Developing Utility-Scale Solar Power in Michigan at the Agriculture-Energy Nexus

Stakeholder perspectives, pollinator habitat and trade-offs

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Publication year: 2021

This report is based on a capstone seminar class under the undergraduate course in Science, Technology, Environment and Public Policy. The course was funded by a corporate gift from NextEra Energy Inc., which develops solar power facilities. Research findings were reported independently from review of NextEra Energy.

We sincerely thank two anonymous pollinator experts and researchers for their peer review of this report.

We sincerely thank our interviewees for the generous donation of their time, insight and expertise.

Thank you to students enrolled in the course who helped conduct interviews, including Giani DiTrapani, Grace Doyle, Osten Eschedor, Hannah Graff, Oren Lerner, Skyler Leslie, Ginny Lindberg, Sara Millies-Lucke, Danny Olweean, Carolyn Ouellet and Alec Wycoff.

Photo on cover page: Assembly Solar, Shiawassee County, Michigan, May 14, 2021. Taken by Aubrey Wigner and Sharlissa Moore

Executive summary

Utility-scale solar power is being scaled up across the Midwest not only due to reduced cost and climate change goals but also because some actors in the Michigan energy sector have presumed that solar development will foment less public resistance than wind power. However, much of this solar generation is being planned for agricultural lands, and some of it for preserved farmland, giving multiple stakeholder groups and decision-making bodies across agricultural and energy communities an interest in whether, how and where this solar generation is developed. To promote multiple land uses and assuage public concerns about farmland preservation, researchers and companies are experimenting with planting vegetation that provides forage and/or nesting sites for pollinating insects. The state of Michigan is requiring that solar facilities located on preserved farmland include vegetation that meets a minimum score on a pollinator habitat scorecard. Goals to meet pollinator benefits entangle the grand challenge of quickly scaling up renewable energy with the complex and also urgent need to address pollinator decline. As Michigan stakeholders develop programs and regulations on solar land use, systematically understanding the synergies and trade-offs between these goals is crucial. Both clean energy and pollinators are public goods that are worth upfront investment to ensure benefits are achieved.

This report presents the results of an analysis of stakeholder perceptions of siting solar power on agricultural land in Michigan. This research inquired: What are the perspectives of different stakeholder groups on the appropriateness of using Michigan's farmland for solar energy generation? What are the benefits and drawbacks of integrating pollinator habitat into these installations in terms of public support, cost and complexity related to simultaneously generating clean energy and benefitting pollinating insects? Interviews were conducted with 59 individuals representing state and local government, agricultural and entomological experts, the energy industry, farmers and farm organizations, and community organizations.

Overall, we found that the effective design of integrated solar-pollinator habitat systems requires input from multiple stakeholders and experts across energy, agriculture, government and communities. However, there is currently a lack of deep collaboration and mutual understanding across disciplines and sectors. We also found that the agricultural community is divided on whether agricultural land should be used for solar power. While pollinator habitat improves perceptions among some stakeholders, it does not for all. Furthermore, we found there is significant potential for public misunderstanding of pollinator habitat outcomes, as the aesthetics and time to establish may disappoint stakeholders with certain expectations.

Pollinator habitat increases the complexity of deploying solar power plants, and numerous questions remain unanswered about, for example, choice of seed mix; requirements for increasing panel height to accommodate taller vegetation; site preparation needs; operations and maintenance (O&M) costs and benefits; location of the pollinator habitat within the solar installation; and the best designs for supporting honey bees, wild bees or monarch butterflies. Furthermore, we found little evidence that solar pollinator habitat will tangibly benefit agricultural operations. The costs of designing and installing high-quality pollinator habitat are at tension with utility request-for-proposal (RFP) processes that serve as a race to the bottom to select the lowest cost bidder rather than the most sustainably designed project. Substantive change in governance and funding structures will be needed to realize the benefits of developing solar pollinator habitat on agricultural land. Regardless, in order to keep expectations reasonable, the public should be informed that trade-offs will be required.

Since there is a market for renewable energy but generally not a market mechanism for benefitting native pollinators, and because the RFP process prioritizes the lowest cost bid, ***we recommend that public investment should be made in the early phases for the following:***

- Fund the costs of site preparation and seed mix for the solar developers who win RFP bids in the early stages of integrating solar pollinator habitat into solar installations.
- Formally engage local publics in setting priorities and goals for the habitat and educating them so that expectations are in line with reality. Conduct systematic social science research on whether pollinator habitat changes public acceptance of solar facilities.
- Fund the careful monitoring of solar pollinator habitat to measure its effects on pollinators. Well-defined goals for the habitat must be established in order to measure success. Goals should be varied across early pollinator sites to measure success (e.g., benefitting threatened and endangered native species, benefitting native species in general, benefitting managed honey bees and increasing pollinator habitat connectivity.)

Audience: This report's results are relevant to policy decisions being made across states about requirements for certified pollinator habitat on solar sites. In Michigan, the research will inform policy and regulation related to solar pollinator habitat and potential future habitat monitoring on preserved farmland. Utility companies and renewable energy developers have also requested this report as they make decisions about qualitative requirements for RFP processes. Local government stakeholders and affected communities can better understand the benefits and drawbacks across agricultural production, pollinators and energy generation. Without public engagement and education, the benefits and outcomes of solar pollinator habitat are likely to be misunderstood at best and, at worst, to sow greater opposition to utility-scale solar projects.

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The problem framing: Urgent needs for energy transitions and pollinator recovery

The avenues by which Michigan and the United States provide the electricity essential for the economy and quality of life are in urgent need of change to ensure reliability and affordability while reducing the environmental impacts of this generation and improving social equity. These energy transitions are among the greatest challenges facing countries worldwide today. Another salient global challenge is reversing the decline in pollinators, including numerous species of native bees, honey bees, butterflies and birds. Pollinators provide critical ecosystem services but are facing numerous threats. These two grand challenges intersect as stakeholders work to identify the appropriate landscapes and places to develop solar power in Michigan. Agricultural land is desirable for solar installations for reasons that will be explained in this report. The state of Michigan is allowing solar developers to locate, or "site," solar panels on preserved farmland but only if they develop habitat on this land to support pollinators. Other states are developing or have already developed standards developers must meet before they can advertise solar power plants as pollinator friendly. This intertwines these two urgent challenges in ways that are laudable; however, numerous questions of feasibility and best practices for achieving quality habitat remain unanswered. Multiple types of expertise and experiences from stakeholders from both energy and agricultural domains are required to successfully address these two challenges. In order to effect change, these stakeholders should collaborate more closely to overcome challenges of interpretation, problem definition and costs. This report identifies and characterizes those issues to facilitate stakeholders' development of more optimal solutions.

The significance and urgency of the energy transition

Energy provides crucial public services, powering all aspects of Michigan's economy. We use electricity to cool our homes and buildings; heat water; provide light; power appliances such as refrigerators, clothes dryers and washers; cook our food; watch TV; and charge phones and other devices.

There are numerous reasons why Michigan's electricity system needs an overhaul. Michigan's existing energy infrastructure is aging and depreciated and will need replacing simply due to age. The state received a C- grade on energy infrastructure on the American Society of Civil Engineers' (ASCE) 2018 Infrastructure Report Card because of high levels of dependency on external nuclear energy and fossil fuels, as well as aging infrastructure (ASCE, 2018).

