advertisements stating facts about solar energy, opponents may come up with a completely opposite information which may confuse the common people. It will therefore be more appropriate if these campaigns are run by neutral third parties such as government agencies or non-profit charitable organizations. Besides, round-table discussions can be arranged in presence of community leaders (church, voluntary group, etc.), property developers and renewable energy agencies to increase the likelihood of having good information.

Conclusion

Worldwide, most studies claim that property values are unlikely to be negatively affected by the adjacent solar farms. However, lack of understanding and awareness have made it difficult to debunk misinformation. Until now, most solar farms have been installed on agricultural land or idle property. After installing solar farms, any change in property value is zero within the margin of error. However, there are other factors like increased tax value, recovered soil quality, partial development, etc. that may contribute to an increased property value. Although people are being misinformed through online platforms, manipulated news and word of mouth, there are some ways which can help them identify the right information. Although educating people in the separation of fact from fiction is a complex process. Only after initiating the process will it slowly be make it easier.

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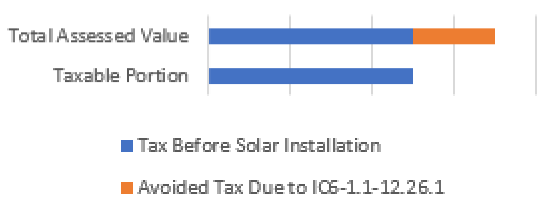
Two-page, 1-sheet Info Card displayed on the next two pages.

Concern: Installation of solar farms can affect nearby property values.

Answer: Studies have shown a near-zero impact on residential properties in the vicinity of a solar farm. The results range from a gain of +7% to a loss of -2% with an average of a +1.6% increase. This is within the margin of error, leading to the conclusion that solar farms do not negatively impact property values.

VALUES OF SOLAR FARMLANDS

The expected project life for utility scale solar farms is approximately 32.5 years and solar installations require approximately 5 to 10 acres of land per megawatt (MW) of capacity. If 5 acres of land is required to install 1 MW solar, then the landowner can make a rent between $200 to $1,600 per acre per year. On the contrary, average corn yield per acre of land is 177 bushels per acre and the October 2022 market price of corn is $6.81 per bushel. Therefore, corn production generates revenue of $1,205 per acre per year. However, the revenue from solar rents requires no expense on the part of the landowner, while farming corn requires cost for seeds, equipment, fuel, chemicals, and labor. Therefore, the profit can be considerably higher for solar. In addition, residential and commercial that purchase and install their own solar projects can avail 30% federal income tax credit. Furthermore, when landowner-purchased solar installations add value to the property, the state of Indiana has exempted 100% of the additional property tax to be imposed due to increased property value assessment. Therefore, landowners can make superior profits and enjoy tax incentives.



RELEVANT STUDIES

A common misconception has grown among neighboring property owners that installation of solar farms in their neighborhood can adversely affect their property values.

The researchers from The University of Rhode Island observed that residential properties within one mile of the solar farm went down by 1.7% upon the completion of the construction of the farm. However, such depreciation was only observed in semi-urban or urban areas where utility-scale solar is relatively uncommon. Rural properties were found not to be affected at all. Another study found that neighboring residential properties experienced growth in price ranging from 0.1% to 7.46% with an average increase of 1.3% and no negative impact was reported. Studies conducted at different sites in Illinois and Indiana show that installation of solar farms resulted in an increased value of the properties ranging from 1-2%. In general, it can be stated that solar farms have no measurable impact on nearby property values, either positive or negative.

FACTORS AFFECTING PUBLIC PERCEPTION

Although there exist several concerns related to solar installations, most of the concerns are adequately addressed by the project developers.

- **Visibility**- Solar installations are typically surrounded by fences for protection purposes. On top of that, aesthetic green landscaping can significantly reduce visual disturbance.
- **Noise**- motors and inverters used in solar projects might create some noise but that is typically not audible from outside the project site.

- **Soil degradation**- solar can improve the quality of over-used soil when installed with deep-rooted grasses and plantings that attract pollinators, and allow the soil to rest.
- **Causes cancer**- Cadmium, found in certain types of solar panels, is a carcinogen, however, only increases the chance of cancer if eaten and digested.

Such misinformation can be spread by profit-motivated businesses, ideological pundits, and agents provocateur due to their vested interest. This misinformation is disseminated through social media (Facebook, Twitter, Instagram, etc.), by sharing news without confirming the facts, manipulating images or videos, and sometimes through word of mouth. In all these cases, people are sometimes unable to differentiate misinformation from facts. The reasons behind this inability are lack of critical thinking skills, age of the decision makers, emotional and sentimental persuasion, etc.

POSSIBLE APPROACHES

Establishing responsible understanding about solar among people can be accomplished by the following:

- Previously proven factsheets can be distributed among society so that people can have an idea on whether their property value is adversely affected by solar or not.
- Inoculation theory can be introduced to those just learning critical thinking, or who are not aware of the benefits of green energy.
- Using the source (i.e., social media) of misinformation as a platform of debunking by neutral third parties such as government agencies or non-profit charitable organizations.
- Round-table discussions can be arranged in presence of community leaders (church, voluntary group, etc.), property developers and renewable energy agencies to increase the likelihood of having good information.

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18.2 APPENDIX B – White Paper on Chemical Leaching from Solar Panels

White Paper on the Potential for Heavy Metal Leachate During the Life Span of a Photovoltaic Solar Module

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Good Questions Project
December 2, 2022

Introduction

The problem this document addresses is public concerns for the potential for heavy metal leaching throughout the lifespan of a PV module. While investigating this issue, a broad perspective was needed. Understanding public opinion and potential misconceptions is vital in knowing what questions need answers. Knowledge of the different generations of PV modules and their specific leachable metals informed on their potential to be hazardous. A clear view of the module's propensity to leach during specific times of its life cycle and in what physical condition was vital in knowing how and where mitigation would need to take place. Comparative studies give perspective on the scale and the potentially unique nature of this issue. Through an exploration of these different aspects the document will discuss potential solutions to the concern.

Methodology

The process used to obtain the information in this report consists of reading peer-reviewed published documents and conducting interviews with industry experts and residents of Indiana. To understand misconceptions that may be in the collective knowledge, internet searches were performed to identify areas of distrust from the general public. In addition, interviews were conducted with residents from across the state to understand public perception. Once a clear idea of the concerns was established, peer-reviewed publications were used in conjecture with industry expert interviews to explore the factual nature of these claims.

Background

There are three generations of Photo-Voltaic (PV) modules, as shown in [1, Fig. 1]. The first two generations will be the focus of this document as the third generation is not prevalent in the market due to much of that generation still being conceptual. Each of these different technology types will present different heavy metal leaching potential. In addition to leaching potential there are many different metals that could leach from a given PV module. The United States Environmental Protection Agency (EPA) has categorized only some to be hazardous and within a specific concentration (mg/L) tolerance. The leaching of these metals can be evaluated at different stages of a PV module's life cycle. By examining the mining/manufacturing, in-service, and end-of-life (EOL) of each technology a better understanding of potential leaching and mitigation processes can be accomplished. There are different experiments that will be examined in this document which are used to measure the mobility of heavy metals as well as the different types of heavy metals, some of these experiments are regulated by the EPA while others have been devised specifically for their individual study. The last aspects that will be considered are comparisons for context. Comparing PV module heavy metal emissions to other energy source emissions as well as comparing other common item's leachate to PV module technology's leachate.

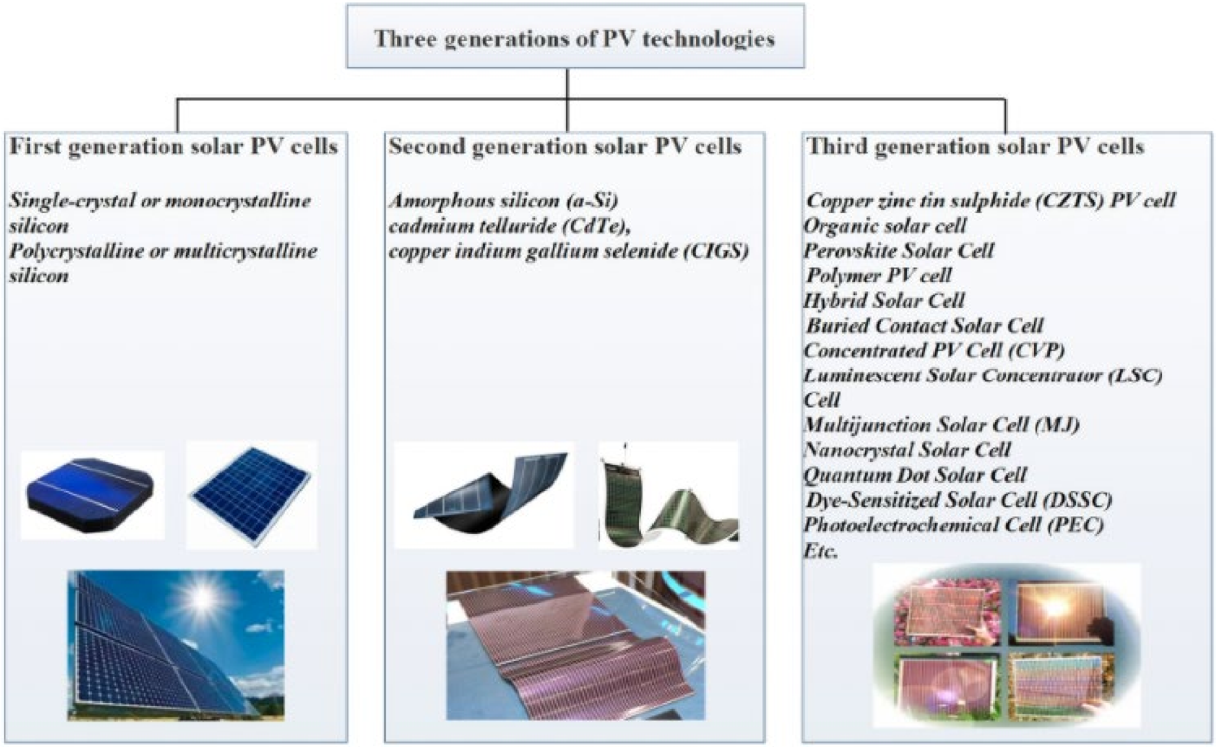

Figure 1. Different types of PV cell technologies categorized in their three generations.

Technologies

Silicon based PV modules are found in both the first and second generation. Crystalline Si (c-Si) is from the first generation and is the most common and commercially available, making up over 95% of the total market [2]. These modules are also an important focus because they have been in service the longest and have the greatest potential to be damaged in service due to the longevity of their service time and subsequently will be coming to their EOL sooner than any other module type. Furthermore, damaged modules have the highest propensity for leaching, they are also most likely to end up in a landfill. Crystalline Silicon can be separated into two separate categories, the monocrystalline (mono) and polycrystalline (poly). They are easily told apart from each other as monocrystalline has a black color and are clearly all one smooth surface, while polycrystalline is a more bluish color and the different crystals are visible. The difference between the two can be seen in Figure 2. With c-Si being the most abundant module in service it is also the most studied. Studies performed on c-Si modules state that of all the heavy metals present, lead (Pb) has a potential to exceed the concentration tolerance while other metal concentrations are negligible [6]. In addition, c-Si modules were observed to have the highest leaching potential among all the PV technologies [12].

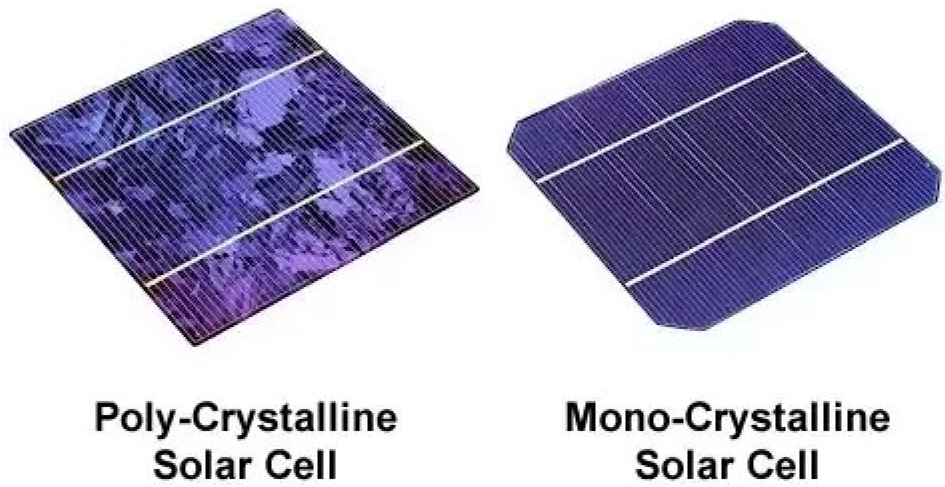

Figure 2. Visual differences in crystalline silicon PV modules

Another silicon-based module technology is the amorphous Si (a-Si), a thin film PV module from the second generation. The thin film technology is visually different from the crystalline technology [Figure 3]. Public opinion is that thin film technology is more visually appealing compared to crystalline, as thin film does not have an aluminum frame and distinct cell separation. Furthermore, as the name suggests the thin film is thinner in profile than crystalline. This type of module is far less prevalent in the commercial and utility space of solar energy, making up only 0.3% of the market [3]. They are newer relative to c-Si, so their EOL is not as imminent. This technology does contain Pb like a c-Si module due to soldering being needed in its fabrication. However, breakage rates are quite low, just like other thin-film technologies.

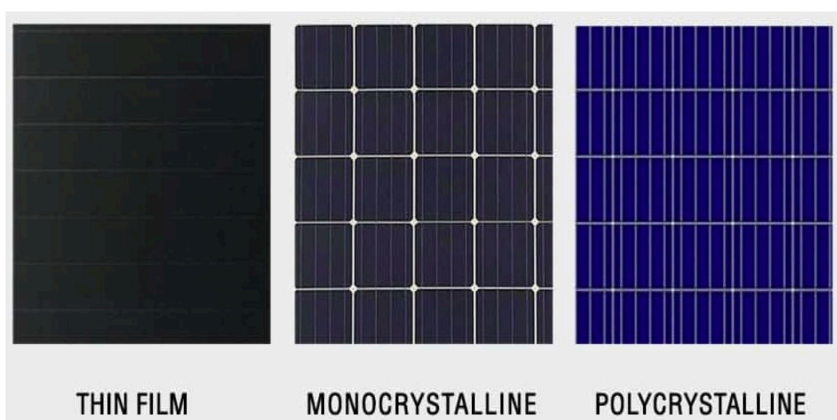

Figure 3. Visual differences in crystalline silicon and thin film PV modules

CdTe are from the second generation of PV technologies and are the second most prevalent module making up 2.4% of the market [3]. This technology's fabrication is like the a-Si module as they are both considered thin-film modules. Being able to visually tell this technology apart from other thin film modules is difficult as the color can vary, this is dependent upon manufacturer. However, the manufacturing process is like other thin films resulting in a similar

Pb content. Unlike the previously discussed modules, CdTe has the potential to leach Cd which is one of the hazardous metals that are a concern in this document. Through a study done on the breakage rates of CdTe modules it was determined that only 1% of modules fabricated are damaged in their 25 - 30 year life span, that is roughly .04% per year. In addition, of that 1%, 33% is during the shipping and installment phase and are therefore replaced and never put in service [7].

CIGS are a second-generation PV technology that have a market contribution of 1.9% [3]. This is another thin-film technology. This technology shares a visual profile like the other thin film technologies. This PV technology has some of the least number of experiments, however we can infer that due to the fabrication being like other thin-film modules that its potential to leach is similar. Once again, finding Pb to be present due to the fabrication of this technology yet it is below the tolerance limit [12]. Leaching procedures have shown CIGS has the potential to leach Cd at levels exceeding the regulation limits. However, the procedures used to obtain these results do not accurately emulate natural conditions, the module is in a highly acidic environment and the module is ground down to a micrometer scale. Therefore, these results are to be taken as a worst-case scenario rather than common findings.

Experiments/Procedures

Through different experimental procedures major factors can be determined about PV modules and their potential to leach heavy metals into the environment. First, the types of heavy metals that could be leached out of a module. Second, the mobility of the different metals to leach from the modules is determined. Lastly, the different types of metals can be categorized as hazardous to the environment or not.

The most universally used procedure is the Toxicity Characteristic Leaching Procedure (TCLP). The TCLP is regulated by the EPA and used to determine the mobility of organic and inorganic analytes that are found in waste [4]. This procedure simulates a landfill environment which is highly acidic. The TCLP pH range of the testing environment is 2.88 – 4.93. A pH scale can be seen in Figure 4 to provide context for pH values in this document. Concentration of specific heavy metals is determined through this procedure, and it can then be determined whether that concentration is above or below the regulatory acceptability level. This procedure is a great resource for detecting specific leachates in potential waste components and can provide a baseline for each module type in knowing which hazardous metals could be present through leaching. In addition, this procedure grants us insight to the leaching potential for the EOL stage of a PV module’s life cycle.

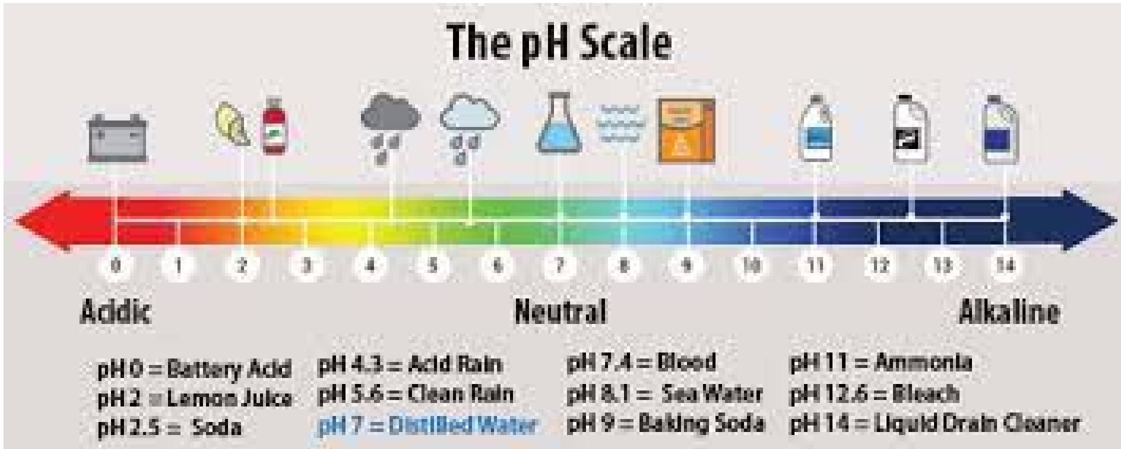

Figure 4. pH scale

Another EPA regulated process commonly used to determine an analyte's mobility is the Synthetic Precipitation Leaching Procedure (SPLP) [5]. This procedure is like the TCLP in its processes except for the environment that is simulating. The SPLP procedure simulates a natural environment rather than a landfill environment [6]. This is done by changing the extraction fluid used in the procedure from an acetic acid used in the TCLP to a sulfuric or nitric acid reaching a pH value closer to natural rain. The SPLP pH testing range is 4.2 – 5.0, and US average rain fall is in the 4.7 – 6.7 pH range [7].

Comparisons were made between international tests and US regulated ones. Specifically, a study commissioned by the Japan New Energy and Industrial Technology Development Organization aimed to create a more realistic approach to determining the in-service leachate potential for PV modules. This test consisted of creating small cracks in PV modules and then simulating acid rain for the equivalent of forty days. This experiment's findings were then compared to EPA regulated tests showing much lower concentrations of lead (Pb) and cadmium (Cd) as seen in [7, Fig. 5].

Geography		United States [7]	Germany [8]	Japan [9]
Leaching Test		U.S. EPA Method 1311 (TCLP)	DIN EN 12457-4:01-03	Ministry of Environment Notice 13/JIS K 0102:2013 method (JLT-13)
Sample size (cm)		1	1	0.5
Solvent		Sodium acetate/ acetic acid (pH 2.88 for alkaline waste; pH 4.93 for neutral to acidic waste)	Distilled water	Distilled water
Liquid:Solid Ratio		20:1	10:1	10:1
Treatment Method		End-over-end agitation (30 ± 2 rotations per minute)	End-over-end agitation (5 rotations per minute)	End-over-end agitation (200 rotations per minute)
Test Temperature		23 ± 2°C	20°C	20°C
Test Duration		18 ± 2 h	24 h	6 h
Leachate Cd Concentration (mg/L)	CdTe PV	0.22	0.0016—0.0040	0.10–0.13
	c-Si PV	Nondetect (< 0.1)	-	Nondetect (< 0.01)
	Limit	1	0.1	0.3
Leachate Pb Concentration (mg/L)	CdTe PV	Nondetect (< 0.1)	-	Nondetect (< 0.01)
	c-Si PV	3–11	-	Nondetect (< 0.01)—0.90
	Limit	5	-	0.3

Figure 5. Summary of leachate test results from international procedures

The most unique study discussed in the document is one done on c-Si modules in service. Soil samples were taken at different proximities from the modules and then analyzed by inductively coupled plasma optical emission spectrometry (ICP-OES). This solar farm had been in service for five years in Buffalo, New York. Therefore, these modules have endured a variety of elemental damage and provide a realistic view of in-service PV modules. The findings of this study were such that little change in concentration was found from directly underneath the modules up to one hundred feet away from the epicenter. The conclusion of this study was that **c-Si PV modules while in-service are not harmful to the** environment and any leachate found in soil samples was below the EPA limits [11].

Through these experiments it has been determined that the leached heavy metals with concentrations at hazardous levels are Pb and Cd. These two elements will be the focus of this document. Pb is used in a main component in solder, which is required to assemble any PV module. Cd is found only in CdTe and CIGS PV technology, and therefore is only a concern for those select module technologies [6].

Comparisons

To better gain perspective on the scale of the heavy metal leachate of PV modules, comparisons to other energy technology and other common items is explored in this document.

Not many experiments have been implemented during the mining/manufacturing process. However, some data has been collected comparing the heavy metal emissions produced during the metal extraction phase of both PV technology and coal power. The findings show that heavy metals are present during the mining phase of PV technologies. However, coal-fired power plants also have heavy metal emissions during their mining phase. The coal mining process was found to produce close to 3,000 times more Pb than PV technology mining processes [8].

A study was conducted to better understand the leachate potential for automobiles. In this study automobiles were shredded and the TCLP test was conducted to obtain the concentration of Cd and Pb. When comparing the Cd leachate of the shredded automobiles to PV modules it is found that CdTe modules have concentrations that are similar in amount, and both fall below the EPA regulated limit. The findings on Pb leachate from automobiles have a range of findings where the upper limit is close to the lower limit of c-Si modules. Therefore, Pb leachate concentrations are higher in c-Si modules generally, but automobiles have the potential to leach just as much Pb [9].

A major culprit of Pb leachate is personal computer components. These devices leach 30-100 times above the regulatory limit. This dwarfs any comparison to PV module technology's leachate potential [10], which tend to fall below the acceptable level or at most two times the regulatory limit.

There is some contention from a study claiming that the TCLP and SPLP are too aggressive of procedures and the results do not represent a realistic condition of the module [7]. The TCLP and SPLP breaks the module into micrometer scale pieces for evaluation, which is in no way like the conditions a module would be subject to in-service or in a landfill. In support of this claim that TCLP is too aggressive of a procedure, it was found through an interview with a local landfill manager that the data they use to categorize waste did not show PV modules posing a hazardous threat and could safely be disposed of in the general waste landfill.

Discussion
There are many different concerns at hand here and therefore several mitigation strategies may be employed. Reducing the potential for leachate, immobilizing the heavy metals in the environment that they are leached, removing the heavy metals from the fabrication of PV modules, and proper disposal procedures are all processes that can be implemented to mitigate these concerns.

In order to remove the potential for leaching from a PV module it must remain intact and encapsulated. This process can reduce the mobility of Pb by a factor of 4.1 - 8.8 rendering a module encapsulated safe from leaching hazardous metals [6]. Furthermore, a study on the weak spots of a module have found that **if a module is undamaged and fabricated with glass laminate encapsulation (GLE) it proves no threat to the environment though leaching heavy metals** [17]. Encapsulation is a step in the fabrication of any PV module, an overview of the process can be seen in Figure 6. Not all modules are encapsulated with glass, 80% of all PV modules are encapsulated with ethylene vinyl acetate (EVA) [18]. The differences between the two encapsulation materials are a matter of module efficiency and cost. No leaching differences have been found between the two different encapsulation materials.

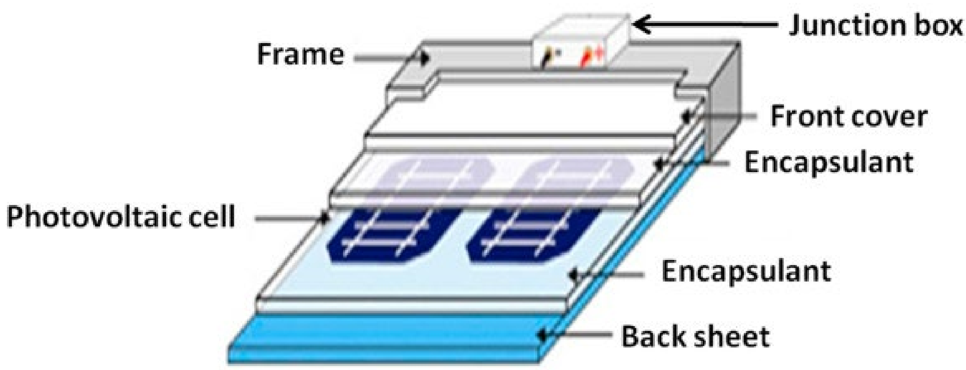

Figure 6. PV module construction diagram

In addition to leaching reduction, steps can be taken to treat the soil below a module to immobilize any leached hazardous metals from endangering the environment. Peat moss can be used to inhibit the mobilization of Pb [13]. Furthermore, Cd mobilization can also be treated in a similar fashion using layered double hydroxides which are prepared from calcinated dolomite [14].

While not specifically related to PV module leachate reduction, removing Pb from solder is an area of interest across all fields of study. The transition to lead free solder is underway world-wide [15]. The European Union is a leader in this area, and it is only a matter of time before it is implemented across the PV technology industry. This will remove the Pb from the equation and provide modules that have zero heavy metal leachate potential.

The largest contributor to reducing EOL leaching is to recycle, or properly dispose of a PV module when damaged or retired from service. First Solar has been successful in recycling 90% of the total weight of a CdTe module [16]. This gives hope to future PV manufacturing companies recuperating materials from retired modules and reducing the amount of waste to be sent to a landfill.

Conclusion

Leaching of heavy metals can occur in PV modules under the right conditions. The concentration amount and the state of the module are not fully agreed upon throughout all the different studies. Some leaching may be possible, but it is not nearly as abundant or pervasive as some of our other electronic waste or other energy sources. By developing better fabrication methods, the possibility for leaching could be nearly eliminated. If there is contamination around a solar farm there are actions that can be put in place to reverse and prevent future contamination. With the right processes in place, it is safe to say that the hazard of heavy metal leachate contamination can be negligible or non-existent.

Future Work

There are many experiments that could and should be performed to get a better understanding of the potential hazards of PV module's leaching heavy metals. As it stands most of the tests done on heavy metal leaching are focused on end of life which is important to understand how to dispose of the modules once they are taken out of service. However, little to no research has been published on the mining and manufacturing of PV modules. In addition, the conditions of a PV module in service have not been fully examined. A controlled experiment examining different operating conditions and construction processes is yet to be done and could help understand if the undesirable metal leachate is produced by the PV modules themselves or the structures installed to facilitate their operation. Furthermore, different stages of degradation of the PV module could play a role in the amount of leachate found, this is another area that can generate future research projects.

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A two-page Info Card on this topic is presented in the next two pages.

Concern: Can solar panels leach poisons into the environment?

Quick Answer: Not if well-made and un-damaged.

More Detail : Leaching of heavy metals can occur in Photo-Voltaic (PV) modules under certain conditions. The concentration of heavy metals is very low from well-made panels, but can increase if the modules are crushed or broken. In acidic conditions, broken modules can leach more. In undamaged solar panels, leaching may be possible, but it is at low levels compared to some of our other electronic waste (e-waste). By developing better fabrication methods, the possibility for leaching can be nearly eliminated. If there is contamination around a solar farm there are actions that can be put in place to reverse and prevent future contamination. With the right processes in place, the hazard of heavy metal leachate contamination from PV modules can be negligible or non-existent.

Photovoltaics

Two main generations of PV are explored in this document, crystalline silicon (c-Si or monocrystalline) and thin film (polycrystalline). These silicon-based PV modules are visually recognizable by their black and blue colors, mounted inside of a metal frame. Furthermore, in blue poly modules the individual crystals can be seen where the black mono c-Si modules are clearly all one smooth crystal. The thin film generation of PV technology is comprised of amorphous silicon, cadmium telluride (CdTe), and copper indium gallium selenide (CIGS) technologies. These modules are recognizable by their deep black color and their thin profile, as the name implies. A visual comparison can be seen in Figure 1. Through regulated procedures and experiments it has been determined that the leached heavy metals with concentrations at hazardous levels are lead (Pb) and cadmium (Cd). Pb is used in a main component in solder, which is required to assemble any PV module. Cd is found only in CdTe and CIGS PV technology, and therefore is only a concern for those select module technologies [1].

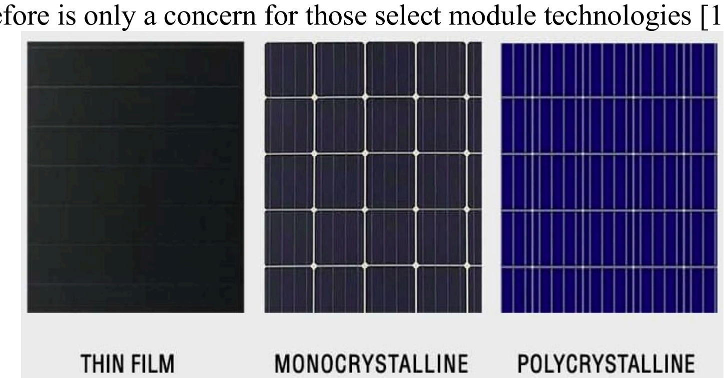

Figure 1. Visual differences in crystalline silicon and thin film PV modules

Procedures / Experiments

The United States Environmental Protection Agency (EPA) regulates two different procedures that are used to determine heavy metal leachate potential. The Toxicity Characteristic Leaching Procedure (TCLP) [2] is used to simulate highly acidic environments within a pH range of 2.88 – 4.93, this simulates a landfill environment, which helps clarify the end of life (EOL) conditions of a disposed PV module. The Synthetic Precipitation Leaching Procedure (SPLP) [3] is a similar procedure except that the environment being simulated is like what a PV module would be subject to while in service, with a pH range of 4.2 – 5.0. The pH of US average rain fall is in the range of 4.7 – 6.7 [4]. A study was done on c-Si modules in service where soil samples were taken at different proximities from the modules and then analyzed by inductively coupled plasma optical emission spectrometry (ICP-OES). The conclusion of this study was that **c-Si PV modules while in-service are not harmful to the environment** and any leachate found in soil samples was below the EPA limits [5].

Comparisons

Through comparing PV module leaching to other energy sources and common items we can gain perspective on the impact of the concerns being addressed. The coal mining process for coal fired power plants was found to produce close to 3,000 times more Pb than PV technology mining processes [6]. It was found using the TCLP that automobiles and CdTe modules have concentrations of Cd that are similar in amount, and automobiles have the potential to leach just as much Pb as a c-Si PV module [7]. A major culprit of Pb leachate is personal computer components, they leach 30-100 times above the regulatory limit [12]. The procedures that claim the highest level of heavy metal leachate are the TLCP and SPLP. There is some contention from a study claiming that the TCLP and SPLP are too aggressive of procedures and the results do not represent a realistic condition of the module (samples are pulverized prior to testing) [4]. A more realistic approach to determining the in-service leachate potential for PV modules was conducted, the findings were much lower concentrations of Pb and Cd [4].

Discussion

There are many different concerns at hand here and therefore several mitigation strategies may be employed. Reducing the potential for leachate, immobilizing the heavy metals in the environment that they are leached into, and removing the heavy metals from the fabrication of PV modules are all processes that can be implemented to mitigate these concerns. A study on the weak spots of a module have found that if a module is undamaged and encapsulated it proves no threat to the environment though leaching heavy metals [8]. Steps can be taken to treat the soil below a module to immobilize any leached hazardous metals from endangering the environment. Peat moss can be used to inhibit the mobilization of Pb [9]. Furthermore, Cd mobilization can also be treated in a similar fashion using layered double hydroxides which are prepared from calcinated dolomite [10]. Solder is used in the fabrication of modules and is the major contributor to the Pb leachate of PV modules. Removing Pb from solder is an area of interest across all fields of study. The transition to lead-free solder is underway world-wide [11].

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18.3 APPENDIX C – White Paper on Grid Balancing with Intermittent Renewables

Can The Electric Grid Balance Renewable Energy?

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Richard G. Lugar Center for Renewable Energy, IUPUI

Good Questions Project

December 29, 2022

Introduction

The electric grid is a network through which power is generated, transmitted, and distributed to consumers. After electricity is produced, the voltage is stepped up at a substation and then transmitted long distances through transmission lines (high voltage allows electricity to travel long distance with minimum loss) either overhead or underground and then stepped down at substation to deliver to distribution lines to consumers. The electric grid provides electricity to various consumers including commercial buildings, production plants, schools, offices and residential places [6].

To properly balance electricity supply and demand on the power grid, grid operators must have a sense of how much renewable energy is being generated at any given moment, how much renewable energy generation is expected, and how to respond to changing generation. All this information can be difficult for grid operators to know due to the intermittent nature of renewable power and the wide variety in the size and locations of renewable energy resources across the power grid. As the proportion of renewable energy capacity on the grid grows, these issues are becoming increasingly important to understand [11]. The continuous growth of electricity demands and the global concern for carbon emissions calls for a significant increase of electricity generation from renewable sources. This requires the development of methods that efficiently integrate the renewable energy supplies into the power grid [1].

Energy Resources in Indiana

Figure 1 shows the contribution of renewable energy to Indiana's net electricity generation from 1990 to 2020. The construction of utility-scale wind energy projects beginning in 2008 marked the beginning of a rapid increase in the renewable energy's share of Indiana's electricity generation. The renewable share of annual electricity generation rose from 0.5% in 2007 to 8.2% in 2020. Wind energy has become the dominant source of renewable electricity in Indiana, contributing 85% of the renewable electricity generated in 2020. Solar photovoltaic generation has grown from virtually none in 2011 to approximately 0.4% of Indiana's total net generation in 2020. The contribution of wind energy remained almost same from 1990 till 2007 and gradually increased to 3% in 2013 and kept growing to about 7% in 2020 [2].

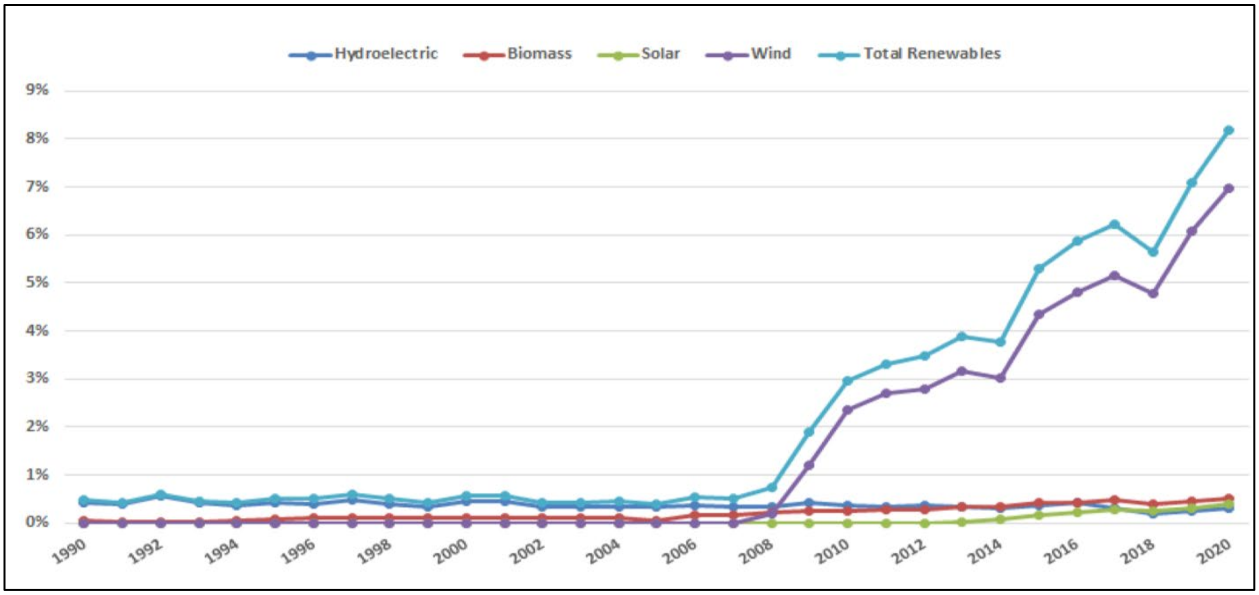

Figure 1:Renewables share of Indiana total energy generation (1990-2020) [2]

Figure 2 shows renewable energy consumption in Indiana from 1960 to 2020. In 1980s, renewable resources contributed over 3% of total energy consumed in Indiana. The expansion in ethanol and wind in the last decade increased renewable resource's share to 7.1% in 2020. With biofuels becoming largest source of renewable energy, supplying 44% of the renewable energy consumed in 2020, followed by wind energy contributing 30%. The share of renewable resources to Indiana's total energy consumption increased from 6.7% in 2019 to 7.1% in 2020 [2].