Furthermore, dependence on fossil fuels for electricity causes air and water pollution. Utility companies in Michigan are in the process of retiring Michigan's coal fleet. Coal-fired power plants are among the top sources of air pollution in the United States. These power plants emit sulfur dioxide, nitrogen oxides and mercury (Revesz & Lienke, 2016). Sulfur dioxide and nitrogen oxides exacerbate health conditions such as asthma, emphysema, bronchitis and heart disease. Both contribute to acid rain, and nitrogen oxides can form ground-level ozone, also known as smog. Mercury from coal-fired power plants settles into water and accumulates in fish, which can harm fetuses when pregnant women consume the tainted fish (Revesz & Lienke, 2016). These burdens are inequitably distributed across demographic groups, resulting in social injustice. In 2040, the Monroe coal-fired power plant will most likely be the last of Michigan's coal-fired power plants to retire (see Figure 1). Coal-fired power plants have a compact land-use footprint but have wide-ranging impacts that are invisible to the average person, including coal mining, plumes of air pollution, coal fly ash storage and other supply chain impacts. Solar and wind have a larger generation footprint but have far fewer impacts across the life cycle.

Another reason an electricity transformation is needed in Michigan is to mitigate climate change by limiting warming to 2.0 degrees Celsius, or ideally to 1.5 C, given that the 2018 report of the Intergovernmental Panel on Climate Change illustrated the dire impacts of even 1.5 C of warming. To limit warming to 1.5 C, global carbon dioxide emissions must decline by 45% of 2010 levels by 2030 and reach net zero by 2050. For a 2 degree limit, emissions must decline by 25% of 2010 levels by 2030 and reach net zero by 2070 (Masson-Delmotte et al., 2019, p. 109). However, even if you, as a reader of this report, do not believe in anthropogenic climate change, the other reasons presented here are sufficiently compelling to transition Michigan's energy infrastructure.

Two other factors drive the urgency of energy transitions. First, transportation has recently surpassed electricity as the largest source of greenhouse gas emissions in the United States (U.S. Environmental Protection Agency, 2019). These emissions mainly come from burning gasoline and diesel in cars and trucks. A transition to electric vehicles offers a technologically feasible alternative, but renewable electricity generation will need to be increased to maximize the climate change benefits of electric vehicles. In Michigan, GM has already committed to a goal of producing only electric vehicles by 2035 (Boudette & Davenport, 2021). Second, though still preferable to coal, electricity generation from the rapidly growing natural gas industry has its share of climate change drawbacks. While natural gas is theoretically assumed to emit one-third of the carbon dioxide emissions of coal because of its greater energy density, methane leaks from natural gas storage facilities, pipeline and distribution infrastructure, and extractive operations reduce this number in practice (McKain et al., 2015; Oyewunmi, 2021). Methane is 20 times more powerful on a per molecule basis as a greenhouse gas than carbon dioxide (Dessler, 2016).

Figure 1: BC Cobb coal-fired power plant in Muskegon, Michigan, being dismantled, summer 2019. Photo by Sharlissa Moore.

Considering these factors, more solar, wind and other clean energy options are urgently needed. Simultaneously, the costs of renewable energy have significantly fallen. Utility-scale solar photovoltaic prices declined 83% from 2010 to 2020 (Feldman et al., 2021). According to the U.S. Energy Information Administration, the LCOE (or levelized cost of energy, which incorporates all the construction and operation costs over a power plant's lifespan) for utility-scale solar power without battery storage is the lowest of all electricity generation technologies, at $31.30/ MWh without the federal investment tax credit, or $29.04/ MWh with it. (See Figure 6 for an explanation of what a MWh is.) The LCOE of onshore wind is the next cheapest option, at $31.45/ MWh. The cheapest dispatchable electricity generation technology (available around-the-clock) is combined cycle natural gas, at $34.51/ MWh (U.S. Energy Information Administration, 2021).

Plans for this renewable energy scale-up largely fall under the jurisdiction of state and local governments, as public utility commissions, utility companies, and state legislatures and governors' offices establish goals for renewable energy development and regulation. Overall, Michigan's state goal is to reach 15% of annual sales of electricity in Michigan from renewable energy (Helms, 2021). But utility companies are exceeding this goal. There are two large investor-owned utility companies in Michigan: Consumers and DTE Energy.[1] Consumers Energy set a goal of sourcing 6,000 megawatt (MW) of solar power by approximately 2030. According to interviewees, even though DTE's overall electricity generation has increased since 2005, it is emitting 25% less carbon dioxide today than in 2005. DTE aims to reach net zero greenhouse gas emissions by 2050 (i.e., 90% carbon reduction plus 10% carbon offsets). Governor Whitmer's Michigan Healthy Climate Plan aims for Michigan to reach net zero emissions, or carbon neutrality, by 2050 (Department of Environment, Great Lakes, and Energy, n.d.). Three Michigan cities have set 100% renewable energy targets. Traverse City committed to 100% renewable energy by 2020 for municipal buildings, and 100% renewable electricity for the city's municipal utility company by 2040 (Carruthers, 2018; McBenge, 2016). The city of Petoskey established a 100% renewable energy goal by 2035 (Perkins, 2019). In June 2020, Ann Arbor adopted the A2ZERO plan to achieve carbon neutrality by 2030, which includes local generation of solar power and generation from large-scale solar power plants on agricultural lands (City of Ann Arbor, 2020). Grand Rapids aims to source 100% renewable energy for municipal operations by 2025 (Kransz, 2020). Lansing is also in the process of identifying urban locations suitable for renewable energy development.

Solar Developers

Solar developers are companies that build solar power plants.

- **Private developers**: Companies that specialize in building solar power plants. This can include engineering, procurement, and construction, commissioning, and operations and maintenance.
- **Utility companies**: Utility companies sometimes develop their own solar projects, often with the partnership of a company specializing in construction. Sometimes a private developer builds the project and transfers it to the utility company to operate.

Box 1: Solar developer definition

With solar developers seeking to site projects on thousands of acres of agricultural land, states have been considering and implementing voluntary or mandatory pollinator habitat development on the land. (See Box 1 for a definition of a solar developer.) In Michigan, developers must plant pollinator plants on part of the land if the solar site includes land enrolled in a time-delimited farmland preservation program under Public Act 116. These are typically called PA 116 lands, and the PA 116 program is further explained in this report. Pollinator habitat initiatives interweave the grand challenge of energy transitions with the grand challenge of addressing and reversing the decline of some pollinator species.

The significance and urgency of the pollinator challenge in the United States and Michigan

Managed honey bees are responsible for most agricultural pollination services and all honey production. However, they are only one of many bee species and are not native to North America. There are over 4,000 native species of bees in North America, of which approximately 465 have been seen in Michigan (Gibbs et al., 2017). Pollinators include a wide variety of native bees, butterflies, beetles and flies, as well as birds and bats. Solar pollinator habitat could benefit either wild or managed bees, or perhaps both, depending on the habitat's design. Not all pollinators are experiencing decline; for example, half of Michigan's bumble bee populations are stable or increasing, while the other half are in decline. The rusty-

[1] DTE was formerly called Detroit Edison, but its formal name is now DTE Energy.

patched bumble bee has not been detected in Michigan since 1999 and is considered extinct in the state (Graham, 2019). In 2020, the U.S. Fish and Wildlife Service (USFWS) determined that the monarch butterfly is eligible for protection under the Endangered Species Act, but declined to list it (U.S. Fish and Wildlife Service, 2020). Michigan is an important state for monarch conservation because the Great Lakes coastlines are monarch migratory corridors (Schroeder, 2014). Monarchs gather at Peninsula Point on white cedar trees in the Hiawatha National Forest in Michigan's Upper Peninsula prior to crossing Lake Michigan in the fall. The shores of Lake Michigan in lower Michigan and Saginaw Bay are also important gathering sites for the fall migration to Mexico (Kirschbaum et al., n.d., p. 75).