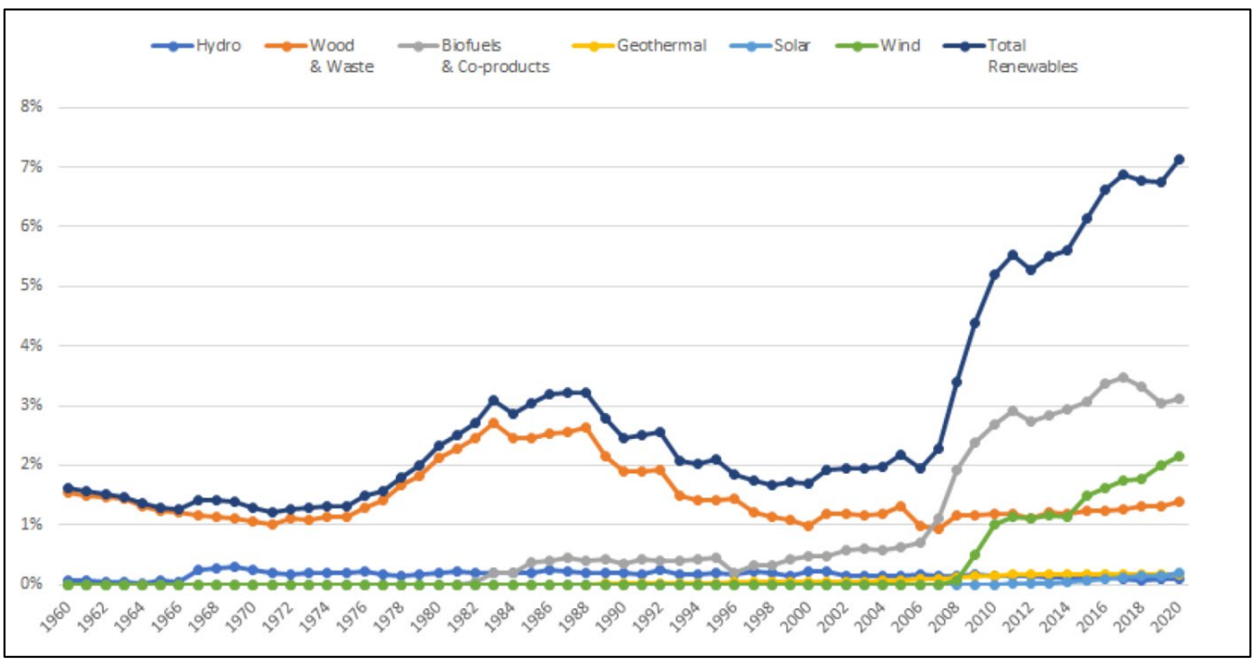

Figure 2:Renewables share of Indiana total energy consumption (1960-2020) [2]

<u>Impacts of Renewables Sources on Electric Grid with Different Penetration Levels</u>

Power grid's stability is defined as the ability of an electric power system, for a given initial operating condition, to regain a state of operating equilibrium after being subjected to a physical disturbance, with most system variables bounded so that practically the entire system remains intact. Power grid stability is classified as: voltage stability, frequency stability, and angular stability [10].

If there is a shortage of reactive power required by load and load increases, voltage will drop. This is most common where there is transmission congestion or high inductive loads. Energy storage can mitigate degraded voltage by supplying continuous reactive power and injecting real power (reactive power is the term used for potential energy within the system, while real power is that which actually drives a load). A sag or interruption in voltage can cause power disturbances that negatively impact power quality. This problem can be more common in distribution systems. Energy storage can mitigate voltage sags by injecting real power for up to a few tens of seconds. This application does not require storage to provide enough power for customers to ride through an outage without loss of power [13].

Spinning reserve uses stored energy to compensate for unexpected contingencies. Spinning reserve specifically refers to storage that can be made immediately available (i.e., with very fast response time). Supplemental reserves and replacement reserves have slower response times and follow sequentially to provide a few hours of reserve power. The power losses decrease with the PV ("Photo-Voltaic") penetration level, if does not exist reverse power flow [13]. This happens because with more PV generation, the more load is supplied locally, and then less power flow circulating along the distribution lines, reducing, consequently, the power losses during the day. Such power reductions, if sudden, can cause grid voltage to rise, possibly damaging appliances and electronics. Power reduction can also happen with a battery, presenting also lower values than when just PV are considered [3]. For about 15% of penetration, storage is optional, while for more than 40% of penetration of intermittent renewable generation sources, grid scale storage is required.

<u>**R**enewable **I**ntegration **I**mpact **A**ssessment by the **M**idcontinent **I**ndependent **S**ystem **O**perator</u>

In 2016, **MISO** launched the **RIIA** study to identify the sub-hourly generation dispatch and inter-regional power flows under 10%, 20% and 30% renewable penetration levels in the Eastern Interconnection. Integration complexity is defined as the ability of the system to meet a renewable integration milestone, while accounting for resource adequacy and ramping, transmission thermal, voltage, and frequency considerations [4].

In figure 3 and 4, the geographic diagram illustrates the study region on a map and shows the output of individual generators and net interchange between regions as directional arcs. The diagram represents generators as circular glyphs, plotted at each generator's location, colored by fuel type, and the area of each glyph sized according to each generator's output at the given timestep [4]. The generation glyphs are semi-transparent to accommodate over-plotting and providing a density visualization of the generation. The glyphs are sorted by curvature, plotting smaller glyphs on larger glyphs to make over-plotted areas easier to read. The diagram represents net interchange with directed arcs, providing a qualitative view of the direction and magnitude of regional power flow.

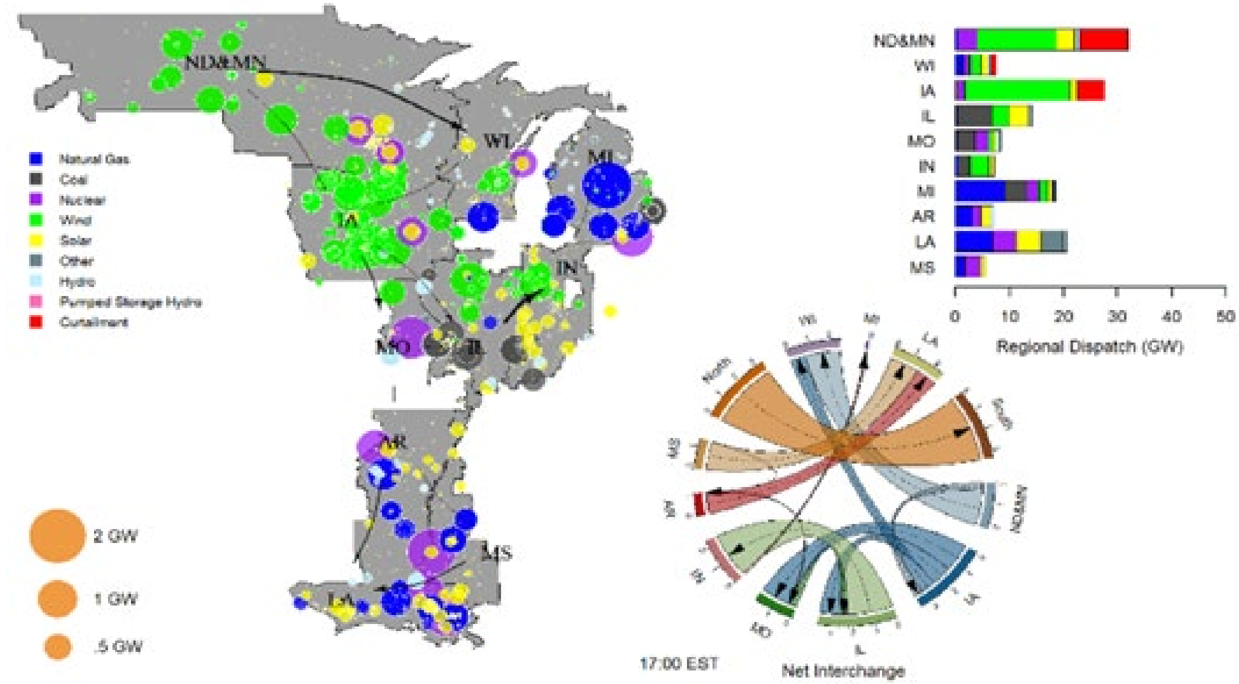

Figure 3: 40% renewable penetration without solutions (red horizontal bars show curtailment) [4]

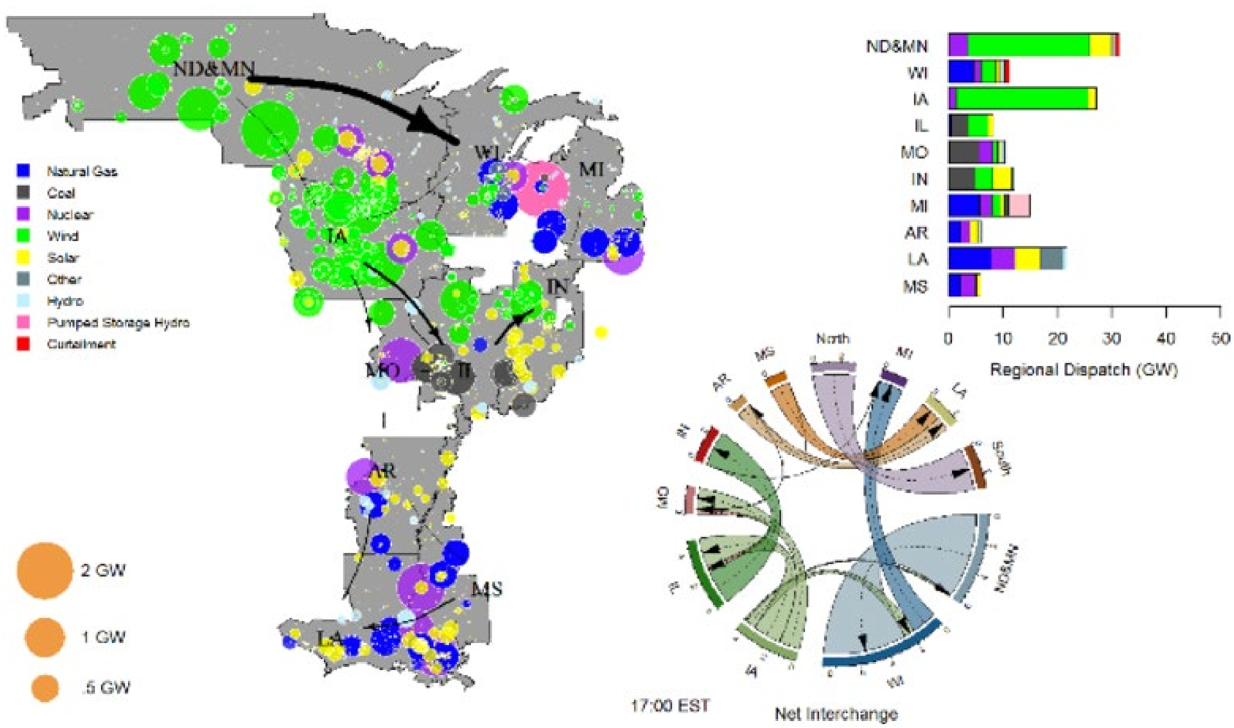

Figure 4: 40% renewable penetration with solutions (less curtailment than fig. 3) [4]

The horizontally stacked bars on the right side further provide direct visualization of wind generation and curtailment at the hour studied. For this snapshot, given the existing system transmission constraints, a notable amount of renewable energy is being curtailed due to inability of the system to deliver zero-marginal cost generation. When the system is unable to deliver low-cost generation, the model needs to commit and dispatch higher-cost generation resources located near the population centers in order to serve load [4].

Transmission Solutions and its Effect on the Enhancement of Resource Deliverability

As renewable integration complexity increases, transmission solutions are needed to increase the deliverability of renewables and are crucial for achieving higher penetration levels (e.g. 30% and above). In the RIIA study, MISO transmission solutions include line upgrades on existing paths, increasing the voltage level of an existing substation, and new line connections.

Fig. 3 and 4 illustrate the effect of transmission solutions on enhancing renewable deliverability. These graphics represent the same operating conditions, whereas the latter is with transmission solutions implemented. By comparing the horizontal bar charts between these two figures, one can easily find that Fig. 4 provides evident visual illustration of the reduction in wind curtailment after including transmission solutions. In Fig. 3 the horizontally stacked red bars on the right side are included to represent the geographical breakdown of renewable curtailments and in fig. 4 the curtailment is reduced for 40% renewable integration with transmission solutions. The power flows on the geo-map further show the relative increase in power flow from renewable hubs to load centers, e.g., from ND and MN to WI as depicted by the thicker black arrow in the geographic visualization and the width of the ribbon in the chord diagram. The transmission solutions identified in this work, using optimization techniques, resulted in a favorable 9% curtailment reduction for MISO (e.g., renewable delivered increased from 34.7% to 38.5% for the 40% milestone) and solved additional complexities related to operating reliability issues (e.g., thermal violations, frequency response, and stability) [4].

The Point at Which Energy Storage is Required for Integrating Renewables

There is a growing interest to become less dependent on fossil fuels and integrating a larger amount of renewable resources for electric power generation, such as wind and solar energy. High penetrations of these renewable resources present technical challenges with regards to power system adequacy, security, and stability [5]. Furthermore, the introduction of bulk energy storage is required to provide isolated systems with high penetrations of renewable energy. Therefore, the size of the renewable resource before energy storage required is dependent on the capacity of the smallest generator to ensure that energy balance and system security are maintained. Renewable energy (RE) resources are non-dispatchable due to their intermittent nature, and battery storage devices (BSDs) play an important role to overcome their inherent variability. Therefore, for optimal operability, BSDs must be appropriately sized. Historical RE generation data can be used for sizing, with the objective to minimize the annualized planning cost [7].

Maintaining energy balance is one of the key technical challenges associated with the implementation of renewable energy. This can be addressed by implementing an Energy Storage System (ESS) when the penetration level is high. The energy balance can be addressed by charging during surplus and discharging in the deficit. The ESS can reduce curtailment and acts as a buffer to decouple the renewable resource from the main power grid, thus reducing the risks associated with high penetration of renewables [5].

Cost of renewable energy production

Figure 5 shows the average construction cost of wind and solar photovoltaic installed in the U.S. from 2013 to 2020. Included also for comparison is the cost of combustion turbine and combined cycle plants installed in the same time period. The cost of PV has dropped by 55% from $3705/kW in 2013 to $1665/kW in 2020. Onshore wind generation capital cost has dropped by 21% in the same time period. The variable operation and maintenance costs for renewable energy generators as wind and solar have a clear advantage because they have no fuel cost, because their fuel is sunlight and wind which are free. [2]

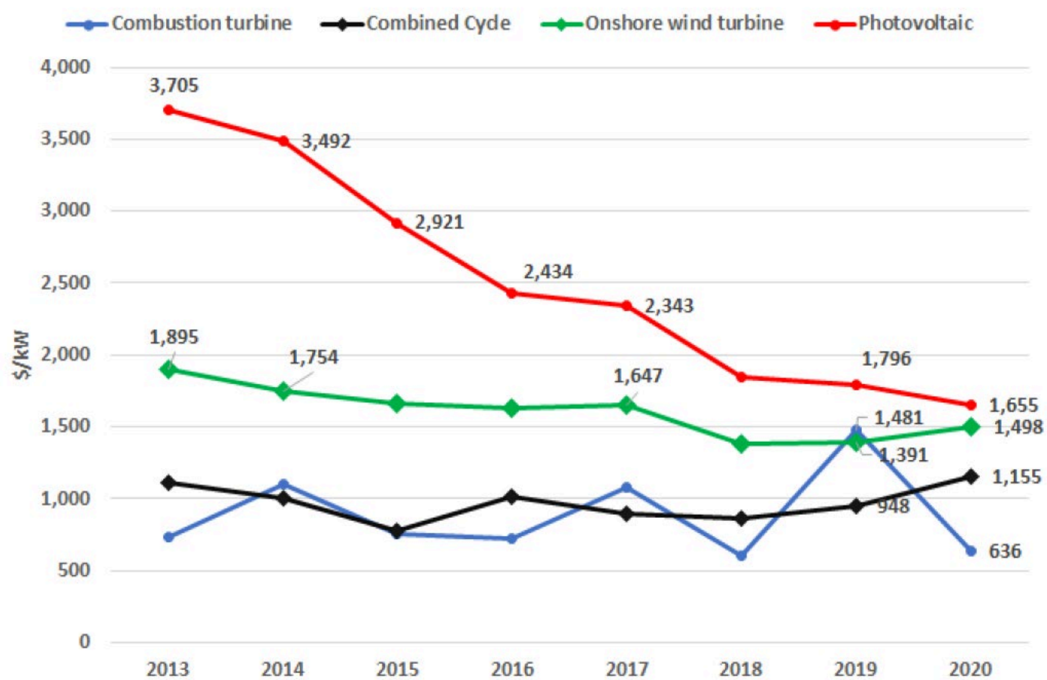

Figure 5: Average construction cost of generation installed in 2013 to 2020 [2]

Levelized cost of new-built solar and wind renewable energy generation technologies compared with marginal cost of selected existing conventional generation are shown in figure 6. It is clear from the figure that levelized cost of solar PV-thin film utility scale is between $28-$37 whereas for coal is between $37-$47.

The average levelized cost of energy for various technologies including utility-scale solar PV, wind, nuclear, coal and gas are compared from the 2009 to 2018 in figure 7. The cost of utility scale solar PV decreases from $359/kWh in 2009 to $442/kWh in 2020 and for wind form $135/kWh in 2009 to $42/kWh in 2018. However, for mature energy resources like coal, where the reduction in production costs went from $111/kWh in 2009 to $102/kWh over the same period.

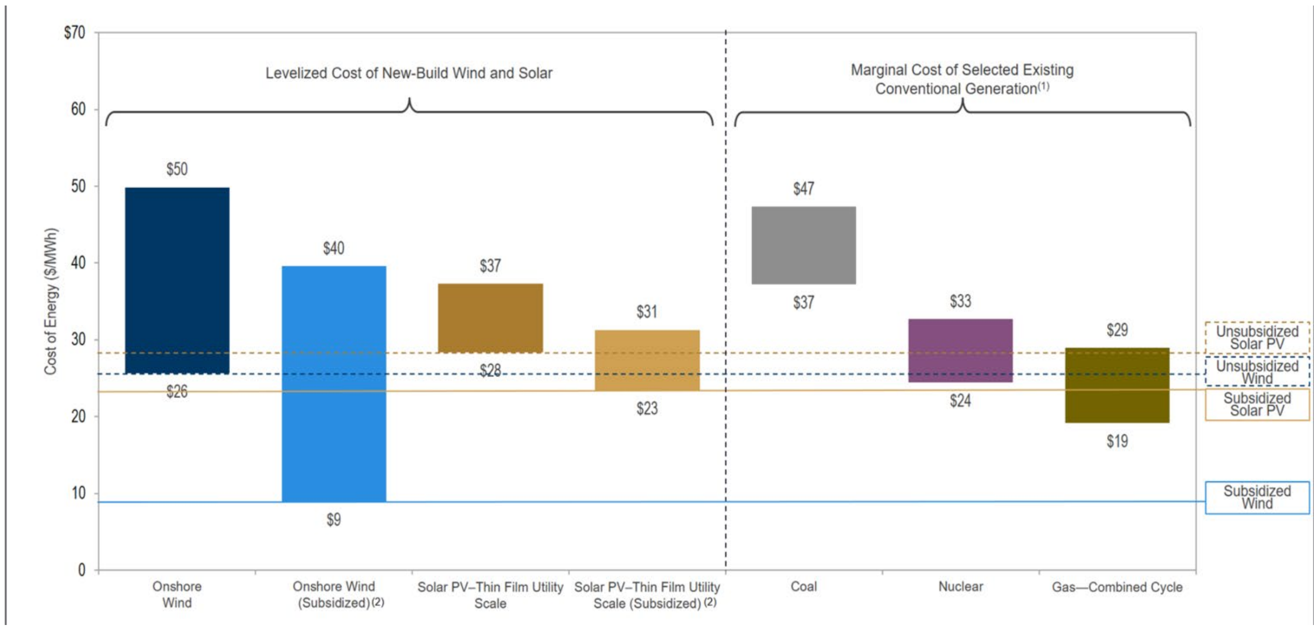

Figure 6: Levelized cost of energy comparison [9]

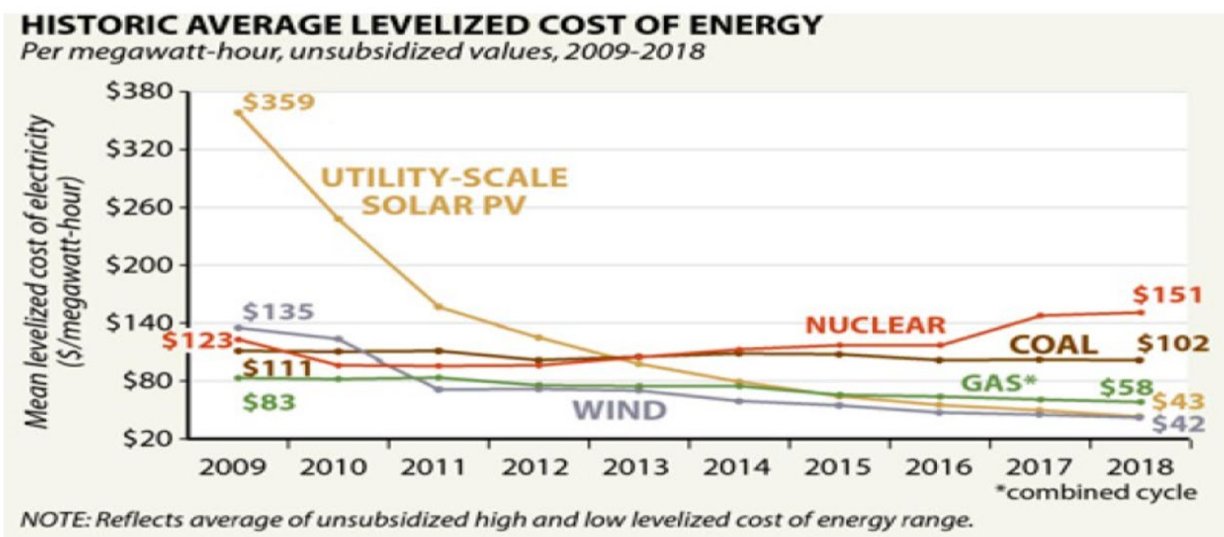

Figure 7: Average levelized cost of energy from 2009 to 2018 [2]

<u>Energy Storage System</u>

Energy storage is essential in enabling the large-scale deployment of renewables, which are in turn needed to support the energy transition. Energy storage can be integrated at different levels of the electricity system, including at transmission and distribution levels. It can provide flexibility and balancing services, frequency control, voltage control in addition to acting as a back-up for variable renewables generation [8]. Energy storage includes a range of technologies, some of which have been utilized for decades across different geographies and markets. Pumped hydro storage is the predominant technology in use and represents over 96% of tracked storage capacity worldwide.

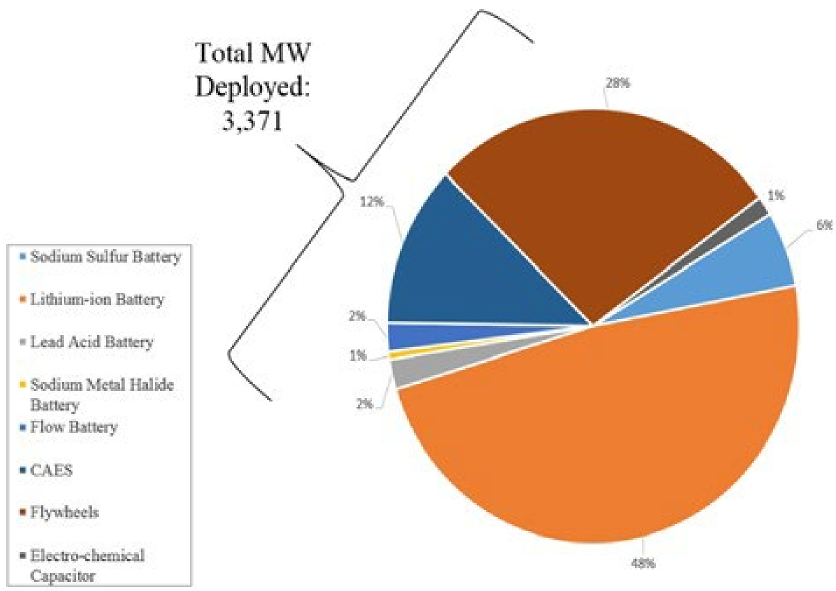

Figure 8: Breakdown of energy storage deployed internationally by technology type and excluding pumped storage hydro [12]

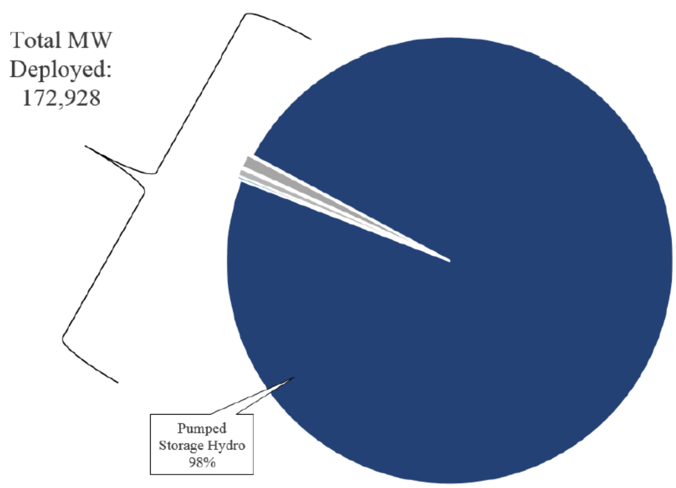

Figure 9: Proportion of megawatts of internationally deployed pumped storage hydro in comparison to other technologies [12]

Load shifting describes the use of energy stored during periods of low demand for periods with high demand. When load is low during the night, excess generation capacity is used to charge energy storage devices. During peak demand hours, stored energy is discharged to augment generation output or transmission and distribution capacity (See Figure 10). This allows generation to be more nearly constant over the course of a 24-hour period and reduces peak capacity needs. Using energy storage to simultaneously fill valleys and lower peaks in the load curve allows utilities to defer capacity upgrades, reduce wear and tear on equipment, and reduce system costs.

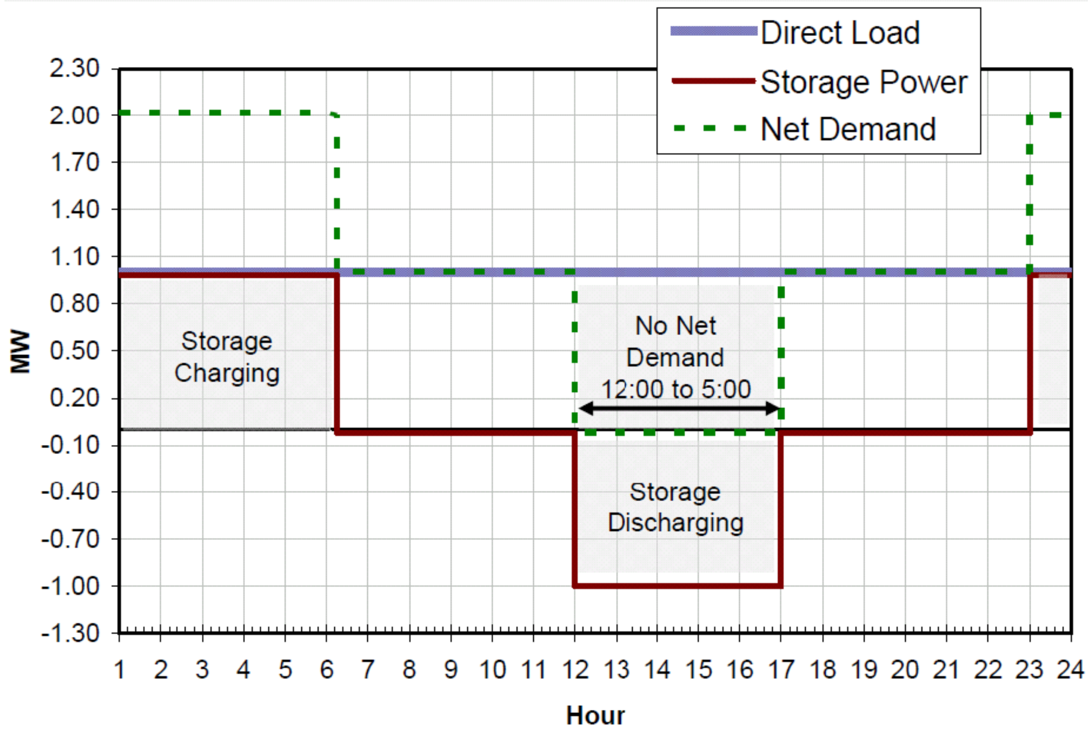

Figure 10: Load Shifting with energy storage [13]

In figure 11, the unsubsidized levelized cost of storage (LCOS) comparison is shown. The cost of storage is for renewable energy produced in front of the meter (energy produced and consumed at same location) when compared to storage for renewable energy produced in behind-the-meter (energy produced at one site and consumed at another site).

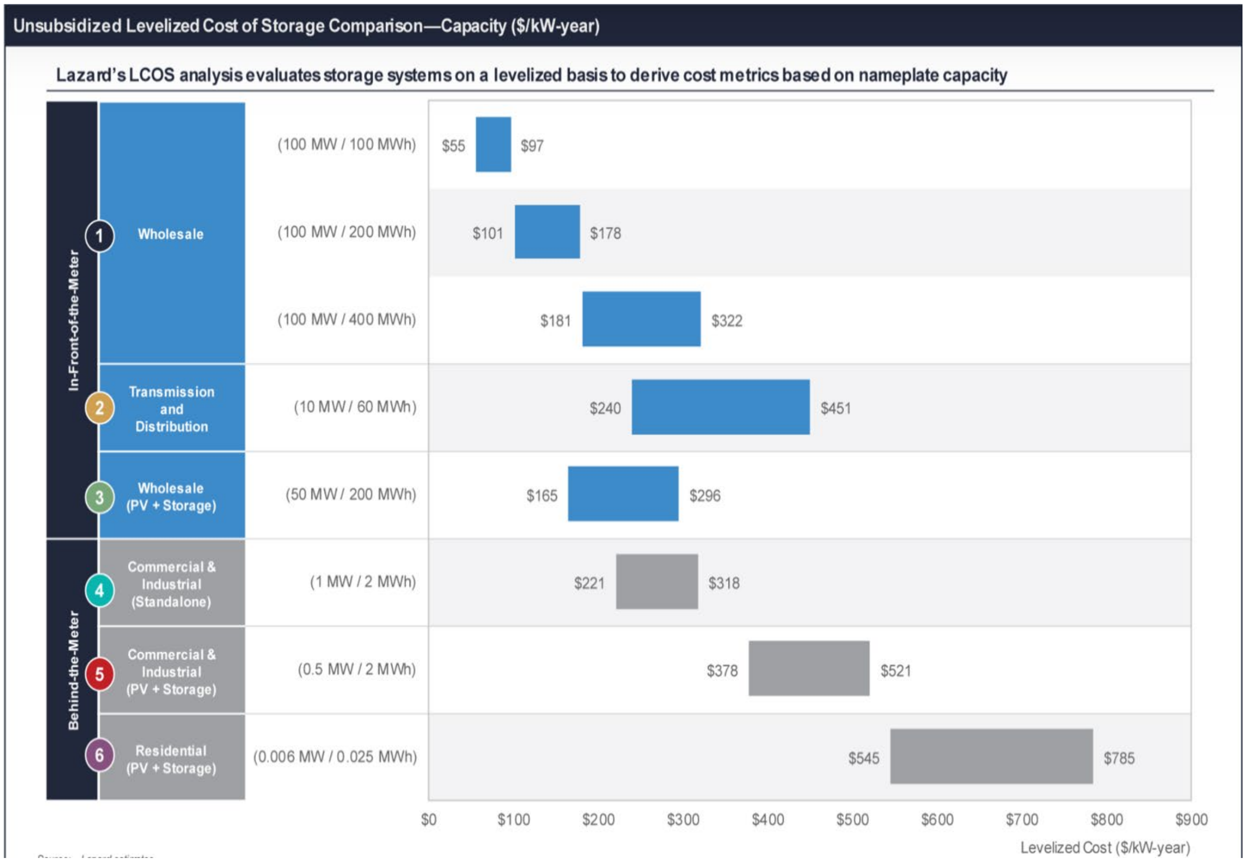

Figure 11: Unsubsidized levelized Cost of Storage Comparison [9]

<u>Pumped Storage Hydropower</u>

Pumped Storage Hydropower (PSH) plants have favorable economics for large-scale energy storage technology. For long-duration storage, PSH and Compressed Air Energy Storge (CAES) give the lowest cost in $/kWh if an Energy to Power (E/P) ratio of 16 hours is used. The metrics are $165/kWh and $104/kWh, respectively, inclusive of Balance of Plant (BOP) and Construction and Commissioning (C&C) costs, while their cost is $660/kWh and $417/kWh, respectively at an E/P ratio of 4 hours. Hence, even at the low E/P ratio of 4 hours, they are competitive with battery storage technologies. Round-trip efficiency is the percentage of electricity put into storage process. When compared to CAES, PSH is a more mature technology with higher rates of round-trip efficiency [12].

Pumped hydroelectric facilities use electricity from the grid during periods of low demand and price to pump water from a lower reservoir to a higher one. That water is then available to generate electricity during high demand and price periods. Due to evaporation and inefficiencies in the pumping and generating processes, less energy is generated than is used. However, the value of the lost energy is more than compensated because low cost, off-peak electricity is converted to high value, on-peak electricity. [2]

In addition to the type of hydropower facility, there are a variety of turbine technologies that are utilized for hydropower production. The type of turbine is chosen based on its particular application and the height of standing water. There are two main groups of turbines used in hydro power projects –impulse and reaction turbine types. The impulse turbine type uses the velocity of the water while the reaction turbine uses both the velocity of the water and the pressure drop as the water passes through the turbine. The impulse turbine is more suited to a high head [14] low flow application while the reaction turbine is more suited to a lower head, faster flow situation [2]

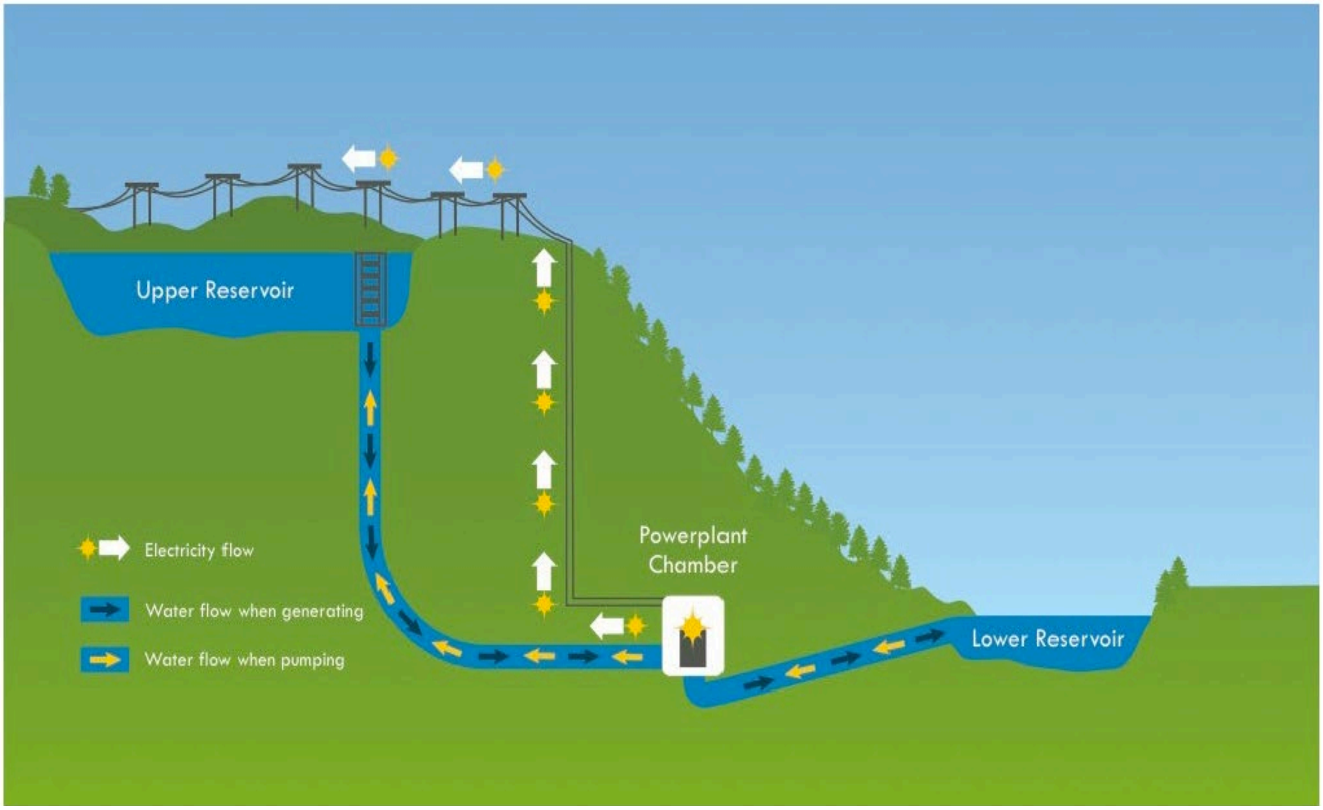

Figure 12: Schematic of a pumped hydro facility [2]

Abandoned mines for underground pumped storage hydropower in Indiana

Indiana has many surface and underground coal mines that are no longer active. According to the Indiana Department of Natural Resources (DNR) there are 701 underground mines in Indiana that are no longer active. Figure 10 shows the location of these mines in blue. [2]

Each of these mines have the potential to host an underground pumped storage hydropower (PSH) ESS facility. Further investigation would need to be done on the suitability of each individual mine, including the condition of the chambers, the depth, the location relative to transmission lines, etc.