Arguably ***the most significant threats to pollinators as a whole are climate change and habitat loss***, although the threats to pollinators could be better understood as multi-faceted and interconnected. Human conversion of grasslands to farms, subdivisions, shopping malls and many other land uses has removed the forage (pollen and nectar from flowers) and nesting sites necessary for pollinator species' survival. Loss of grassland prairie habitat is a primary cause of decline in ground-nesting solitary bee species (Kline & Joshi, 2020). Furthermore, the United States has 40 million acres of monocrop turfgrass lawns, often devoid of flowers because of herbicide use (Jabr, 2013). Pollinators that are "specialists," or depend on only one or several plant species for foraging or nesting, are most affected by habitat loss. For example, *Dufourea monardae* is a specialist of Monarda (or bee balm) (Gibbs et al., 2017). In another example, monarch butterflies are threatened mainly owing to habitat loss since the caterpillars rely only on milkweed for food. "Generalist" bees, such as some bumble bee species, are less affected by habitat loss. Honey bees require significant nectar and pollen resources to maintain large colonies, but they can be moved to suitable locations by bee keepers.

An additional factor affecting pollinators is ***the use of insecticides in agriculture*** and by homeowners. For example, neonicotinoids have recently received attention because they are highly toxic to bees. The chemicals are coated onto seeds used in agriculture, and absorbed by the plants' tissues, and can therefore be found in nectar and pollen (Sanchez-Bayo & Goka, 2016). Bees can then be harmed depending on the dose and exposure length when they ingest contaminated pollen, nectar or water. From 1997 to 2012, the insecticides used in U.S. agriculture have resulted in a 9-fold to 121-fold toxic load increase to bees, depending on the region (Douglas et al., 2020). The largest increases occurred in the "heartland" USDA region (e.g., Ohio, Indiana, Illinois, Iowa, Missouri) due to widespread use of treated seeds. After evaluating the same body of scientific evidence on neonicotinoids, the European Union restricted the use of neonicotinoids while the U.S. Environmental Protection Agency did not (Bianco et al., 2014).

Parasites and pathogens pose a severe threat to native bees and honey bees. For example, a parasitic mite, *Varroa destructor*, infects colonies and can transmit pathogens that lead to honey bee colony collapse (Bianco et al., 2014). Pathogens (e.g., *Nosema, crithidia*) can quickly spread across the country since commercial honey bees are transported from place to place.

Commercial beekeepers face numerous challenges. The work is arduous. One beekeeper interviewed for this study reported that he typically works 100 hours per week. To provide pollination services to agriculture, beekeepers move the insects from one crop to the next, which often requires traveling across the country. If the bees were kept near a monocrop, such as almond trees, they would starve once the crop finished blooming. U.S. commercial beekeepers lost an estimated 43.7% of their colonies from April 2019 to 2020 (Bruckner et al., 2020). Due to these large losses, this interviewee reported that most beekeepers are struggling to keep their businesses afloat. However, commercial beekeeping is economically important. For example, it contributes $1 billion annually to Michigan's economy through pollination of certain crops (Hansen et al., n.d.).

***Pollinator decline affects native species and ecosystems and agriculture**.* Most fruits and vegetables require pollination, such as blueberries, cherries, apples, asparagus, squash, carrots and pumpkins, as well as legumes like beans. Overall, 35% of the food people eat requires insect pollination (Bianco et al., 2014, p. 8). Declines in pollinators can therefore reduce crop production and agricultural revenue. In addition to managed honey bees, wild pollinators also play a role in crop pollination and can even pollinate some crops more effectively (e.g., tomatoes, strawberries) than managed European honey bees (Garibaldi et al., 2013). One study found that a reduction of both native pollinators and honey bees would reduce U.S. production of apples, tart cherries, sweet cherries, blueberries and watermelon (Reilly et al., 2020). In addition to the agricultural benefits, wild flowering plants also depend on pollinators, so conserving pollinators is also essential for maintaining biodiversity and ecosystem health (Ollerton et al., 2011).

An intersecting challenge: Loss of farmland in the United States

According to the American Farmland Trust, agricultural lands were converted to other uses at a rate of 2,000 acres per day between 2001 and 2016, with a total of 11 million acres lost (Freedgood et al., 2020 p. 30). Approximately 7 million of these acres were converted to low-density residential developments, and 4 million acres were converted to urban and highly developed land use. Furthermore, in Michigan, agriculture annually contributes over $104.7 billion to the economy (Michigan Department of Agriculture and Rural Development, n.d.-b).

On average, there are four times as many U.S. farmers over the age of 65 than under 35 (Freedgood et al., 2020). A mass transfer of land is therefore imminent, especially as the majority of farms are no longer inherited (p. 18). Decisions of retiring farmers will shape the overall landscape available for farming. Leasing or selling agricultural land for solar power is one retirement option for farmers. Though economic considerations are certainly among the most important factors in farmers' decisions about their land, many farmers also feel an "ethical relation" to their land, believing they have a "moral obligation to conserve" it (Vaske et al., 2018, p. 1127). Furthermore, many farmers view farming as a lifestyle that is deeply interconnected with their identity, rather than a job (Vayro et al., 2020). Farmland conservation organizations, such as the American Farmland Trust, are generally advocating against the use of farmland, particularly farmland with high quality soils, for large-scale solar power generation (American Farmland Trust, n.d.).

Rather than making assumptions that solar generation will impede agricultural integrity, studies are needed to understand how many acres of farmland, and what types of crops grown on that farmland, would conflict with food production for the duration of a 30-year lease at the macroscale. Such a figure would be more complex than a simple amount of acreage because land leases and sales affect the price of agricultural land and the resilience of specific farming communities. Further research will be needed on this matter to ensure that solar development does not disrupt food security, and also to ensure that concern about conversion of farmland to solar power is not exaggerated.

Summary: Solar futures

In summary, siting solar power on agricultural land is interweaving three challenges: retrofitting aging and polluting energy systems, supporting pollinator health, and avoiding loss of prime farmland in the United States. Solar power has long been associated with utopian outcomes (Moore, 2019). For example, it has been seen as a technological fix, or a "techno-fix," that allows people to use "new technologies to avoid making social or political changes" (Laird, 2001). Historian and political scientist Frank Laird studied how advocates of large-scale solar power installations have long argued that these installations are a techno-fix because they can be plugged into the existing grid infrastructure quickly, with the greatest cost efficiency, fewer changes in governmental and societal institutions, and minimal behavior changes in energy use (Laird, 2001, p. 156). Another set of solar advocates have long argued for a greater paradigm shift in how electricity is generated and consumed, replacing today's electricity infrastructure with decentralized rooftop solar systems owned by communities and individuals. These advocates assume distributed solar power will cause people to be more responsible in conserving energy and improving energy efficiency, focusing on their local community and local revenue generation, and improving the equity of energy outcomes. This too is a version of a techno-fix because it assumes that inanimate solar panels and a more individualistic ownership model will de facto improve social outcomes. In this study, we see techno-utopian expectations being set around a new domain: the intertwining of pollinator habitat and agriculture into solar power facilities to avoid trade-offs. In reality, achieving social and environmental benefits requires strong stakeholder consultation and collaboration and time-consuming work to tailor project benefits to specific communities and build trust so that trade-offs can be made in an equitable and responsible manner.

These techno-fix framings have set high expectations that solar power can avoid any negative outcomes or trade-offs. Social scientists have studied how peoples' expectations for new technologies matter greatly; they have noted that setting expectations high and disappointing them often impedes technological development (e.g., Van Lente, 2000). In our research, we identified a variety of ways that intertwining the goals of developing clean solar power relatively quickly, improving pollinator health and increasing abundance, and avoiding farmland consumption can let down the expectations of stakeholders.

In contrast, techno-realist perspectives treat all technologies as having both benefits and drawbacks, requiring the evaluation of trade-offs. Further, the trade-off calculus will change based on the context of the specific site. Solar developers themselves often set very high expectations when advocating for projects and their benefits, which can backfire, resulting in pushback from members of the public affected by new solar installations, particularly at a time when trust in institutions is at a record low. Additionally, researchers typically focus in depth on a single-issue domain, which can lead to disappointed expectations when the trade-offs related to their priority area intersect with the trade-offs of a different priority area. The public's expectations can be disappointed when concrete projects that have trade-offs and local complexities are proposed for their neighborhood or community.

This framing is not meant to excuse poorly planned solar development, nor is it meant to suggest that people involved in solar development ought not to do their best to avoid, improve, and ameliorate project trade-offs. Rather, we suggest that carefully establishing techno-realist rather than techo-utopian expectations for solar development on agricultural lands through stakeholder engagement and interdisciplinary collaboration is currently lacking in the United States but necessary for setting reasonable expectations and managing trade-offs.

Methodology

We conducted 50 interviews with 59 people representing five stakeholder groups: formal academic experts with PhDs employed by universities who research pollination (n=8), energy utilities and developers (n=12 with 17 interviewees), public policymakers and public policy experts focused on engineering and economics (n=16 with 17 interviewees, plus one written response), farmers and farm organizations (n=8 with 10 interviewees), and community organizations (n=5). These interviewees are labeled by group: expert, energy, policy, pub pol econ, ag, and communities, respectively. We contacted a total of 117 potential interviewees to request their participation. We conducted the interviews using Zoom teleconferencing service from October 2020 to April 2021. Most interviews were one hour long. We use a numbering system to identify the interviewees rather than naming them in order to protect their identities. We omitted numbering when we used an identifying feature, such as institution type, to identify an interviewee.

We also attended the virtual town hall for the Carroll Road Solar Farm proposed for Lenawee County, and we watched a recording of a Michigan Senate hearing on proposed changes to property tax structure for solar power. We attended and took and analyzed notes on four webinar meetings held by MSU Agricultural Extension in fall 2020 and a January 2021 webinar by the Bee and Butterfly Habitat Fund.

The interviews were professionally transcribed. We coded, or categorized into themes, the transcribed interview question responses using Atlas.ti software. Three people on the research team did most of the coding, and the lead author reviewed all codes to ensure that the results were uniform. We used a combination of theoretical, analytical and descriptive coding with a total of 351 codes. The theoretical codes were developed primarily using papers on renewable energy siting by Apostol et al. (2017), Devine-Wright (2011), Laird (2001), Moore and Hackett (2016), Phadke (2010), and Smardon et al. (2017). We grouped the codes into nine overarching themes: pollinators and pollinator habitat, wildlife and environment, agriculture, policy, land use and place, epistemology, energy, references to states outside of Michigan, and cooperation and engagement. The theoretical codes were mostly subsumed under these categories. We further grouped each code category into subgroups and then wrote memos about the findings from each subgroup.

Technical literature overview: Solar on agricultural lands

The term “agrivoltaic systems,” or agrivoltaics, is being used both in marketing and scientific journal articles to refer to the combination of solar energy and agriculture production on the same land (Pascaris et al., 2020). While agrivoltaics and solar siting on agricultural lands is a relatively new area of research, there is a growing body of technical literature that focuses on solar pollinator habitat, co-location of solar panels and farming for food and biofuel crops, changes in water quantity and quality, and effects on soil. Researchers are also evaluating crops’ shade tolerance, the impacts of water runoff from the panels on crops, changes in wind patterns and soil temperature, and possible crop protection from hail (Dupraz et al., 2011). Furthermore, a project called InSPIRE, led by the National Renewable Energy Laboratory (NREL) and Argonne National Laboratory, examines pollinator seed mix and operations and maintenance costs for pollinator habitat. It includes experimental research in Minnesota at three types of sites: dry and sandy soil, prime farmland, and a wetland. The researchers expect to publish results in fall 2022.

Initially, solar developers in the southwestern United States would blade the site—removing the vegetation, rocks and other materials from the site—and grade it to level the surface. Then they would apply herbicides and in some environments lay gravel. These practices can cause erosion and drainage issues on the site; therefore, it has become more common to simply sink the piles, or posts, with the solar panels affixed to them into the ground without removing vegetation. Alternatively, or in addition, turf grass is seeded under the panels.

Tables 1 and 2 provide an overview of the existing technical articles that have studied agrivoltaics and pollinator habitat interventions to facilitate dual land uses on solar sites. The wide range of issues explored in these articles begins to illustrate the plurality of goals related to implementing effective pollinator habitat or growing crops or other vegetation on solar sites. These issues are outlined in Table 1 and include the provision of ecosystem services, growing food crops, growing biofuel crops, minimizing irrigation needs through water runoff and shade from the solar panels, growing different types of grass, applying seed to the site using different methods, grazing, evaluating pollinator habitat options, and providing wildlife and bird habitat.

Table 1: Technical literature by thematic focus (LucidChart)

Table 1: Technical literature (Dual land use techno-interventions) by thematic focus

Focus area	Studies	Focus
Providing ecosystem services	Barron-Gafford et al. (2019); Semeraro et. al. (2018); Walston et al. (2018); Walston et al. (2021)	Food production Water efficiency-- less heat stress for crops Pollination Economic services (honey, medicinal plants) Sediment retention Carbon sequestration Increased panel efficiency
Growing food crops	Amaducci et al. (2018); Aroca-Delgado et al. (2018); Barron-Gafford et al. (2019); Dinesh & Pearce (2016); Dupraz et al. (2011); Malu et al. (2017); Marrou et al. (2013); Marrou Guilioni et al. (2013); Marrou, Wery, et al. (2013); Majumdar & Pasqualetti (2018); Moreda et al., (2021); Ravi et al. (2014); Sekiyama & Nagashima (2019); Weselek et al. (2019)	Solar power for greenhouses Chiltepin pepper, jalapeño, cherry tomato Grapes, wheat, lettuce, cucumber, corn, potato Agave for biofuel
Minimizing irrigation needs through water runoff and shade	Barron-Gafford et al. (2019); Hassanpour et al. (2018); Ravi et al. (2016)	Irrigation from rain runoff from panels Reduced water for washing panels Decrease of dust/ erosion Greatly increased crop irrigation efficiency 126% increase in biomass of grass
Growing different types of grass	Beatty et al. (2017); Hassanpour et al. (2018)	Grew warm and cool season grasses to revegetate site; different level of vegetation found on areas of site based on moisture & temperature
Applying seed	Beatty et al. (2017)	Trialed a nurse crop, straw mat with fiber backing, and bare ground seeding: similar results
Grazing	Kochendoerfer et al. (2021)	Preliminary data suggest feasibility of grazing sheep (Not peer reviewed)
Planting pollinator habitat	Blaydes et al. (2021); Fox & Bennett (2019); Graham et al. (2021); Semeraro et al. (2018)	Plan to plant melliferous crops at solar sites Site-specific nature of habitats affects pollinator design
Observing animal & avian use of site	Beatty et al. (2017)	Grass planting and panels provided deer bedding and bird perches
Soil quality	Choi et al. (2020)	Redistribution of moisture from the panels onto the site. Analyze soil quality.
Decision-support tool	Randle-Boggis et al. (2020)	Developed a decision support tool for ecosystem co-benefits at solar parks
Cost	Schindele et al. (2020)	Examines added cost of agrivoltaics

Table 2: Technical literature by type of evidence (LucidChart)