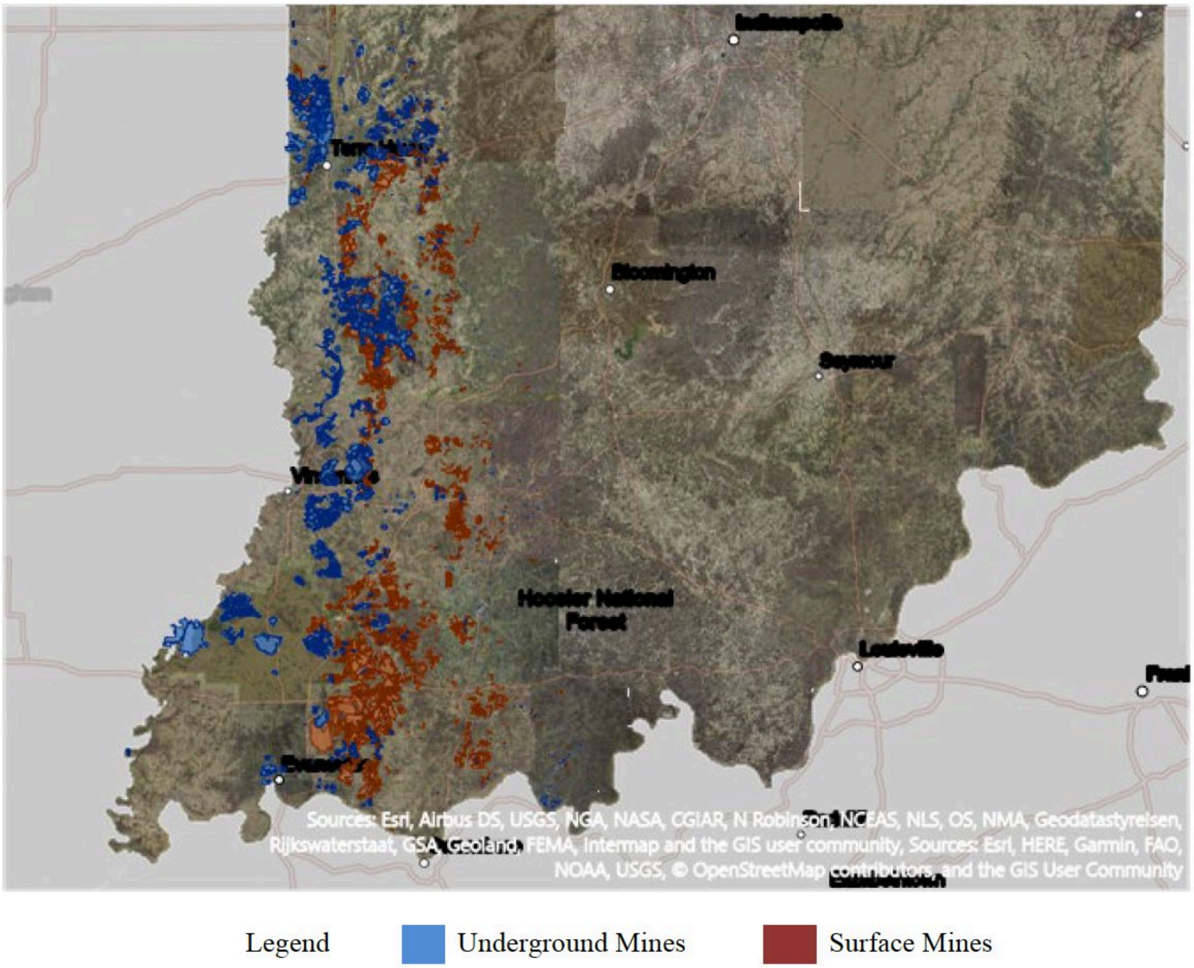

Figure 13: Location of abandoned mine sites in Indiana [2]

<u>Conclusion</u>

Generating electricity using renewable energy resources (such as solar, wind, geothermal, and hydroelectric energy) rather than fossil fuels (coal, oil, and natural gas) reduces greenhouse gas emissions from the power sector and helps address climate change. While renewables are preferable to fossil fuel generators from an emissions standpoint, power output from renewable sources depends on variable natural resources, which makes these plants more difficult to control and presents challenges for grid operators.

To accommodate a penetration of variable renewable energy above about 15%, the modern grid will require more flexibility on both the electricity supply and demand sides. Different methods to increase grid flexibility and improve the integration of renewable resources analyzed in this paper are: Energy storage; and Transmission Solutions. Energy storage can be paired with variable renewables to accommodate fluctuations in renewable generation over the course of the day or several days. Electricity can be stored during times of high generation (for solar, during sunny days; for wind, during times of high wind speeds) for later use during periods of high demand. Building more transmission lines to connect areas endowed with plentiful renewable resources (e.g., very sunny or windy areas) with areas of high electricity demand can increase the value of renewable resources and reduce uncertainties of their electricity generation. For example, building solar plants in deserts that get sunshine most of the year can reduce weather-dependent uncertainty associated with the system's production.

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A two-page Info Card on this topic is presented in the next two pages.

Can The Electric Grid Balance Renewable Energy?

The electric grid can easily balance lower levels of about 5% of renewables. To accommodate a penetration of variable renewable energy above about 15%, the modern grid will require more flexibility on both the electricity supply and demand sides. Different methods are used to increase grid flexibility and improve the integration of renewable resources, including: energy storage, curtailment, and transmission solutions.

There is a growing interest to become less dependent on fossil fuels and integrating a larger amount of renewable resources for electric power generation, such as wind and solar energy. High penetrations of these renewable resources present technical challenges with regards to power system adequacy, security, and stability. Furthermore, the introduction of bulk energy storage is required to provide isolated systems with high penetrations of renewable energy.

The electric grid is a network through which power is generated, transmitted, and distributed to consumers. Power grid's stability is defined as the ability of an electric power system, for a given initial operating condition, to regain a state of operating equilibrium after being subjected to a physical disturbance, with most system variables bounded so that practically the entire system remains intact.

To accommodate a penetration of variable renewable energy above about 15%, the modern grid will require more flexibility on both the electricity supply and demand sides. Different methods to increase grid flexibility and improve the integration of renewable resources analyzed in this paper are Energy storage, Curtailment and Transmission Solutions. Energy storage can be paired with variable renewables to accommodate fluctuations in renewable generation over the course of the day or several days.

Electricity can be stored during times of high generation (for solar, during sunny days; for wind, during times of high wind speeds) for later use during periods of high demand. Building more transmission lines to connect areas endowed with plentiful renewable resources (e.g., very sunny or windy areas) with areas of high electricity demand can increase the value of renewable resources and reduce uncertainties of their electricity generation.

Maintaining energy balance is one of the key technical challenges associated with the implementation of renewable energy. This can be addressed by implementing an Energy Storage System (ESS) when the penetration level is high. The energy balance can be addressed by charging during surplus and discharging in the deficit. The ESS can reduce curtailment and acts as a buffer to decouple the renewable resource from the main power grid, thus reducing the risks associated with high penetration of renewables.

Energy storage is essential in enabling the large-scale deployment of renewables, which are in turn needed to support the energy transition. Energy storage can be integrated at different levels of the electricity system, including at transmission and distribution levels. It can provide flexibility and balancing services, frequency control, voltage control in addition to acting as a back-up for variable renewables generation. Energy storage includes a range of technologies, some of which have been utilized for decades across different geographies and markets. Pumped hydro storage is the predominant technology in use and represents over 96% of tracked storage capacity in the US.

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18.4 APPENDIX D – Pitch Deck for Sun Melon Agrivoltaics Project

The spreadsheet below is the financial pro forma for a combined PV and watermelon farm. This includes reduction in yield from the dual operation. The result shows a $93,000 benefit to the farmer with this agrivoltaic project. The business pitch deck follows on subsequent pages.

Description	Value	Unit	Comments
price of watermelons	$11.70	$ /CWT	nasa.usda.gov reports $11.70 per CWT; Reports 370 CWT per acre
Yield per acre	370	CWT/acre	
(Yield /Acre in CWT) * (Price/CWT)	$4,329	$/acre-year	
Agrivoltaic yield reduction	80%	percent	80% yield was taken from Fraunhofer study
Yearly watermelon Gross Profit if grown with PV	$3,463	$ /acre-year	(Yield /Acre in CWT) * (Price/CWT) * (.8)
$ Value that Solar PV needs to provide in order match a field that is only made of watermelons	$866		(Gross profit of an acre of only watermelons) - (Gross Profit if grown with PV)
Single-axis tracking commercial PV production	315	MWhr/acre-year	Median value from 4 sources (see comments in cell)
Photovoltaic production reduction	80%	percent	Guess, based on possibly wider gaps between rows, etc.
Wholesale price of electricity	35	$/MWh	Does not include federal tax crecits
Profit from PV only	$ 8,820	$/acre-year	
Total revenue per acre - Watermelon Agrivoltaics	12,283	$/acre-year	Agrivoltaic yearly revenue - compare to watermelon only
Revenue percentage increase over crop only	284%		This profit can be used to pay down the solar panels
Cost to install MW-class solar farm	1,090,000	$/MW	Installation costs - median value
MW per acre	0.133	MW/acre	median value (ranges from 5-10 acres/MW)
Capital costs for PV	$ 145,333	$	up-front costs
Time to recoup investment (while still enjoying same revenue as with crop only)	**$ 18.27**	**years**	Even drawing the same revenue per acre as watermelon alone, the PV will pay for itself in less than 20 years
Lifetime of PV	30	years	Typical
Lifetime surplus profit (above crop revenue)	**$ 93,293**	**$**	At the end of the PV lifetime, this is the extra profit, above and beyond the revenues from growing watermelons alone

The Sun Melon

What is the Sun Melon?

- The Sun Melon is a watermelon grown alongside solar panels
- Its purpose is to give farmers a profitable and sustainable crop that provides income year-round.
- Farmers have two crops: watermelons and electrons.

Design

- Watermelons planted around solar panels.

https://insolight.ch/wp-content/uploads/2020/05/agrovoltaics-optm.jpg

FMEA

SUN MELON FMEA

Function/ Process Step	Potential Failure Mode	Potential Failure Effects	Severity	Potential Causes of Failure	Occurrence	Current Controls	Detection	RPN	Actions Recommended
PV Installation	Loose Connections	Fire	10	Improper crimping	2	Manual inspection	2	40	Having a professional installer that is aware and follows industry standards mitigates if not prevents loose connections from happening.
				Cross mating	1	Manual inspection	1	10	
		Reduced electricity generated	3	Improper crimping	2	Manual inspection	2	12	
				Cross mating	1	Manual inspection	1		
		Shock Hazard	10	Improper crimping	2	Manual inspection	2	40	
				Cross mating	1	Manual inspection	1	10	
PV Operation	Damaged components	Fire	10	Machinery accident	3	Manual inspection	1	30	Make sure that there is enough space around solar panels to allow machinery to move
				Low quality components	2	Manual inspection	2	40	A professional installer that follows industry standards will push for quality components
		Power Loss	5	Machinery accident	3	Manual inspection	1	15	Make sure that there is enough space around solar panels to allow machinery to move
				Low quality components	2	Manual inspection	2	20	A professional installer that follows industry standards will push for quality components
		Shock Hazard	10	Machinery accident	3	Manual inspection	1	30	Make sure that there is enough space around solar panels to allow machinery to move
				Low quality components	2	Manual inspection	2	40	A professional installer that follows industry standards will push for quality components
	Loose Connections	Fire	10	Machinery accident	3	Manual inspection	1	30	Make sure that there is enough space around solar panels to allow machinery to move
				Low quality components	2	Manual inspection	2	40	A professional installer that follows industry standards will push for quality components
		Power Loss	3	Machinery accident	3	Manual inspection	1	9	Make sure that there is enough space around solar panels to allow machinery to move
				Low quality components	2	Manual inspection	2	12	A professional installer that follows industry standards will push for quality components
		Shock Hazard	10	Machinery accident	3	Manual inspection	1	30	Make sure that there is enough space around solar panels to allow machinery to move
				Low quality components	2	Manual inspection	2	2	A professional installer that follows industry standards will push for quality components

Target Market

Indiana watermelon farmers

Watermelon festival organizers: To promote the Sun Melon

Intellectual Property

- **American Sunmelon**: A tradename filed with the United States Patent and Trademark Office (USPT) Sept. 19, 1989. It is currently a dead trademark


Competition
Watermelon farmers
Food Distribution Companies


Product Goals
Profitable: Costs &Profit
Sustainable: Green Effects
Marketable: Organic Tactic

Costs

- Solar PV Installation
- Nonresidential solar system costs $1.36 per watt.

Average solar panel cost by system size in Indiana

System Size	System Cost	System Cost (after ITC)
3 kW	$10,410	$7,703
4 kW	$13,880	$10,271
5 kW	$17,350	$12,839
6 kW	$20,820	$15,407
7 kW	$24,290	$17,975
8 kW	$27,760	$20,542
9 kW	$31,230	$23,110
10 kW	$34,700	$25,678

Cost Mitigation

- **Indiana Property Tax Benefits:** For a solar energy system: “the deduction equals the out-of-pocket expenditures for the components and the labor involved in installing the components”

- **State Grants:**
  - The Rural Energy Innovation Grant Program (status-closed)
  - High Energy Cost Grant (status-closed)

- **Federal Grants:**
  - Federal State Marketing Improvement Program
  - Specialty Crop Block Grant Program
  - Federal State Marketing Improvement Program
  - Rural Energy for America Program (REAP) grant

- **Farm Service Agency (FSA) Loans**

Loans

- Farm Service Agency (FSA) Loans
- Rural Energy for America Program Renewable Energy Systems & Energy Efficiency Improvement Guaranteed Loans & Grants

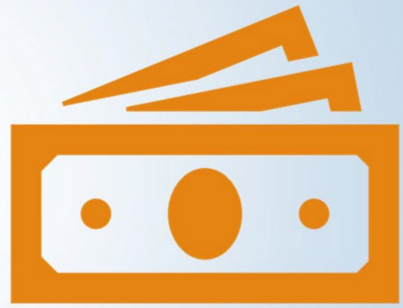
Profit

- ROI
- Payback periods

ROI & Payback period

- A 5kW system in Indiana
  - Payback period of 12.79 years
  - The 20-yr savings is $19,717

- The average ROI for a traditional solar farm is between 10 to 20%. Most solar farms pay off their system within five to ten years, and then have at least 30 years of free electricity after that.



Sustainability

- How it interacts with pesticides?
- Reduces carbon footprint
- Shades plants from sweltering heat
- Reduces transpiration to keep soil moist
- Maximizes land usage

Marketability

- Sun Melon brand
- Organic Tactic: Since it's renewably and sustainably grown, you can charge more.
- A sustainable option to watermelons is appealing
- Agrovoltaics gives it a unique marketing angle to separate it from regular watermelons.

Networking

- Personally reach out to local farmers
- Melon Festival organizers

References

- Solar panel PNG (pngimg.com)
- Watermelon clipart 20 free Cliparts | Download images on Clipground 2022
- Product – Insolight
- https://www.seia.org/research-resources/solar-market-insight-report-2020- q2
- https://www.solarreviews.com/blog/what-is-a-solar-farm-do-i-need-one#:~:text=Solar%20farm%20installation%20costs%20are,between%20%24890%2C000%20and%20%241.01%20million.
- https://www.energysage.com/local-data/solar-panel-cost/in/
- https://leverage.com/financing/solar-farm-return-on-investment/

18.5 APPENDIX E – Pitch Deck for Sillycone Bunny Ranch

A field-trip destination concept to teach children about solar panels and electricity has a funny name. Solar panels, or photovoltaics, are most often made from the element silicon, pronounced "SILL-ih-con" (short O sound). Many non-technical people mis-pronounce this word, conflating it with the much more familiar term silicon**e** (with an 'e'). Silicone is the clear goop used in body implants, and is pronounced with a long O: "SILL-ih-c**o**ne". We avoid this confusion with a name designed to be more memorable for young people.

The financial pro forma for Sillycone re-uses the same PV portion as the Sun Melon concept in the prior appendix. Added are the costs for rabbits and their hutches, the drinks and food offered, the merchandise and swag for sale, and the electricity-related hands-on technology of a Jacob's Ladder (rising, lengthening electric spark), Plasma Globe (tendrils of lightning inside a glass sphere), van de Graaf accelerator (makes long hair stand on end), and a Tesla Coil music maker. Revenues are generated by admission fees, which rise with age, feeding tickets, plus sale of food and merch. The spreadsheet below summarizes the financials for Years 1 and 2, and assumes that subsequent years are identical to Year 2.

Sillycone Bunny Ranch Yearly Profitability			
	Based on : Est. (150 adults, 100 teens, 175 kids) / yr		
YEAR 1	**Totals**		**Notes**
Total Cost/yr	$	33,128.50	Sum of total costs; **startup Cost**
Total Net Profit/yr	$	13,412.50	Sum of net profits
YEAR 2	**Totals**		
Total Cost/yr	$	31,139.07	Sum of 2nd year total costs; yearly cost going forward
Total Net Profit/yr	**$**	**19,119.93**	Sum of 2nd year net profits; yearly net profit going forward

One can see that it does not require a large number of yellow school busses to make a small profit when this petting farm learning center also includes PV. Larger profits can obviously be realized with greater attendance, so that, as word spreads among teachers and principals, a Sillycone Bunny Ranch could become a going concern generating a living wage. Other examples of combining PV with animals may be emulated from this example, and provide a way to educate our young students of the value of solar energy in a memorable way.

A pitch deck suitable for a business plan competition is presented in the following pages.


Sillycone
Bunny
Ranch


What is Sillycone Bunny Ranch?
A local attraction where people can pet bunnies and experience electrical entertainment
Petting area
Electrical venues
Food & Drinks

Intellectual Property

- Sillycone Bunny Ranch has not been trademarked.
- USPTO has a dead Sillycone trademark and live a live Bunny Ranch trademark.
- The live Bunny Ranch trademark is for escort services.