Table 2: Dual land use techno-interventions literature by geography and scale

Focus area	Studies	Geography	Solar size
Computer models	Amaducci et al. (2018); Dinesh et al. (2016); Dupraz et al. (2011); Majumdar & Pasqualetti (2018); Malu et al. (2017); Moreda et al. (2021); Sekiyama & Nagashima (2019); Walston et al. (2018); Walston et al. (2021)	Arizona, California, France, India, Italy, Japan, Midwest US; Spain	Very small
Experiments	Barron-Gafford et al. (2019); Beatty et al. (2017); Choi et al. (2020); Hassanpour et al. (2018); Graham et al. (2021); Marrou, Guilioni et al. (2013); Marrou, Wery et al. (2013); Marrou et al. (2013)	Arizona, Oregon, Colorado, France	1.4 MW or smaller except Graham (10 MW)
Economic analysis	Schindele et al. (2020)	Germany	up to 10 MW
Desktop/ literature review	Aroca-Delgado et al. (2018); Blaydes et al (2021); Dupraz et al. (2011); Fox & Bennett (2019); Ravi et al. (2014); Ravi et al. (2016); Randle-Boogis, 2020; Semeraro et al. (2018); Weselek et al. (2019)	Italy, India, California	Under 1 MW

Much of the technical literature uses computer modeling and thought experiments. Furthermore, the experimentation that has been conducted has been on relatively small solar sites: 1 MW or smaller. There is a dearth of data on solar sites over 50 MW. This gap is important for pollinator habitat as the O&M, especially for invasive species, is likely to be more challenging on larger sites. Policy requirements or voluntary recommendations for pollinator habitat that have recently been implemented in Michigan and other states provide an opportunity for studying early implementation of pollinator habitat and other dual-use projects at solar sites. These sites should be studied to measure their effectiveness and to develop recommendations for improvement in environmental, social and economic outcomes.

Siting solar power: Contradictions between broad public support and local opposition

Overall, the Michigan public strongly supports a transition to wind and solar energy. According to the State of the State survey, 82% percent of the public supports a transition away from coal in Michigan (55% strongly support and 27% somewhat support). Support for solar power is almost ubiquitous: 90% of the public supports more solar use in Michigan (64% strongly support and 26% somewhat support). Support for more wind energy use in Michigan is also strong, with 86% of the public supporting more use of wind (59% strongly support and 27% somewhat support) (Moore & Anctil, 2018).

Despite this broad public support, siting this much renewable energy is complex from a social perspective. Public willingness to lease land—with the support, or at least without ardent opposition from neighboring households—is the most complex and least controllable factor in identifying solar sites and successfully siting solar power plants. Michigan developers seeking to site wind on agricultural land have faced opposition from farmers and other community members because of noise, disruption of sense-of-place, potential damage to farms' irrigation systems, and perceived conflicts with hunting. The controversy led to a wind moratorium in Huron County. Protest signs that read "NO solar farms" are common on the roadsides near and even directly adjacent to the Assembly Solar construction site in Shiawassee County (Figure 2) (Montanez, 2021).

According to interviewees, Michigan has proven to be among the most challenging states for siting wind power plants because it lacks large parcels of contiguous land owned by single landowners, which are more common in states such as Texas. In the southwestern United States, large tracts of federally owned Bureau of Land Management (BLM) land have been proposed or developed for renewable energy. In contrast, there are only 610 acres of BLM land in Michigan (Vincent et al., 2020, p. 28). A researcher we interviewed explained that land east of the Mississippi River tends to be privately owned in smaller parcels, which poses challenges for developers.

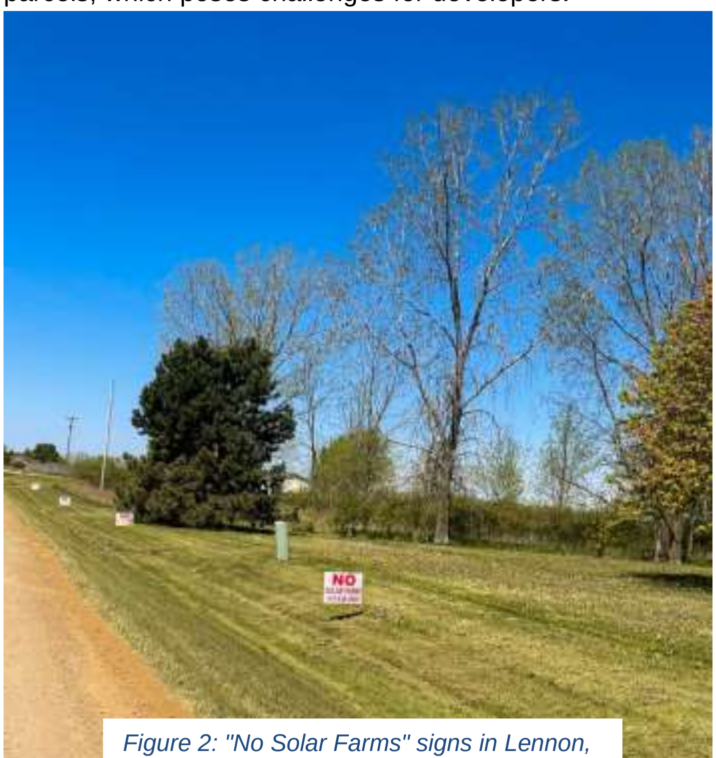

Figure 2: "No Solar Farms" signs in Lennon, Michigan. Photo by Sharlissa Moore.

Given the small fraction of the overall land that is needed for solar power, a common visualization in renewable energy development discussions suggests that there is a surfeit of barren, empty space for solar installations (i.e., just a small box). See Figure 3 for an example of such a visualization. This often leads people to assume there ought not to be any conflicts over land use and also that there 'must be somewhere to put solar power that is better than here.'

Figure 3: Desertec Foundation illustration of the amount of land needed for concentrating solar power plants to power world and regional energy demand. Creative Commons, Desertec Foundation.

Overall, people respond to survey questions with a hypothetical conception of renewable energy, which can shift when a concrete project is proposed on a landscape that they value. Social science studies on renewable energy siting conflicts consistently find that proposed solar sites are not just areas of vacant land but are places valued by nearby communities for reasons that are both tangible—loss of the use of the land, reduction in property values, fears about safety—and intangible because they are related to peoples' identities and values (e.g., Devine-Wright, 2011; Moore & Hackett, 2016). The factors that cause people to value a parcel of land do not necessarily objectively exist within the land, but exist vis-à-vis the perceptions, memories, ideas and feelings of community members. Barren, flat farmland in the eyes of one person is an important landscape with history and value to another person, who may therefore resist change to that landscape. This subjective valuation of places is the overarching reason that most commonly underpins community opposition to renewable energy.

For people whose values for the land are instrumental and tangible, monetary compensation and other mitigation measures can often address concerns. A new Department of Energy initiative proposes formal Community Benefit Agreements.[2] Developers sometimes provide "good neighbor payments" to compensate people who live near the solar facility but who do not financially benefit from leasing their land. One interviewee (pub pol econ 9) described this as the equivalent of "baking a pie and taking it over [to a neighbor]." Another interviewee (communities 3) stated:

> The company actually paid [an unhappy neighbor] even though he wasn't a landowner. They made a financial contribution to him, basically to buy his goodwill ... Since then, he stopped complaining about the project, and he's happy about the income that it generated.

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[2] See Community Benefit Agreements, Department of Energy, Office of Economic Impact and Diversity, https://www.energy.gov/diversity/community-benefit-agreement-cba-toolkit.

Furthermore, while many opponents of solar facilities fear they will reduce property values, most studies have found that solar power does not reduce property values, and some have even found an increase in property values (Al-Hamoodah et al., 2018, p. 68). While a national study on property values is lacking, a forthcoming study from Lawrence Berkeley National Laboratory is expected to address this gap. However, for people whose values for the land are more intangible, monetary compensation is often insufficient and offers can even backfire (Moore & Hackett, 2016).

In addition to payments, another means of reducing literal aesthetic impacts is to select visually appealing fencing. A “green fence” consisting of trees, hedges, and shrubs can obscure the view of the solar facility for neighboring households and also provide resources for pollinators. Best practices indicate barbed wire fences and chain link fences should not be used. Rather, a livestock fence (Figure 4) that better fits the community aesthetic of an agricultural place, or other decorative fencing, should be used, even though it increases the cost. (Note that fencing is required to adhere to North American Electric Reliability Corporation standards.)