Competition

- Zoos
- Pet shops
- Orchards
- Animal Farms
- Local Attractions

Petting zoo

Entry Fee:

$10-Adults (18+)

$7.50-Teens (13-17)

$5.00 Kids(3-12)

Free-(2 & under)

Pay to feed animals ($1)


Electrical Venues
Vaan de graaf generator
Plasma Globes
Jacobs Ladder
Tesla coil music ($2/song)


Merchandise
Apparel
Souvenirs


Hop-Corn
Cotton-Tails
Sandwiches
Silly-Cones
Lemonade
Water
Food & Drinks


Costs: Equipment & Supplies (exclusive of PV)
Year 1: $33,000
Year 2: $31,00
Food: $19,500
Merchandise:$2,500

Cost Mitigation & Startup

- Grants:
- USA Grant Applications
- FHLBI | Elevate (Small Business Grant)
- The Amber Grant | Grants for Women in Business | WomensNet (ambergrantsforwomen.com)

- Loans:
- 7(a) Small Business Loan | GovLoans
- Lending - Indy Chamber

- Crowdfunding

Net Profit (exclusive of PV)

- Yearly est: 425 people (150 adults, 100 teens, 75 children)
- Year 1: $13,400
- Year 2: $15,000
- Food: $12,000

Marketing

- Field Trip
- Birthday Parties
- Mascot: Sunny the Bunny

Holiday Specialization

- Christmas (Lights)
- Easter (Chocolate Bunnies)
- Halloween(Lights)

18.6 APPENDIX F – Methodology for Mapping Tool

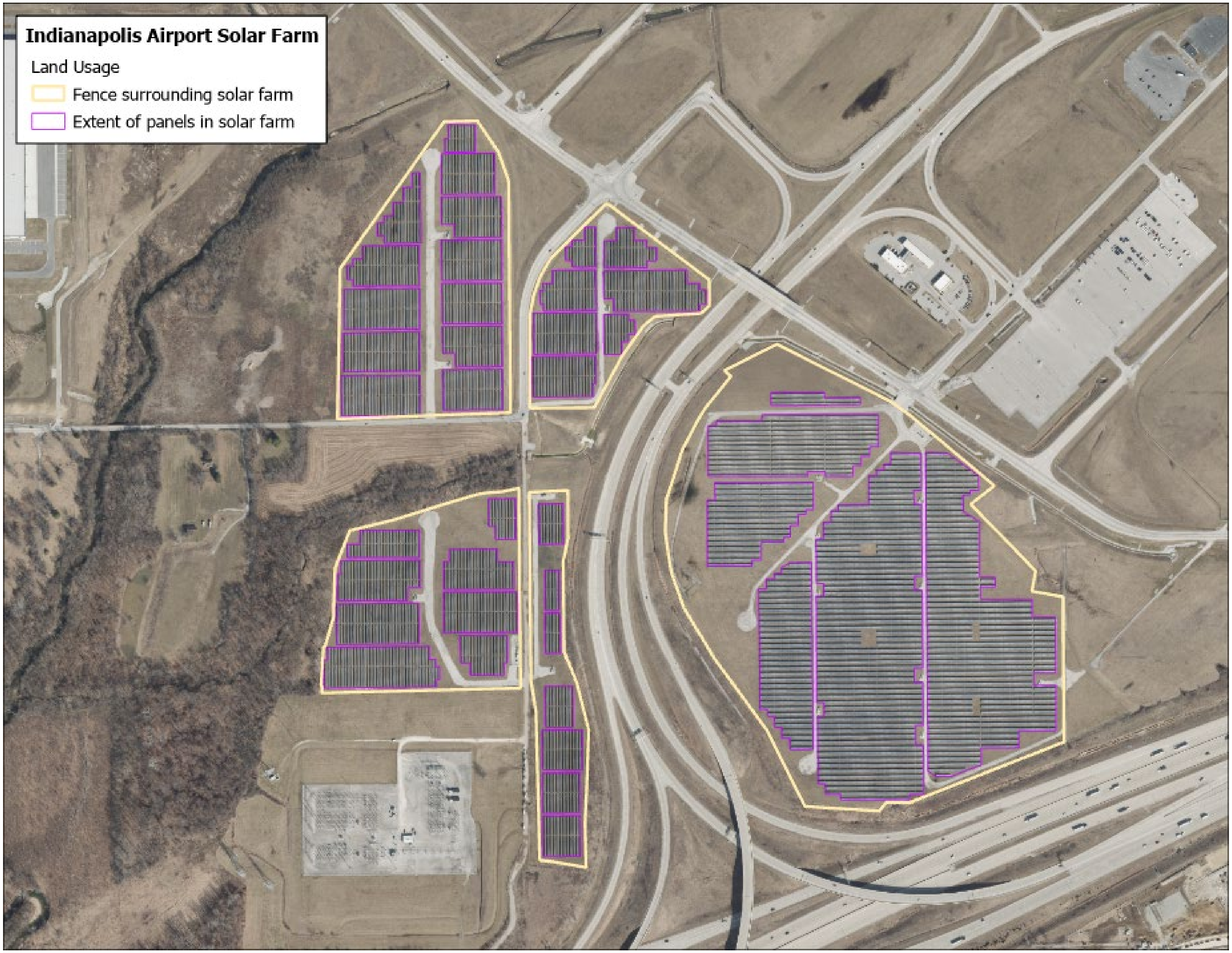


Figure 1. Indianapolis Airport Solar Farm

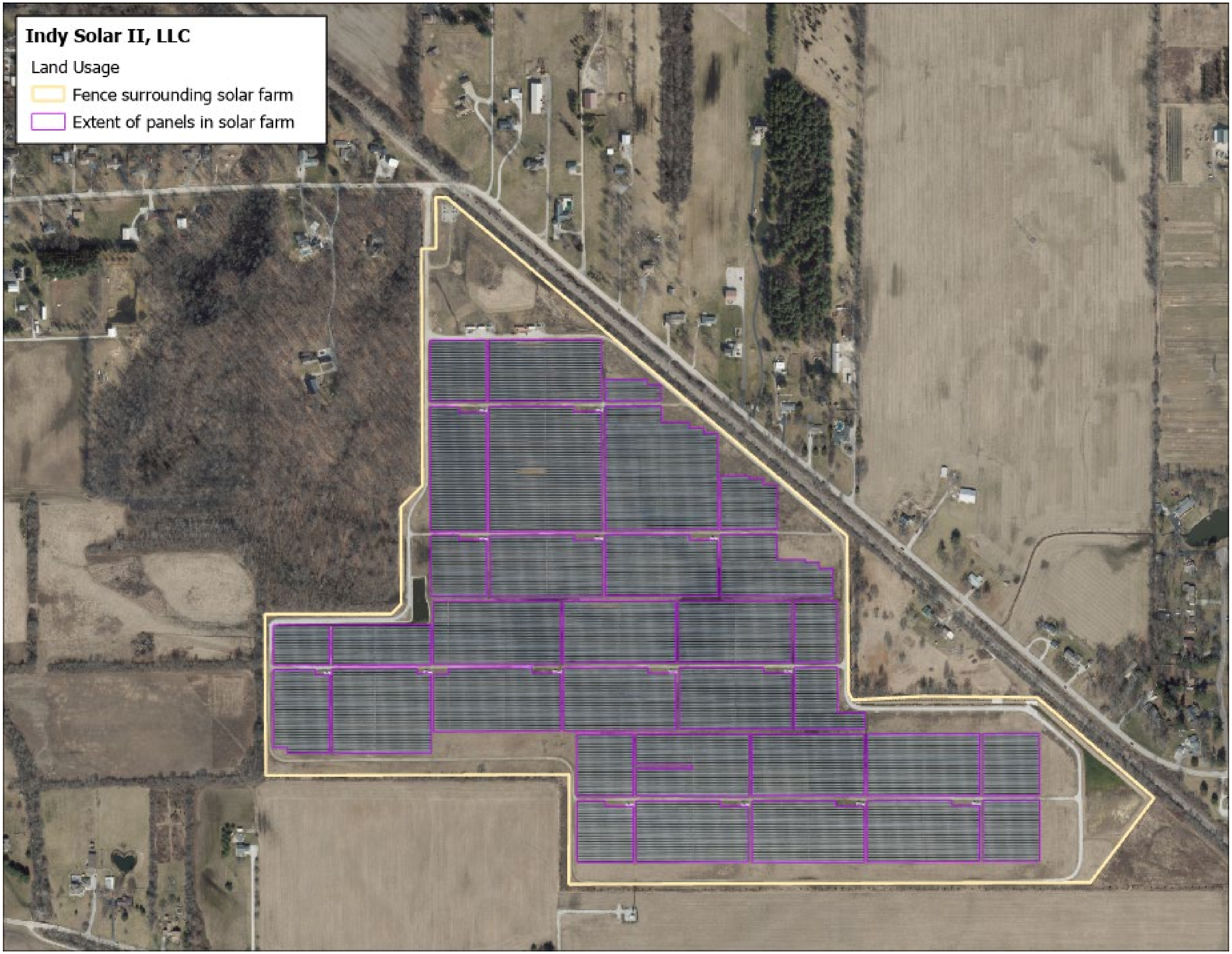


Figure 2. Indy Solar II, LLC

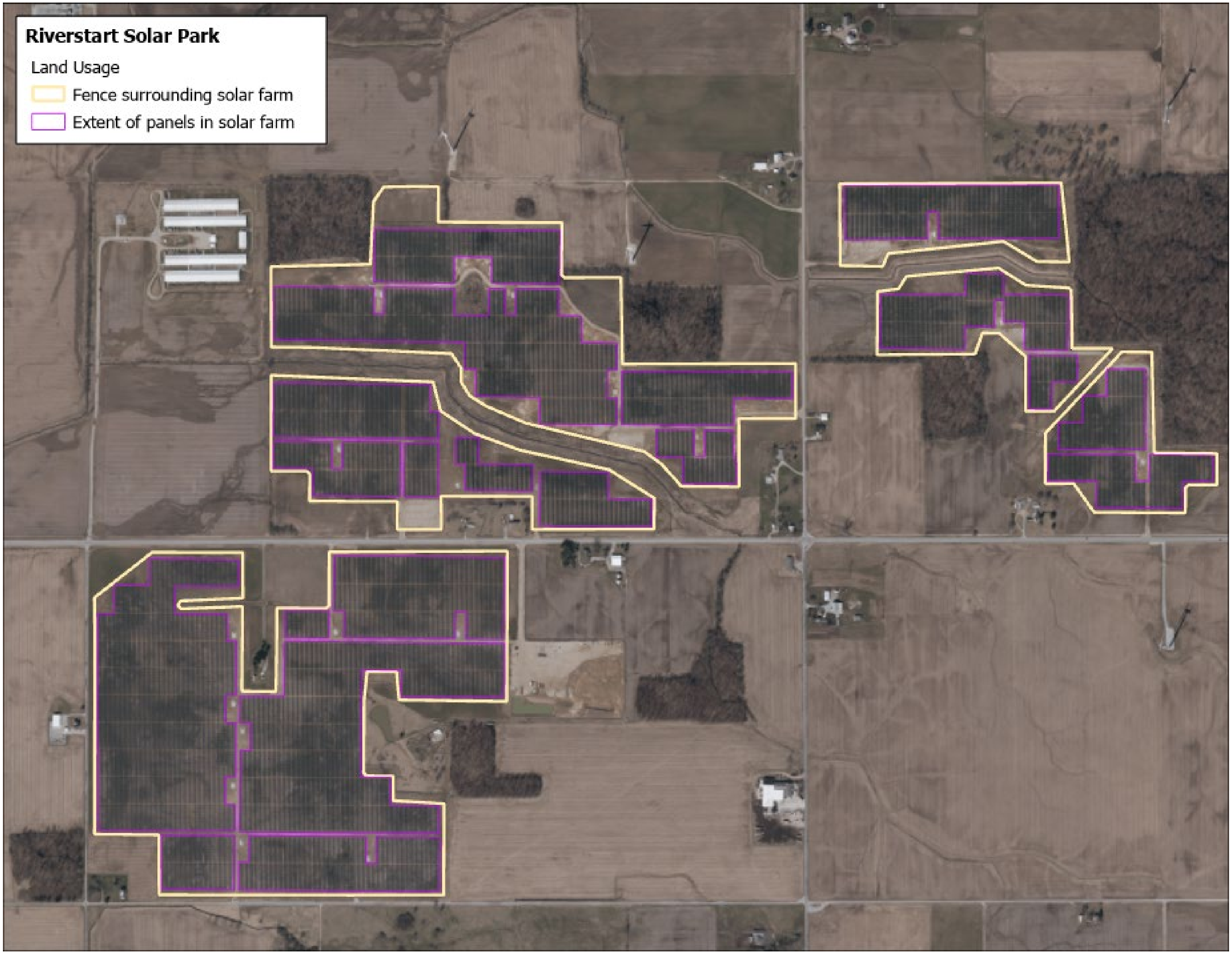


Figure 3. Riverstart Solar Park

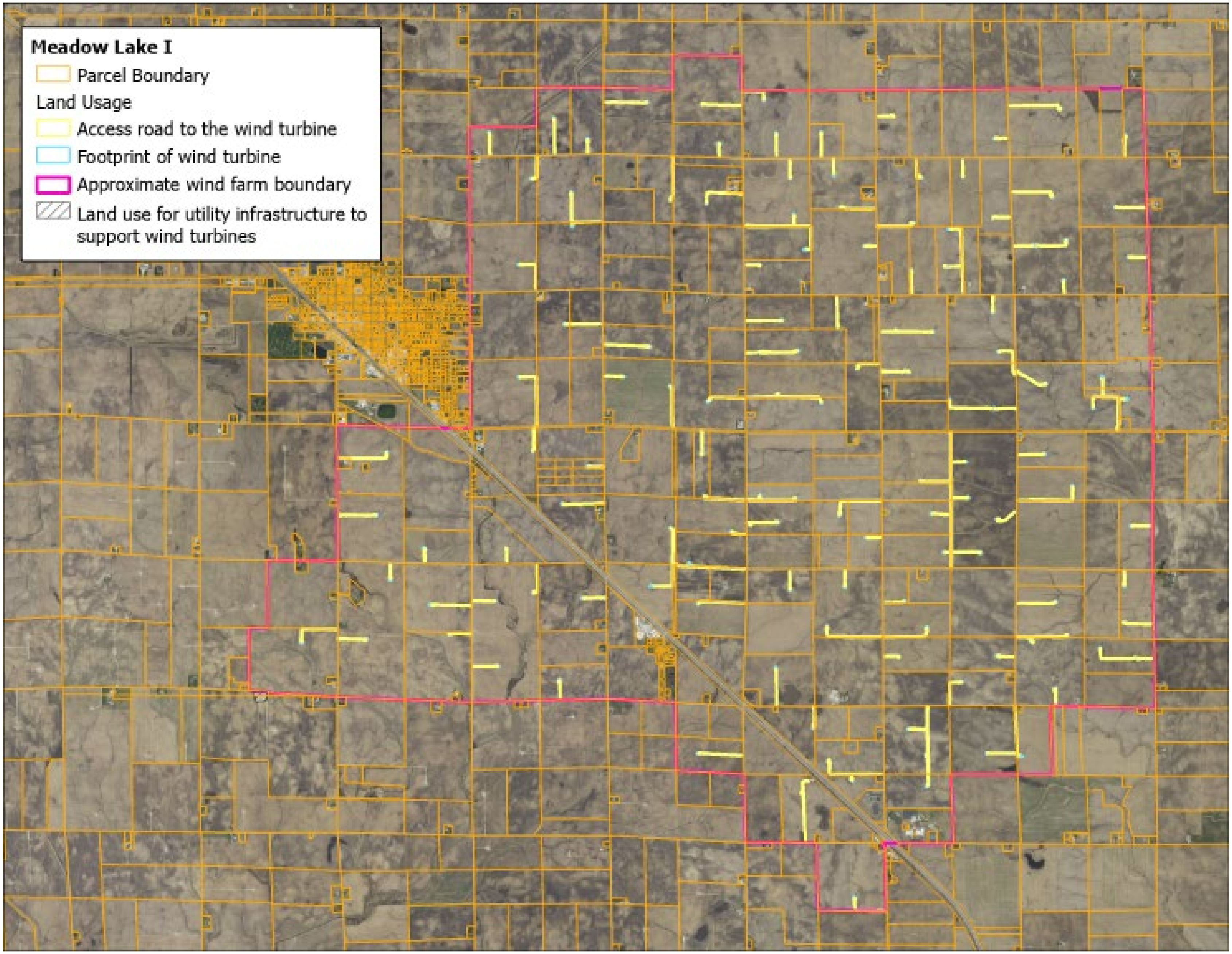


Figure 4. Fowler Ridge I

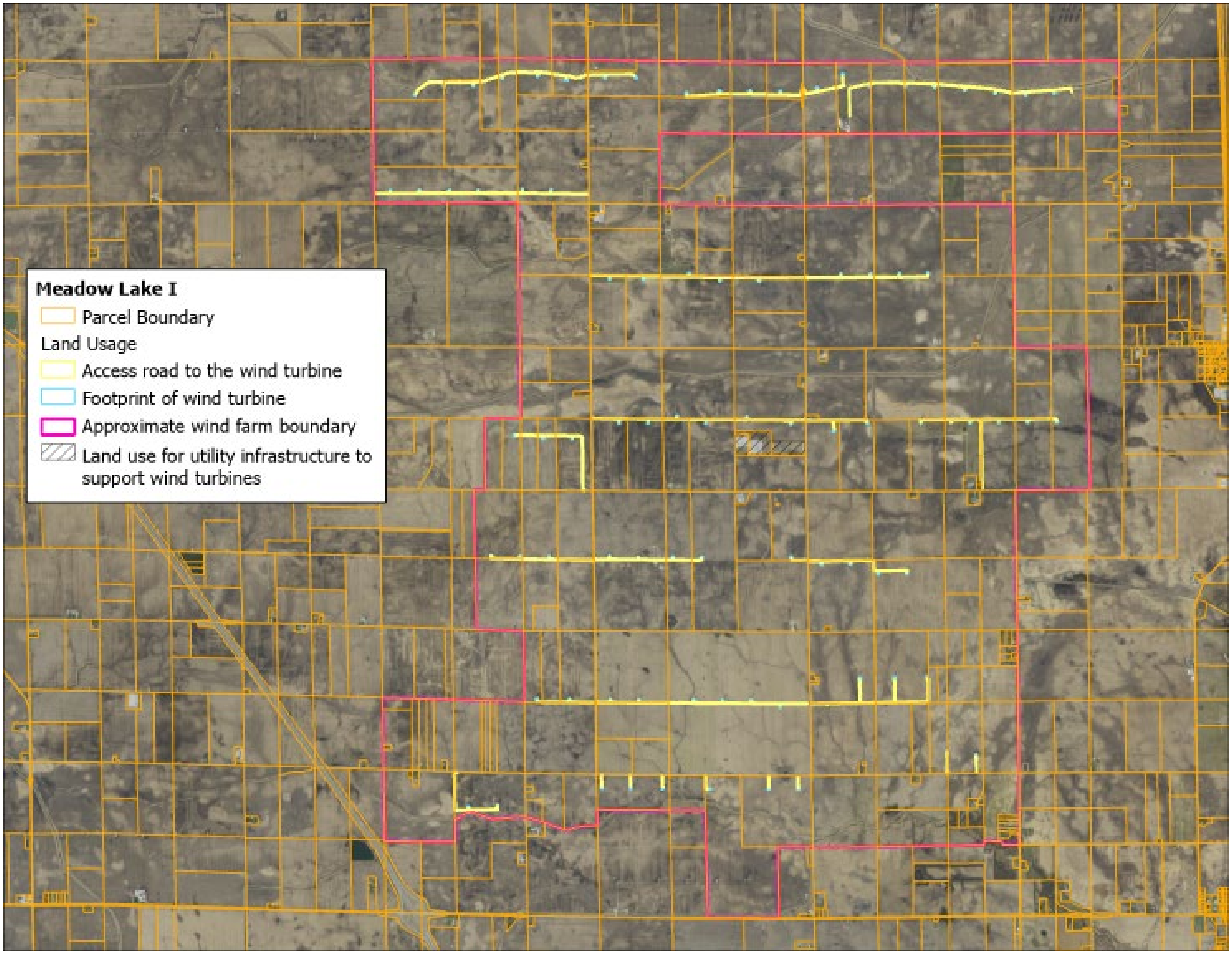


Figure 5. Meadow Lake I

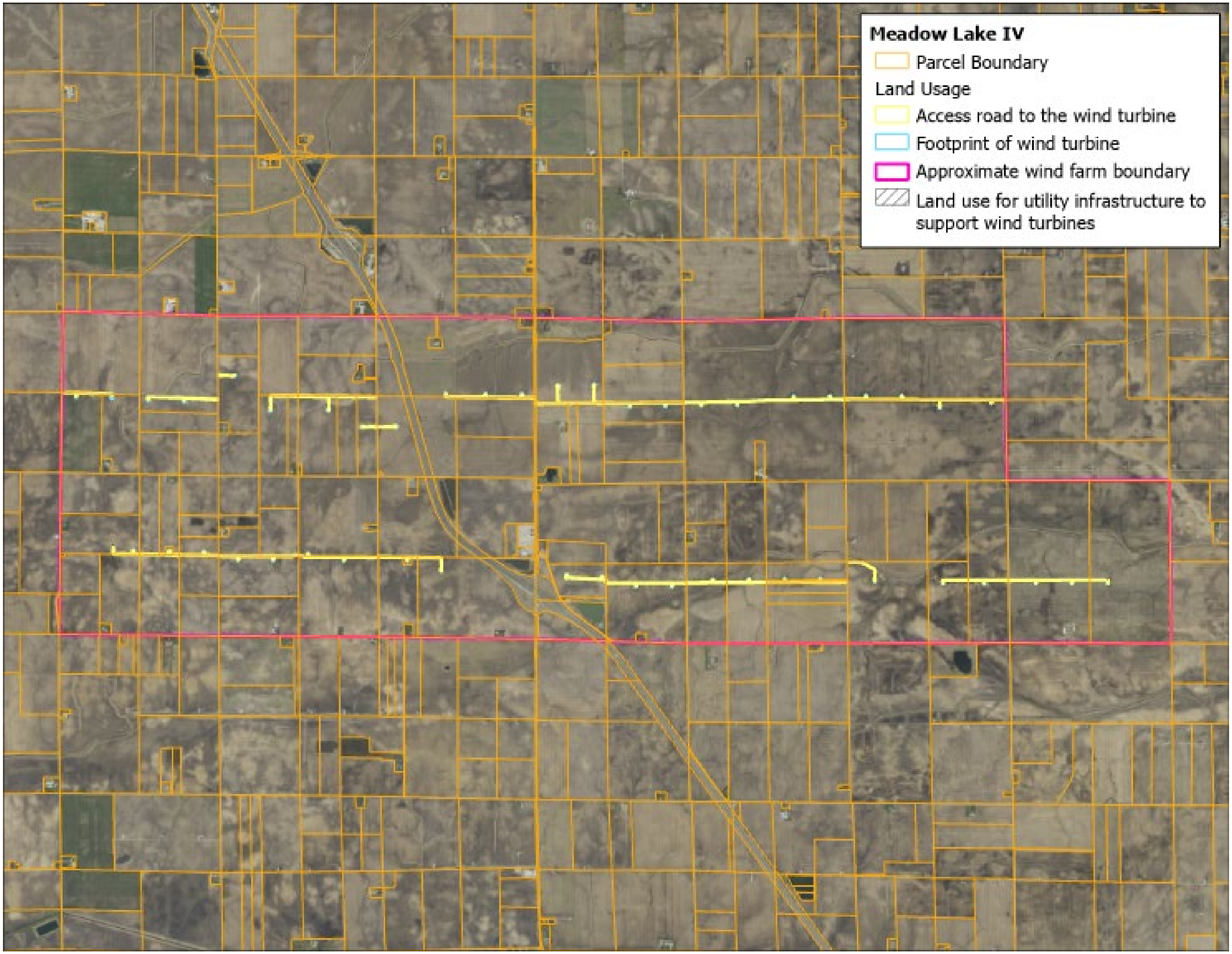


Figure 6. Meadow Lake IV

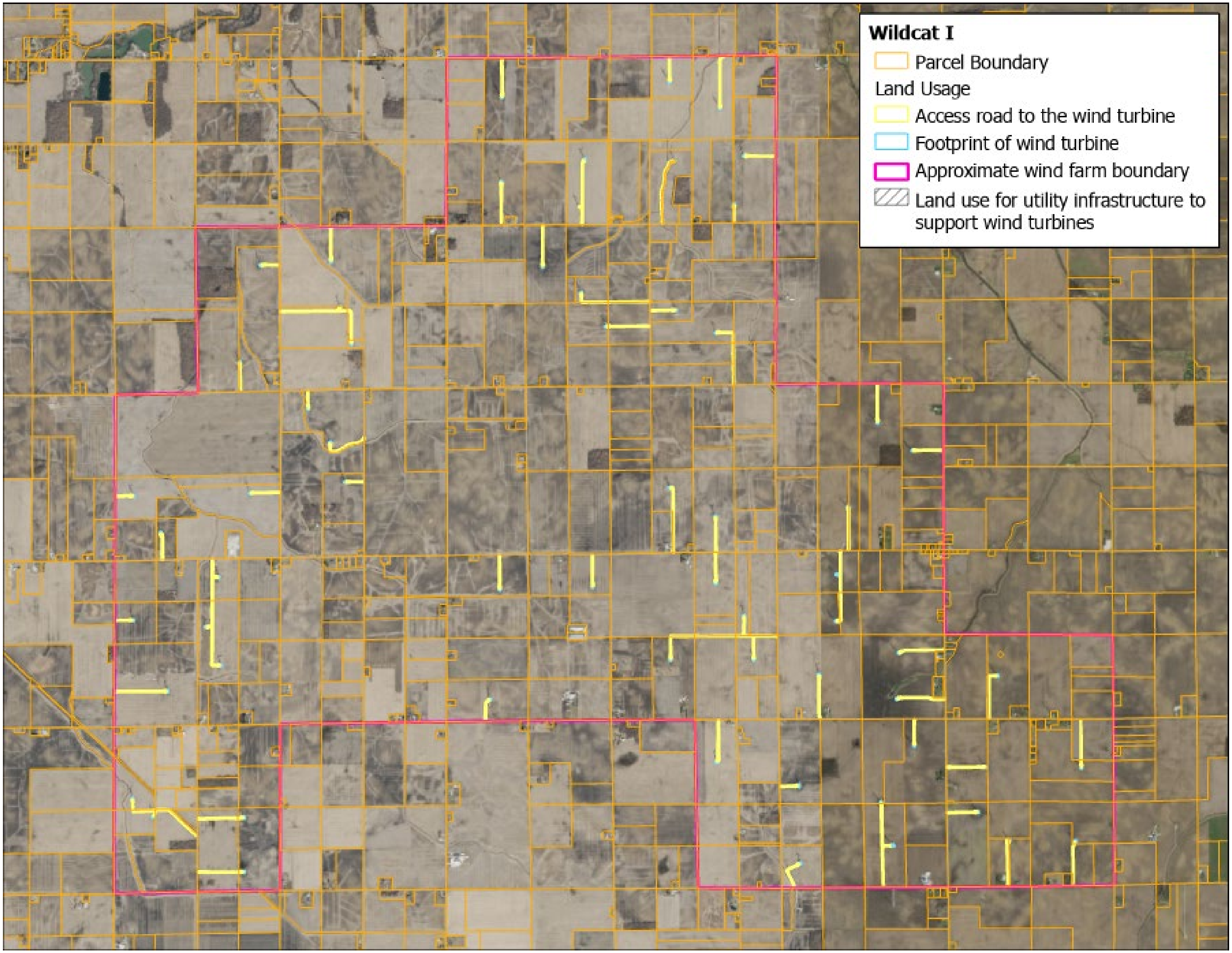


Figure 5. Wildcat I

Figure 8. Wind Farm Infrastructure

Custom Mapping Tool Source Code

```
import arcpy
def find_nearest_supply_curve(site_fc, supply_fc):
    arcpy.analysis.Near(site_fc, supply_fc, '10 Miles', 'NO_LOCATION', 'NO_ANGLE',
'GEODESIC')
    with arcpy.da.SearchCursor(site_fc, ['NEAR_FID']) as cursor:
        for row in cursor:
            nearest_fid = row[0]
            with arcpy.da.SearchCursor(supply_fc, ['capacity_mw'], f'objectid =
{nearest_fid}') as supply_cursor:
                for supply_row in supply_cursor:
                    capacity = supply_row[0]
                    return capacity
    return None
def return_cfo_count(site_fc, cfo_fc):
    sel_cfo = arcpy.management.SelectLayerByLocation(cfo_fc, 'INTERSECT', site_fc,
'10 Miles', 'NEW_SELECTION')
    return arcpy.management.GetCount(sel_cfo)[0]
def get_employment_info(site_fc, census_fc):
    messages = []
    messages.append('<b>Employment Information</b><br/>')
    messages.append('The proposed site intersects the following 2010 Census
Tracts:<br/>')
    sel_empl = arcpy.management.SelectLayerByLocation(census_fc,
overlap_type='INTERSECT', select_features=site_fc, selection_type='NEW_SELECTION')
    with arcpy.da.SearchCursor(sel_empl,
['residents_who_work_in_construct','residents_who_work_in_utilities','total_employed_
residents', 'namelsad']) as cursor:
        for row in cursor:
            construction = row[0]
            utilities = row[1]
            total = row[2]
            tract = row[3]
            construction_perc = construction / total
            messages.append(f'{tract}<br/>')
            messages.append(f'- Total residents employed in 2019: {total:,.0f}<br/>')
            messages.append(f'- Residents employed in the construction sector in
2019: {construction:,.0f}<br/>')
            messages.append(f'- Residents employed in the utilities sector in 2019:
{utilities:,.0f}<br/>')
    return messages
def get_education_info(site_fc, census_fc):
    messages = []
    messages.append('<b>Education Information</b><br/>')
    messages.append('The proposed site intersects the following 2020 Census
Tracts:<br/>')
    sel_edu = arcpy.management.SelectLayerByLocation(census_fc,
overlap_type='INTERSECT', select_features=site_fc, selection_type='NEW_SELECTION')
    with arcpy.da.SearchCursor(sel_edu,
['totalpopulation','total25pluspopulation','sharehighschoolgradorhigher','totalbachde
greeorhigher','namelsad']) as cursor:
        for row in cursor:
```

```
            total_pop = row[0]
            total_25plus = row[1]
            share_hs_higher = row[2]
            total_bs_higher = row[3]
            tract = row[4]
            share_bs_higher = (total_bs_higher / total_25plus) * 100
            messages.append(f'{tract}<br/>')
            messages.append(f'- Total residents at least 25 years old:
{total_25plus:,.0f}<br/>')
            messages.append(f'- Share of these residents with at least a high chool
degree: {(100*share_hs_higher):,.0f}%<br/>')
            messages.append(f'- Share of these residents with at least a Bachelors
degree: {share_bs_higher:,.0f}%<br/>')
    return messages
def ScriptTool(proposed_site):
    # VALUES OF IMPORTANCE
    MAX_INT = 9999999999

    SOLAR_SUPPLY_CURVES_URL =
'https://gisdata.in.gov/server/rest/services/Hosted/Indiana_Solar_Supply_Curves_2020/
FeatureServer/0'
    WIND_SUPPLY_CURVES_URL =
'https://gisdata.in.gov/server/rest/services/Hosted/Indiana_Wind_Supply_Curves_2021/F
eatureServer/20'
    CFO_URL =
'https://gisdata.in.gov/server/rest/services/Hosted/Confined_Feeding_Operations/Featu
reServer/2080'
    EMPLOYMENT_URL =
'https://gisdata.in.gov/server/rest/services/Hosted/Census_Tracts_with_Employment_201
9/FeatureServer/9'
    EDUCATION_URL =
'https://gisdata.in.gov/server/rest/services/Hosted/Census_Tracts_with_Education_2022
/FeatureServer/14'

    SOLAR_MW_PER_ACRE = 0.62
    SOLAR_CONSTRUCTION_JOBS_10MW = 40
    SOLAR_PERMANENT_JOBS_10MW = 1

    WIND_MW_PER_ACRE_MIN = 0.0037
    WIND_MW_PER_ACRE_MAX = 0.012
    WIND_CONSTRUCTION_JOBS_10MW = 11
    WIND_PERMANENT_JOBS_10MW = 1

    # Convert the feature set into something useful
    fc = arcpy.management.CopyFeatures(proposed_site, 'in_memory/sites')

    # Loop through the polys
    total_acreage = 0
    utm = arcpy.SpatialReference(26916)
    with arcpy.da.SearchCursor(fc, ['SHAPE@']) as cursor:
        for row in cursor:
            # Project geometry
            proj_poly = row[0].projectAs(utm)
            # Get acreage
            acres = proj_poly.area * 0.0002471054
```

```
            total_acreage += acres

    # General output
    message_items = []
    message_items.append(f'<b>Proposed Site Size:</b> {total_acreage:,.0f}
acres<br/>')
    cfo_count = return_cfo_count(fc, CFO_URL)
    message_items.append(f'There are {cfo_count} confined feeding operation(s) within
10 miles of this proposed site.<br/>')

    # Create output for solar
    solar_mw_estimate = total_acreage * SOLAR_MW_PER_ACRE
    solar_construction_jobs_estimate = SOLAR_CONSTRUCTION_JOBS_10MW *
solar_mw_estimate / 10
    solar_permanent_jobs_estimate = SOLAR_PERMANENT_JOBS_10MW * solar_mw_estimate /
10
    message_items.append('<b>Solar Farm Estimates:</b><br/>')
    message_items.append(f'This area could generate approximately
{solar_mw_estimate:,.0f} MW of energy annually in the case of a solar farm.<br/>')
    message_items.append(f'A solar farm this size could lead to
{solar_construction_jobs_estimate:,.0f} construction jobs and
{solar_permanent_jobs_estimate:,.0f} permanent jobs.<br/>')
    nearest_solar_supply_curve_capacity = find_nearest_supply_curve(fc,
SOLAR_SUPPLY_CURVES_URL)
    if nearest_solar_supply_curve_capacity is not None:
        message_items.append(f'The nearest solar supply curve indicates a capacity of
{nearest_solar_supply_curve_capacity:,.0f} MW. See <a
href="https://www.nrel.gov/gis/solar-supply-
curves.html">https://www.nrel.gov/gis/solar-supply-curves.html</a> for additional
information.<br/>')
    else:
        message_items.append(f'The nearest solar supply curve could not be
found.<br/>')

    # Create output for wind
    wind_mw_estimate_min = total_acreage * WIND_MW_PER_ACRE_MIN
    wind_mw_estimate_max = total_acreage * WIND_MW_PER_ACRE_MAX
    wind_construction_jobs_estimate = WIND_CONSTRUCTION_JOBS_10MW * wind_mw_estimate
/ 10
    wind_permanent_jobs_estimate = WIND_PERMANENT_JOBS_10MW * wind_mw_estimate / 10
    message_items.append('<b>Wind Farm Estimates:</b><br/>')
    message_items.append(f'This area could generate approximately
{wind_mw_estimate_min:,.0f} MW to {wind_mw_estimate_max:,.0f} MW of energy annually
in the case of a wind farm.<br/>')
    message_items.append(f'A wind farm this size could lead to
{wind_construction_jobs_estimate:,.0f} construction jobs and
{wind_permanent_jobs_estimate:,.0f} permanent jobs.<br/>')
    nearest_wind_supply_curve_capacity = find_nearest_supply_curve(fc,
WIND_SUPPLY_CURVES_URL)
    if nearest_wind_supply_curve_capacity is not None:
        message_items.append(f'The nearest wind supply curve indicates a capacity of
{nearest_wind_supply_curve_capacity:,.0f} MW. See <a
href="https://www.nrel.gov/gis/wind-supply-
curves.html">https://www.nrel.gov/gis/wind-supply-curves.html</a> for additional
information.<br/>')
```

```
    else:
        message_items.append(f'The nearest wind supply curve could not be
found.<br/>')

    # Employment & Education information
    message_items += get_employment_info(fc, EMPLOYMENT_URL)
    message_items += get_education_info(fc, EDUCATION_URL)

    # Output
    for msg in message_items:
        arcpy.AddMessage(msg)

    return ''.join(message_items)

# This is used to execute code if the file was run but not imported
if __name__ == '__main__':
    # Tool parameter accessed with GetParameter or GetParameterAsText
    proposed_site = arcpy.GetParameter(0) # Polygon showing proposed site

    msg = ScriptTool(proposed_site)

    # Update derived parameter values using arcpy.SetParameter() or
arcpy.SetParameterAsText()
    arcpy.SetParameter(1,
```

18.7 APPENDIX G – Skit for PSHAUM Energy Storage Technology

Coal Miners to the Rescue

by Peter J. Schubert © 2022, reprinted by permission.

Dramatis Personae

1. Coal Miner (hard hat)
2. Wind Fan (propeller beanie)
3. Economic Development Professional (dealer's visor)

MINER: We need more coal-mining jobs, so we can get back to work!

WIND: Coal is old as yesterday's news.

ECON: We need to re-train you for a new job, like working the top of a wind pole mast.

MINER: MY work is UNDER the Earth. Not up above! Can't teach an old dog new tricks. Can't change the stripes on a tiger. Cain't change the spots on a leopard.
(*aside*) Plus, I'm afraid of heights.

WIND: (*aside*) …and, **I'm** afraid of tight places.

ECON: Well, renewables are the wave of the future. Coal mine jobs are at ebb tide. You either need to step up, or step aside.

WIND: Yeah, man. We need cleaner energy. Burning coal is burning the whole world.

MINER: But the problem with wind and solar is this: It comes and it goes. Coal now: Coal is "Always On", and we've got 500 years worth right here in Indiana.

WIND: Maybe so, but wind and solar will be here FOREVER, and it's free! Air and sunlight are FREE!

MINER: That's downright un-American.

ECON: But wind and solar projects are enriching Hoosier communities all across our Great State.

MINER: That may be fine for famers and their land, but what about Coal Country, huh? What are WE gonna do?

ECON: Have you heard about P.S.H.A.U.M, invented by the Lugar Center at IUPUI?

WIND & MINER (*together*): What's That?

ECON: It stands for Pumped Storage Hydro using Abandoned Underground Mines. They propose turning old coal mines into huge energy storage systems using water.

COAL: I'm listening…

ECON: They clear out the mine, then build a lake above it. When there is excess wind, like at night, they pump water up and fill the lake.

WIND: I like this idea, already!

ECON: Then, when the grid calls for more power, they drop the water down into the mine space, and generate electricity in the process.

COAL: And sell it?

ECON: Yes, now they SELL the electricity they stored the night before.

COAL: Now, THAT's the American way.

WIND: And, as a bonus, now wind power can be "Always On".

COAL: So, tell me more about what happens in this coal mine?

ECON: The mine is re-purposed. We need miners underground to coat the coal seam with shotcrete. We need to blast out a power house. And we need French drains for the water flow.

COAL: You know, I got a bunch of buddies out of work. You suppose I could bring them by your office?

ECON: Sure! We'll need dozens, maybe hundreds!

WIND: This means more capacity for wind, right? More jobs above ground, too, right?

ECON: Absolutely! With the Lugar Center's P.S.H.A.U.M. technology, we put Hoosiers to work, we lower the cost of electricity for everyone, and we clean up our Great State.

COAL: And WE get to go back UNDER the ground!

WIND: And WE get to go work **ABOVE** the ground!