Figure 4: Assembly Solar, fencing, dandelions, May 14, 2021. Photo by Sharlissa Moore.

Many interviewees were optimistic that siting solar power will be less contentious than developing wind energy has been in Michigan. Interviewees discussed the difference between large, “vertically massive” wind power developments that can be seen for miles (energy 9) and more “concentrated,” lower profile solar developments (energy 8). The term “viewshed,” analogous to watershed, is used to describe how renewable energy looks within a landscape (Smardon et al., 2017). However, opposition to renewable energy is therefore not simply about what people literally see on the landscape (Wolsink, 2018). A community member (3) stated:

> The aesthetics [were] another big concern that several community members talked about [at a zoning hearing]. They spoke about moving to our area because it was a quiet and rural area with

> scenic landscape, natural landscape uninterrupted by human installations and if that was appealing to them and [they] were wanting to maintain that around their property. The property owners in the rural community where the power is being generated are benefiting because they're being paid for their property use, but I think in rural communities, it's a sense of ownership or connection to the land [that] is sometimes much stronger than the financial ramifications. I think there's a mindset in rural communities that rural communities take care of the land, and so they're benefiting from it but in a way that is reciprocal to their care.

This quotation illustrates how aesthetics go beyond literally seeing the infrastructure on the landscape. Therefore, it will be important to bear in mind that while solar installations may face less resistance than wind, solar will still be controversial with some stakeholders because of disruption of sense of place.

Finally, the achievement of energy equity is another factor that complicates overall acceptance of solar power when solar development is situated in a particular place. Who has in the past benefited and who has been harmed by electricity generation is one consideration that affects energy equity. Affordability is very important in Michigan. One social science study found that Detroit residents are concerned that energy extractive practices entrenched in fossil fuel generation in the state of Michigan will continue, with Detroit producing solar power that is exported to the rest of the state rather than benefiting local residents. The study also found that people in Detroit are very concerned that renewable energy will increase their electricity prices and that this will place a disproportionate burden on low-income residents (Graff et al., 2018). All of these factors—people's local value for the landscapes where they live, people's concern about tangible economic harms, and energy equity concerns—increase complexity in siting renewable energy generation within the landscape.

Benefits and drawbacks of solar power in general

Low cost: The most commonly identified benefit of solar power in interviews was the cost, and avoidance of the price volatility that can result from using fossil fuel commodities to produce electricity. This provides stability and certainty in energy costs, as utility companies sign 20- to 25-year fixed cost power purchase agreements. An interviewee from DTE stated that utility-scale solar power is the "best value plan for our customers and also matched up very directly against the goals and objectives that our customers expressed to us when we met with them." An interviewee from a national solar organization argued that the reduction in cost has reduced the politicization of solar power. "In many areas, as the cost of solar has come down, it's become a less partisan issue, and just more an economics issue." Note that this refers to the cost of solar power compared to the cost of other options for new energy generation (not the cost of electricity from existing depreciated power plants) and compared to the relative cost infeasibility of solar power just several years ago. Interviewees also mentioned that **solar power is less complex** than wind, with fewer moving parts.

The next most commonly discussed benefit of solar power was the **favorable job outlook**, with a potential for the construction jobs to be local. Additionally, interviewees commonly cited the **reduced carbon dioxide emissions** from solar power compared to fossil fuel technologies, which can help utility companies meet their carbon dioxide emissions reduction goals. An interviewee from the West Coast discussed how this could have positive long-term effects for agricultural industries. For example, mitigating climate change will protect specialty crops like wine grapes from wildfires. Three interviewees addressed the **health benefits of replacing fossil fuel generation**, which is a commonly discussed priority among environmental activist groups in the state. That said, interviews with utility companies addressed the difficulty in pricing the health benefits, social benefits, and generally the intangible benefits of solar power, since the utility sector has not priced these costs and benefits in the past.

A number of interviewees discussed the benefits of solar power in **meeting demand at peak hours of the day or peak seasonal demand in the summer**, when HVAC needs switch from heating from distributed natural gas, to air conditioning from the electricity grid. While California has experienced issues with the mismatch in supply from solar power and electricity demand, Michigan has different electricity demand patterns than California. Therefore, reducing peak demand is a benefit of solar power.

One interviewee discussed the importance of solar as part of **diversifying the sources of our electricity and improving energy security**. However, this is less common in the discourse than it was historically (Laird, 2001), likely because the shale revolution has provided such a large supply of domestic oil and natural gas. Further, less than 1% of U.S. electricity is generated using fuel oil.

Land use and solar power overview

Estimates vary for the average land use requirements for utility-scale solar power per MW. Badilion et al. (2020) find that utility-scale solar photovoltaic plants use 3.5 to 6.2 acres per MW of installed capacity. According to an older NREL study, utility-scale solar photovoltaic plants over 20 MW in capacity require an average of 7.9 acres of direct land use per MW (Ong et al., 2013). Even using the more conservative figure, developing Consumers Energy's 6,000 MW solar power goal would require 47,400 acres of land. In 2017, Michigan had 9,764,090 acres of farmland (U.S. Department of Agriculture, 2017). Therefore, the goal would require, at most, 0.005% of Michigan's farmland. However, past experience with energy siting shows that the small percentage of land used does not mean that siting will be uncontroversial.

Aside from farmland, Michigan has 4.6 million acres of state-managed land (Michigan Department of Natural Resources, n.d.). Approximately 85% of this land is forested, and the rest is state parks, state game, and wildlife areas. Therefore, most of this land is not well suited for solar power generation, although according to interviewees, the Michigan Department of Natural Resources is evaluating small parcels of degraded land under its jurisdiction for solar power development. Michigan's federally owned land is managed by the forest service (2,874,631 acres), National Park Service (632,280 acres), U.S. Fish and Wildlife Service (117,816 acres), and Department of Defense (12,262 acres) (Vincent et al., 2020, p. 28). Therefore, this land is either forested, important for wildlife and conservation, or is used for military operations. Furthermore, federal land requires an extensive environmental review process under the National Environmental Policy Act (NEPA). The other primary types of land for ground mount solar are brownfield sites such as contaminated areas and landfills, which we will discuss in further detail later in the report.

Interviewees expressed uncertainty about the impacts of utility-scale solar power on wildlife and threatened and endangered species since it is a relatively new technology to the state. An interviewee from Consumers Energy stated that solar is "still new for us. And so, we're still studying and trying to understand and learn about those potential impacts." DTE has more experience because the utility company has already constructed a large-scale solar power plant. Impacts on wildlife and threatened and endangered species are site-specific and therefore difficult to generalize.

According to interviewees from the Fish and Wildlife Service, siting solar power on agricultural land generally has fewer environmental impacts than on undeveloped land with greater biodiversity (e.g., wooded areas, riparian zones, wetlands, grasslands). Since agricultural land provides large tracts of contiguous land already, the solar installation would not cause further fragmentation of habitat. The Nature Conservancy is also developing wildlife fences and monitoring for solar sites. Furthermore, agricultural land does not typically provide high-quality habitat for rare or endangered species. If land that provides habitat for a species listed as endangered or threatened by the federal or state government were to be converted for solar power, there could be negative effects on such a species. Interviewees mentioned the Kirtland’s warbler, a bird that was delisted as an endangered species a number of times (Cornell Lab, n.d.). However, since the warblers live in jack pine forest in Michigan’s Upper Peninsula during the summers rather than on agricultural lands, conservationists we interviewed did not anticipate there would be any effects on that species.

Interviewees discussed land use and visual impacts as the most common drawbacks of solar power. A number of interviewees saw pollinator habitat and other multiuse land as an opportunity to mitigate the land-use impacts of solar power. These habitats can provide “ecosystem services.” Several interviewees argued that solar power can increase the biodiversity of the landscape if well planned. One interviewee from an NGO stated:

> When they are putting in these solar farms, they’re thinking beyond the solar. They’re thinking about pollinators. They’re thinking about nature, and that is very encouraging, and I’m telling you just being [at a solar site] this summer, the wildlife, the butterflies, the grasshoppers, the praying mantis, the native bees, it is amazing to me.

The remainder of the report discusses these expectations.

The governance of solar power: The role of federal, state and local scales

Federal government

Most renewable energy decision-making in the United States is governed at the state and local levels. The most important role the federal government has played in promoting a transition to solar energy is the Solar Investment Tax Credit, or ITC, which provides a 26% federal income tax credit on the construction of both residential and utility-scale solar power plants (Solar Energy Industries Association, n.d.). The tax credit is currently set to phase out, falling to 22% for projects beginning construction in 2023 and 10% for commercial projects beginning in 2024. However, it is possible the Biden administration could extend the tax credits. Federal environmental regulation can also affect solar development. For projects developed on federal land, which would be unusual in Michigan but is common in the Southwest, an extensive environmental review process must occur under the National Environmental Policy Act (NEPA). An environmental consultant explained that the NEPA process can triple the cost of the environmental review for solar projects.

For projects on any land, developers must comply with the federal Endangered Species Act, the Migratory Bird Treaty Act, the Clean Water Act, and other federal environmental legal protections.

However, an interviewee from the U.S. Fish and Wildlife Service explained that typically projects can move forward in Michigan even if there are endangered species on the land.

> Generally, even when somebody is building something in endangered species' habitat, it would be really, really rare for the Fish and Wildlife Service to advise stopping a project for solar because even the Endangered Species Act provides permitting mechanisms. There are ways that almost every project can go forward if somebody chooses to do that.

In summary, at the federal scale, all national environmental laws must be followed, and the federal government provides tax credits. However, most decisions about renewable energy are made at the state and local levels.

State government

The state legislature develops legislation that sets renewable energy requirements in the state of Michigan. This legislation typically comes in large reform packages, seen in 2000, 2008 and 2016. Michigan has a state-mandated requirement of 15% renewable energy by 2021 (see Figure 5). Large utility companies have established more stringent requirements.

<u>Michigan energy laws:</u>

2008: Clean, Renewable and Efficient Energy Act
Required 10% of electricity sales from renewables by 2015. (Later increased to 15% by 2021).
Required to be 50% privately owned.

2016: Public Act 341:
Required investor-owned utilities to submit an integrated resource plan for new generation. Competitive procurement required.

Figure 5: Michigan energy laws

The Michigan Public Service Commission (MPSC) is a regulatory agency with oversight of investor-owned utility companies. The legislature has required utility companies to submit integrated resource plans (IRPs) to the MPSC that detail and justify plans for future energy generation. These plans are driving the growth of solar power in Michigan. According to an interviewee from the MPSC, for Consumers and DTE, "solar was the go-to resource for all of the needed capacity [in the IRP] and also addresses the cost situation. And the cost of solar is continuing to decrease." However, unlike in some states, Michigan regulatory organizations are not involved in permitting power plants.

Local government

Michigan is unique in the level of autonomy that local townships, municipalities and counties, have over power plant permitting. The state has no jurisdiction unless the development affects state-owned land. This decentralized process subjects renewable energy development in Michigan to complex and contentious local politics and planning processes. Unlike state policies, local ordinances and zoning for land use can quickly change, meaning developers can lose their right to develop a site in a matter of weeks. Local zoning laws establish the required distance, or setbacks, between the solar installation and roads or houses. Local authorities can also require pollinator habitats and other project add-ons.

According to an energy sector interviewee (1), there are over 2,000 zoning districts in the state of Michigan. Furthermore, large solar installations often span multiple zoning jurisdictions (energy 5). Some interviewees explained that when renewable energy zoning is in the hands of local governments, zoning ordinances are more easily influenced by local public opinion, and even by manipulation or misinformation. If people on the zoning and planning committee in the relevant jurisdiction oppose renewable energy development, they can implement policies that de facto prohibit it. An interviewee (ag 8) explained:

> Just through the township meetings, the opposition [members] were able to generate enough questions in people's minds that they just decided to not allow it, is what it boiled down to. We tried to go through the zoning process and get it zoned. We tried to work with local residents, but ... the local township boards adopted a zoning policy that was just too restrictive. That's what's happening to the solar farms in this area also. The local townships are putting zoning in place, but it's just too restrictive to develop the project.

Because of these challenges, several interviewees argued that the state should have more control over permitting solar power plants. For example, a farmer (ag 8) saw local politics as too restrictive for renewable energy development because of the ability to enact ordinances that block projects, and also as too onerous and contentious for local officials. They stated:

> If you could develop some state guidelines and take the pressure off the local officials and say, "Hey, this is what the state says we can do." Then it [puts] less pressure on the local officials. And then the community as a whole can say, "Yes, we want this," or "no, we don't," based on state guidelines. I think personally, I think that's a better way to develop across the state.

Several interviewees argued that local power plant permitting should not change and is desirable because local governments know their community interests best (policy 3, 4). One interviewee stated:

> Siting for sure should be a local issue. [It should be controlled by] whatever jurisdiction has the authority to do planning and zoning for some of the smaller units of local government within their borders. But for the most part, that's extremely local. So, township or city planning and zoning for the siting of things—they know their area the best.

Most interviewees did not expect it would be feasible to foist permitting from local control. An energy sector interviewee (6) explained that in 2008, the legislature considered moving wind energy permitting to the state level. However, this provision was eliminated from the 2008 energy legislation because "the local governments felt like we were taking away the authority that they had to site the energy projects, and they felt that they knew their communities better than we would at the state level." Another energy interviewee (5) stated that "Michigan is never going to eliminate township zoning on behalf of solar developers. So, I would just [suggest] having some guidance or best practices for zoning [from the state]." In addition to state guidance, interviewees recommended that developers should approach local governments with a collaborative attitude. One interviewee (policy 2) stated:

> If the developers come in in a very heavy-handed way and say, "We want a mandate that we can go wherever we want to, and we're going to overrule local decision-making, and we're going to give you what we give you. And here's the capped amount, and statutes says this is what you get, and you'll take it and be happy." Then you're going to see a lot more resistance. You'll see probably some local units using zoning to zone out solar because they don't want it. They don't want the hassle of it.

Overall, control of local government over renewable energy siting in Michigan presents challenges, as well as benefits, but would be difficult to change due to precedent. The next section discusses tensions between local and state governments in potential changes to the way that utility-scale solar energy is taxed in Michigan.

Potential changes to tax codes

The ways in which renewable energy transformations are interwoven with existing problems and inequities in tax policies is another example of the complexity of this grand challenge. Several interviewees saw the local tax revenue solar power provides for local communities for 20 to 25 years as a main benefit of solar power. For local governments, solar power can be an economic development proposition. For instance, a lumber mill town uses solar income to meet their business goals (pub pol econ 7). A developer at a town hall meeting about a proposed project in Lenawee County stated, “Over its anticipated 35-year operational life, the [200 MW] Carroll Road Solar Project is anticipated, or expected, to generate approximately $35.1 million in local tax revenue.”