(*COAL and WIND look at each other, with wide smiles*)

ECON: Plus, we can use the lake for recreation, and as an additional water supply. In the North, we can use old Gypsum mines. By **working together**, PSHAUM can help EVERY Hoosier.

TOGETHER: (*shoulder hug in a row, ECON in middle singing*)

(ALL) I like Renewable En-ergy

(ALL) The jobs are there for You and Me

(WIND) I'm a big fan (*points to hat)*

(COAL) Coal miner's can (*points finger up*)

(ALL) Work this together in Har-mon-y

(*all bow as one)*

18.8 APPENDIX H – Podcast on Land-Use Changes for Solar Farms

Lugar Center Answers: Series 1: Misinformation about Renewable Energy
Episode 1: Land Use Changes for Solar Farms

Hello, and welcome to the podcast program The Lugar Center Answers. This is Series 1 on the topic of "Misinformation about Renewable Energy". This is episode number 1, titled: "Land Use Changes for Solar Farms".

I am your host, Dr. Peter Schubert, director of the Lugar Center for Renewable Energy. To learn more about the Lugar Center, please visit our website at www.lugarenergycenter.org.

Today's topic is on land use changes. This is a term used when the purpose of a parcel of land is changed from one category to another. Of particular interest in this episode is when farm land used for agricultural purposes is changed to utility-scale solar, sometimes called solar farms. In this podcast, we aim to put the issues surrounding such a land use change into context, and to address some of the questions and concerns raised about converting crop acreage into a photovoltaic energy facility.

First, a bit of history.

The Eastern part of America was once forested across much of its area. There were also prairie lands with grasses, rushes, and sedges, a mix of annuals and perennials whose roots extend very deep into the earth. These are the so-called "native species" that people plant to beat back "invasive species", or to try to return the land to its original nature.

When European immigrants became settlers, they worked hard and "cleared the land", burning the trees, and plowing the native grassland.

Imagine how the earlier occupants viewed this mass destruction of habitat? Of course the indigenous animals were displaced, decimated, slaughtered, driven away. But also the original inhabitants, themselves immigrants from a much, much earlier wave of Americans, viewed this with distaste, and sometimes anger. They were also driven away, also decimated.

The creation of the modern farm in America was the most aggressive land use change in this history of the world, with the possible exception of the Sahara desert. It is likely that the northern part of the African continent was once green and lush, a vast area just about equal to the continental United States. Then, humans brought their sheep and goats, to lush green pastures. These ruminants are believed to have chewed the native plants down to nubs, and the entire area eventually became a lifeless desert.

Now, we are experiencing several types of land use changes that are having a big effect on traditional American farms.

One land use change that all of us have watched, our whole lives, is cropland converted to cul de sacs. As cities grow and as affluent people seek homes in the suburbs, farmers are offered a pretty penny to sell off and retire to Florida.

Let's think about farming as an occupation for a moment.

In the year 1900, 70 percent of Americans lived on farms, or worked on farms. Food was local, and farms were how we fed the population. Fast-forward to today, and the percent of American who are still farming for a living is a mere 3 percent.

Now, think about the mid-point of that gigantic shift, around the 1950s or 1960s. Back in the day, when a farmer grew old and was ready to retire, his son would often take over. It was, and still is, a great source of pride to keep farmland "in the family". This is an extremely powerful and deep emotion for those who work the land.

However, in the 2020's, few are those farmer's sons and daughters who stay on the land. Farming is hard work. Farmers must understand their business, be mechanically-inclined, willing to work long hours, and be financially savvy. Being a farmer requires self-discipline. Farming is becoming increasingly technical, with GPS on combines, complex and hazardous chemicals, soil health monitoring, hybrid seeds, and more. For young people learning to farm, they are likely to go to college, to ag school, to learn how to maximize their yields and revenues with the latest and greatest information, equipment, and methods.

Once exposed to college, some youngsters discover a bigger, brighter world. One in which most of their fellow co-eds will move off to high-paying 9-to-5 jobs in dynamic, exciting cities across the country.

What does this mean for the traditional farmer? It often means many years to retirement. Our bodies do not remain young forever. As they age, farmers are just like everyone else, with aches and pains, other interests, and maybe not as much energy as they had in their own youth. You can see why some farmers may consider selling off and retiring on the Gulf.

But most would rather keep the farm in the family. How can they?

Consider the wealthy for a moment. It is a cliché that the children of great wealth are often lazy, spoiled and feel entitled. Rare is the scion who equals or surpasses the achievements of the patriarch. No, it is more likely that one of the grandchildren will have that spark, that fire-in-the-belly, the drive, to succeed, to win. Now, what if the same is true on farms? Could the grandkids of a farmer return, eagerly, to the farm?

This is the reasoning behind some farmers who lease their land to developers of solar energy. They learn that the steel posts holding up the photovoltaic panels can be readily pulled back up, after the 25 year lease expires. That the land will have rested, and be ideal for a return to cropland. Meanwhile, these farmers, as they age, receive a steady, dependable income from the use of their land. In this way, some farmers are able to bridge the gap generation, and keep the farm in their own family.

However, there are many voices arguing against such a land use change. There are objections and concerns, some of which are legitimate. But some of these objectors seek to sow doubts with misinformation. Why? Some misinformation comes indirectly from energy companies, such as those that derive their income from fossil fuels. They are, of course, protecting their businesses, as you might expect.

So, how can a farmer make sense of this information overload? How to tell real information, real concerns, real issues, from those that are spun from the dark imaginations of others. Let's start with the real issues. There are four that come up frequently.

One, is aesthetics – how things look. Those who grew up with vistas of farmland and forest frown at the idea of high-tech solar panels. Sunlight may glint off their metal edges. Motors may grind as they follow the sun, electrical boxes may hum as they deliver electricity to the grid. These are all real, and merit discussion and consideration.

Two, is hazards: toxins and fires. It is true that some types of solar panels are made of heavy metals that you do not want to catch on fire. And it is true that solar panel fires have occurred. These are also real issues. There are good solutions, and it is important to ask these questions of your solar developer.

Three, is damage to the land. Yes, installing solar farms can damage drainage tile. Yes, the panels can change how rain lands on the earth, and how the water drains away. Developers must be held to account to address these issues – for sure.

Four, is property rights. Some county or state lawmakers may restrict, limit, or penalize solar farms, based on their own gathering of intelligence, and their own values. Some independent farmers may resent being told what they can or cannot do on their own land. While it is true that government authorities routinely address issues of what can be done on your own property, there is a potential for overreach, or for decision-makers to have been misinformed in order to sway their rulings. It is vital that citizens vote for candidates that represent their own values.

Now, let's take on some of the misinformation that is spread about solar farms. Most misinformation starts with a grain of truth, then spins it out of all proportion. A widely-circulated story is this: birds mistake solar panels for water, land on top, catch on fire, then fly, burning, into nearby woods, and then the whole county burns to ash and cinder.

Our research at the Lugar Center shows that solar fires can occur, but it is rare. The US does not gather this information, so we are compelled to use data from Germany and the United Kingdom, where this issue is tracked. We found that fire risk comes from cheap parts designed by untrained technicians and installed by inexperienced laborers. Even when a developer selects vendors based only on price, and not on qualifications or experience, the chance of a solar farm catching on fire is 200 times lower than the chance of your home catching on fire. This is worth repeating in a different way. In any given year, there is a small chance that your house or dwelling will catch fire from lightning, bad wiring, dropped cigarettes, faulty appliances, or a backyard leaf fire that goes out of control. The chance of this happening to you, in America, is about one in one thousand. So, if you lived in the same house for 500 years, chances are 50:50

that your home would burn down at least once. However, if you live nearby to a solar farm, you would have to live to be 10,000 years old before having the same risk of fire out there, beyond the setback, happening near you.

Loss of property values is the most common misinformation spread by established energy interests, political idealogues, and conspiracy theorists. They know that farmers are extremely sensitive to economic issues. If something does not "pencil out" to a farmer, they will drop it like a hot coal. We can see that a solar farm may actually raise the value of the farmland it's installed upon because of that steady income, and the ability to re-convert to cropland after the lease is up. But what about neighbors?

Nearly all commercial solar farms have setbacks, typically several hundred feet, from any homes or roads. Also, most project developers will plant vegetation around the fence enclosing the photovoltaics. These include arborvitae, and similar ornamental plants that will soon grow and block any ground-level view of the solar farm from passersby.

Solar farms do make some noise, from the sun-tracking gear, and the inverters and combiner boxes that prepare their energy for the grid. And, it is possible these gears will squeak, and become annoying. Project developers want to keep this gear operational, so greasing the movements is part of their regular maintenance. If a neighbor hears this, and they call up the owner, chances are very good it will be resolved quickly.

Finally, how about the next purchaser of the land? What if a neighbor simply hates solar on principle, regardless of how benign it is for the environment, regardless of the energy independence it provides America. What if they just hate the very IDEA of solar, and decide to sell off and move away? What about their property values?

Studies we found show that new purchasers of such property take a "who cares" attitude, and that property values, in general, neither increase nor decrease adjacent to a solar farm. This is one of those non-issues that nevertheless crop up frequently from those trying to stop a solar farm before it gets started.

There are many more issues that can be addressed, and the attempts at misinformation will only continue to grow – that is, until this becomes a non-issue. By way of comparison, you may recall the "Food versus Fuel" debates of the early 2010's. This is when corn-based ethanol was really taking off, and people worried that food prices would skyrocket if we diverted corn from animal feed to a gasoline additive. In 2022, in the State of Indiana, half of the corn grown goes to ethanol. And, prior to the Russian invasion of Ukraine in February of that year, food prices were generally okay.

Think about this.

In only 10 years, 50% of Indiana corn was diverted from food to fuel, and nothing bad happened. Lots of farmers are making lots of money. More of our gasoline is produced domestically. And the debate has faded away.

Probably by 2032, the concern over solar panels will fade. Until then, please do your homework. Take with a grain of salt the vehement objections you will certainly hear. You will hear first from objectors, and this will tend to make you skeptical of proponents, who only come to you later. This is a weakness of being human – first impressions are very strong in us.
Do your homework, listen to all sides. Make your own decisions.

And remember how we got here. Land use changes are nothing new. Over time they become accepted practice. We humans resist change. Vested interests protect their own. Keep aware of these factors, and you are likely to make your own decision for your own best interest. That should be the right of everyone.

If we can help you in your own decision-making, please let us know.

Thank you for your attention.

18.9APPENDIX I – White Paper: Do Solar Farms Influence Local Weather?

Solar farms and their effect on local climates

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Good Questions Project

Executive Summary

A concerning matter on local climates has begun to arise as the industry for solar energy started to further develop. Since Indiana is home to many farmers and their agricultural roots thrive in this state, citizens have voiced their opinions on solar farms and the impacts it could potentially have on their businesses. Upon research, it has been concluded that local climates having an impact on solar farms have given an ambiguous answer, with some research strongly favoring Urban Heating Effect increasing temperature levels up to 2.5 °C to 4 °C while others have argued that the research is biased as they include changes in the energy and albedo changes. Even if there are changes in temperatures, there would be a difference of ~0.5 °C due to seasonal changes. Regardless, heat is released during the night, creating a healthy feedback loop.

Introduction

This report will focus on the scientific impacts that solar farms could have on local climates and identify the types of misinformation and what precautionary measures can be taken to enlighten the community with facts. The goal of this report is to show people the actual result solar farms would have on local climates.

Indiana is currently ranked 6th national wide for solar energy despite 1.27% of the state's electricity coming from solar. As of 2022, 1,391 MW of new solar has been installed in just the second quarter of 2022, powering 159,975 homes. The growth projection is expected to skew up to 8,741MW in the next 5 years, which is encouraging as investments within Indiana was $875 million in just 2021 [1].

This rapid growth over the years has caused concerns in local communities due to the ambiguity in established research, and the pressure from global warming arising. Past studies have shown mixed results when it comes to the effects of solar farms, and this paper will cover all aspects of the results. It can be argued that most of the public is in favor of using solar energy, or any renewable energy, as long as it's not within the proximity of their homes, farms, and agricultural lands. This makes it challenging to easily implement solar farms when large spaces are needed.

Solar Farms and Urban Heat Island Effect

Indiana has started to execute their newest and largest solar projects in the U.S., and approximately $1.5 billion has been invested in this. The Mammoth Solar project ranges over 13,000 acres and is projected to generate power for 275,000 households across Starke and Pulaski Counties in northwest Indiana. For visuals, this size is equal to 1,000 football fields. The project is expected to be divided into 3 phases; Mammoth North, Mammoth South, and Mammoth Central.

With all of these solar progressions, major concerns about solar altering the climate have begun to surface, especially in rural areas. Indiana contributes up to $31.2 billion in agriculture, over 94,000 farmers reside in Indiana since 80% of the land in Indiana are devoted to forests, farms, and woodland. With this statistics, citizens have questioned the implementation of utility-scale solar energy to avoid loss to their family roots and traditional sources of income.

Vasilis Fthenakis and YuanHao Yu, authors of the research paper 'Analysis of the Potential for a Heat Island Effect in Large Solar Farms', [5], investigated the hypothesis that solar farms affect local weather. PV panels convert most of the solar irradiation into heat, potentially altering the air-flow and temperature profile near panels, subsequently affecting the thermal environmental. Through numeric simulations, they were able to conclude that for some photovoltaic (PV) modules temperature was higher than that of the surrounding air during the day, and below ambient during the night. However, this did not translate to all PV solar farms, as other modules did not induce a day-after-day increase in average temperature. This made the researchers declare that any changes in local climate from PV plants are not a significant concern, because the results were mixed.

Fthenaskis and Yu also experimented with the cooling effect as height of the PV module was increased above the ground. They analyzed the air temperature at different downwind distances from a solar farm at 9am (cool) and at 1pm (warm). At 9am, the heat from the solar array dissipated at heights of 5 m to 15 m, while at 1pm, it takes up to 18 m to dissipate because the temperature of the panels reached the daily peak.

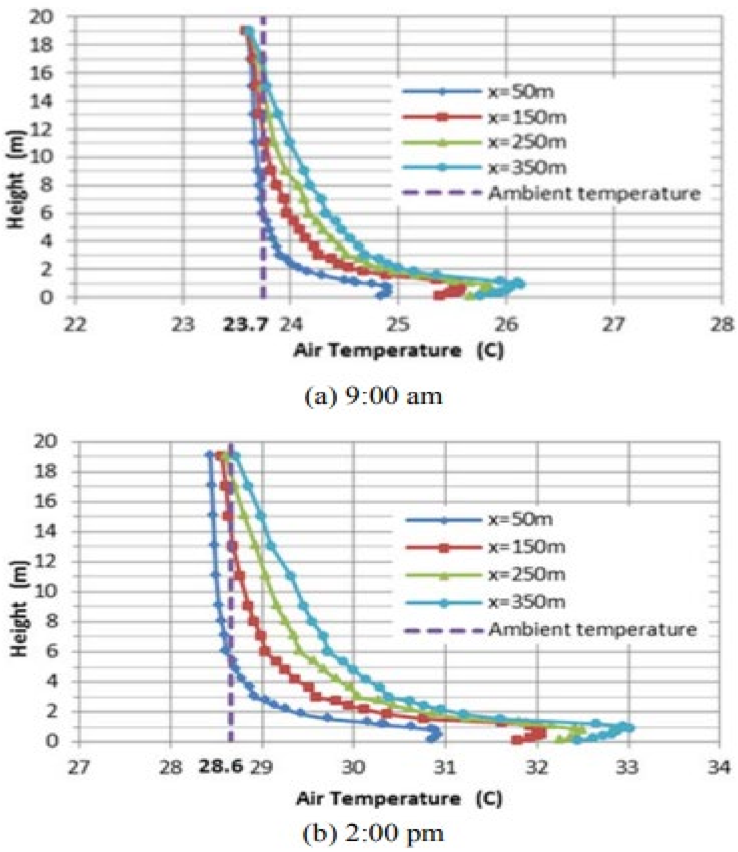

Fig. 16 Air temperatures within the solar farm, as a function of height at different downwind distances. From 2-D simulations during a sunny summer day (7/1/2011) at 9 am and 2 pm.

Figure 1. Temperature drop-off from edge of solar farm in the morning (top) and mid-afternoon (bottom).

Another factor is the roads between rows of solar panels. These were found to create space for the solar farms to experience cooling. They concluded that increasing the size of the solar farm will not produce a significant Urban Heat Island effect (this being the observation that cities are warmer than the surrounding countryside due to trapping of solar heat)[5].

While Fthenaskis and Yu have concluded that their simulation produces minuscule changes in local temperature from solar farms, A. Barron-Gafford, et. al published ‘The Photovoltaic Heat Island Effect: Larger solar power plants increase local temperatures’[6]. In this article, they discovered that larger PV power plants have created changes in the landscape, reducing the natural albedos in desert locations. Lowering terrestrial albedo from ~20% in natural deserts to ~5% alters the energy balance of absorption, storage, and releases of short and long wave radiation.

PV installation shade a portion of the ground, reducing heat absorption in surface soils. Since the panels are thin and have little heat capacity per unit area, PV modules emit thermal radiation, particularly during the day when the PV modules are often 20 °C warmer than ambient temperatures. In desert installations, the PV panels reflect and absorb upwelling long wave radiation, preventing the soil from cooling as much as it might during the night. Also, in desert locations, having no vegetation beneath PV modules reduces the amount of cooling due to transpiration, relative to installations in temperate climates, such as Indiana..

While some models have suggested that PV systems can actually have a cooling effect on the local environment, depending on the efficiency and placement, the authors of this research has concluded that those studies are limited in their applicability. They argue that such studies consider changes in the albedo (reflectivity) and energy exchange within an urban environment rather than natural ecosystems of interest to the GQP. Also, they say, most previous research is based on untested theory and numerical modeling. They claim for any and all urban heating effects to be examined with empirical data obtained through rigorous experimental terms.

PV panels allow some light energy to pass, which leads to greater heat absorption for un-vegetated soils, contributing to greater heat flux from the soil that potentially is trapped under the PV panels. The authors monitored the air temperature at each arid solar farm sites for over one year using aspirated temperature probes 2.5 m above the soil surface and found the average annual temperature to be 22.7+0.5 °C in the PV installation, while the nearby desert ecosystem was only 20.3 +0.5 °C, indicating the presence of an Urban Heat Island effect in deserts.

Conclusion

Most of the concerns about solar farm and its changes on local climate can be concluded as not having strong scientific support. There is certainly local heating, but this dissipates within a few tens of yards from the edge of a solar farm. Cooling behavior is also provided by the lanes between rows of PV panels, and by the transpiration (evaporation from leaves) of plants growing in the shade of the panels. So, yes, solar panels do get warmer than the surrounding environment, but their impact on local weather, in temperate climes, is essentially negligible.

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19.0 Revision Log

Revision Date	Revision Description	Paragraphs Affected	Editor
7 Dec 22	Structure for Phase 2 tasks	ALL	P. Schubert
13 Dec 22	First nearly-complete draft	ALL	P. Schubert
15 Dec 22	All elements included	ALL	P. Schubert
27 Dec 22	Add IC 8-1-41 and 8-1-42	Section 13	P. Schubert
29 Dec 22	Provide printable 3-page FAQ	Section 7.1	P. Schubert