Currently, the main legislative initiative in Michigan related to solar power proposes a payment in lieu of taxes, or PILT, model. Solar facilities are currently taxed as category 352–industrial personal property solar/wind, with taxes decreasing as the solar equipment depreciates. Furthermore, the cost of the solar equipment has declined in recent years, although the reduced cost enabled solar to be economically competitive on the grid. There are also real property taxes on the land utilized, which has market changes in value like all properties do. In contrast, the PILT would implement a payment on each megawatt (MW) of installed electricity capacity of a maximum of $3,500 per MW. In comparison, Ohio’s PILT (or PILOT) is between $6,000 and $8,000 per MW, depending on the percentage of Ohio-based jobs the project provides, and local jurisdictions can add taxes up to a total of $9,000 (Vorys, 2019). A PILT provides a more stable and predictable tax structure for the company and the local government compared to the current structure. Furthermore, it could avoid previous problems with wind installations, in which the Michigan State Tax Commission accelerated the depreciation rate for wind equipment, spurring ongoing litigation between local government and wind developers (Nelson, 2021). On September 10, 2020, Curtis VanderWall, a Republican from District 35, introduced SB 1105, formally proposing the PILT (S. Bill 1105, 2020). That same day, VanderWall also introduced SB 1106—a similar bill—along with Kevin Daley, a Republican from District 31 covering Bay, Lapeer, and Tuscola counties (S. Bill 1106, 2020). Governor Whitmer vetoed both bills in late December. However, the discussion on the bills illustrates some of the tensions with solar power development on a local scale in Michigan.

The Michigan Senate Finance Committee held a hearing on these bills on September 20, 2020. Several small solar companies testified in support of the PILT. Steve Levitas, Senior Vice President for Strategic Initiatives at Pine Gate Renewables, LLC, testified in support of the initiative. Pine Gate Renewables is a medium-sized utility-scale solar power developer based in North Carolina, with an office in Midland, Michigan. The company develops 2 MW to 20 MW solar installations in Michigan, completing eight 2 MW solar facilities in Genesee and Saginaw counties in January 2021 (Pine Gate Renewables, 2021). Southern Current, another medium-sized developer based in Charleston, South Carolina, also testified in support of the PILT. An interviewee representing a small solar developer explained that property taxes are a major expense for the developer over the lifetime of the facility; thus, the developers target areas with the lowest property tax rates. To illustrate, they explained: “Our solar array in [Michigan is near the] Indiana border. If I were to build it south of where we built it, we’d probably pay a third of the property taxes that we pay in Michigan.” An interviewee from a large developer that exclusively builds projects larger than 50 MW was neutral about the legislation. These larger developers have a higher profit margin on projects and are less affected by the tax code.

Supporters of the PILT who testified at the hearing argued that Michigan's tax policy needs to be updated to ensure Michigan can attract investment in solar development. They argued that Michigan is the only Great Lakes state that lacks a property tax abatement structure for solar power. Dan Papineau, representing the Michigan Chamber of Commerce, called the tax situation a "total mess," explaining he worked with industry representatives to develop the PILT proposal to address the problems. Papineau claimed that the "ornery" tax system stifles investment in solar power plants. The competitiveness argument is difficult to fully substantiate for two reasons. One, As of mid-August 2021, the Midcontinent Independent System Operator's transmission queue for Michigan includes a robust 9,390 MW of solar projects (Midcontinent Independent System Operator, 2021). Furthermore, interviewees familiar with the situation indicated that placing a bid on a project to the utility company is very competitive, with multiple companies bidding. Second, Michigan utility companies are increasing their solar energy goals, and the Midcontinent grid operator does not permit a state to import a high percentage of its electricity generation. Therefore, it seems unlikely these goals will be substantially met out of state.

Officials representing local units of government in the hearing opposed the legislation. They were concerned about the lack of evidence that the $3,500 per MW rate was appropriate and fair. The University of Michigan has since published a report with more guidance on an appropriate rate (Gold and Mills, 2021). This is a complex question since the current payments depend on local property tax millage rates, which are different in each jurisdiction, and on a complex equipment depreciation and multiplier schedule in Section B of the personal property tax form (Michigan Department of Treasury, 2021). Therefore, some jurisdictions may earn more taxes on solar under this model, and others may earn less, although only if they are able to negotiate for the maximum rate. The Lapeer facility, which generates the majority of DTE's installed solar capacity at the time of this report's publication, or 52 MW, would earn $182,000 per year in PILT payments, which is substantially less than it currently receives, in addition to payments for leasing the city-owned land.[3] The city of Detroit charges 63.3 mills ($63.30 per $1,000) for industrial personal property, whereas many townships and smaller cities, such as Lapeer, have much lower millage rates, sometimes more than half of Detroit's rate (Michigan Department of Treasury, 2020). Therefore, how the PILT rate compares to current taxes will depend on the specific jurisdiction's millage rate. The PILT does not account for the fact that property tax rates are different in more urban areas, where land available for development may be scarce, versus more rural areas. The PILT also does not account for the electricity produced, and therefore revenue generated, from a site each year in MWh. See Figure 6 for an explanation of a MW and MWh. The state of New York's policy offers an alternative; the state has exempted solar installations from property taxes but allows local governments to opt out of this exemption or set their own PILOT rate (New York State Energy Research and Development Authority, n.d.).

[3] Thank you to Dale Kerbyson from Lapeer City for providing additional information on property taxes.

What is a megawatt (MW) and a megawatt hour (MWh)?

A megawatt (MW) is a measure of power and refers to the nameplate capacity of the installation, or the maximum amount of energy per second that could be produced by a solar power plant in the sunniest possible conditions. In reality, the solar facility does not produce at nameplate capacity during all hours of the day due to clouds, sun angle, and shading. A MWh is a measure of energy. In this case, it refers to the amount of energy produced by a solar facility.

In 2017, DTE had 56 MW of installed solar power capacity. At the proposed PILT rate of reimbursement, the taxes paid on this energy generated would be $3,500 x 56 MW = $196,000.

The PILT reimburses facilities based on their installed capacity in MW not the electricity generated in MWh. There would be some variance in electricity produced each year due to different amounts of sunlight. In 2017, DTE's solar installations produced 82,204 MWh of electricity. With the same solar capacity, DTE produced 96,571 MWh in 2018 and 76,912 MWh in 2019.

Figure 6: Power (MW) and energy (MWh)

Local government officials' reluctance to accept this rate should be understood within the context of the constrained tax situation for local governments in Michigan. An interviewee (pub pol econ 2) explained that "the State of Michigan has established a financial structure for local governments that is one of the most limited in the country. We fund our cities, villages, townships and counties almost solely on property taxes." According to this interviewee, during the Great Recession, the reduction in property value negated as much as 50% of some local communities' tax revenue. The Proposal A amendment to Michigan's constitution prevents local governments from increasing property taxes at greater than 5%, or the rate of inflation, which means that tax revenue has not rebounded since the end of the Great Recession (Walcott, 2016). Since most local units of government can only tax property, the state has a unique program in which 21.3% of state-collected sales tax is supposed to be redistributed to local governments for unrestricted use. This money was intended to go to local governments with a small property tax base but higher population density. However, the state diverted a total of $6.9 billion of this revenue sharing away from municipal governments between 1994 to 2015, with revenues falling from $900 million per year in 2001 to $260 million per year in 2014 (Citizens Research Council of Michigan, 2015). The state used the funds to balance the general fund budget. Of the remaining amount, 60 percent is allocated to the city of Detroit (Citizens Research Council of Michigan, 2015). Because of this constrained local tax situation, local governments are likely to prioritize whatever new land uses will provide the most tax revenue, particularly if there is limited available land for development within their jurisdiction.

Changes to the tax structure have broader implications for trust among local governments, state government and solar developers. Interviewees expressed that local governments are worried that the state is not looking out for their best interests by attempting to limit already-constrained tax revenue opportunities for local governments through a PILT. Even if the set amount for the PILT is fair to local governments and to developers, the PILT still presents a potential impediment to renewable energy development because it is fostering resentment, which may result in fewer solar projects being developed. Tax revenue plays a large part in a local government's decision to permit renewable energy development. In relation to changes in the wind depreciation schedule, one interviewee (policy 3) explained:

> So the revenue that [the county government] thought they were going to get from [wind] declined dramatically. And so there is a bitter taste for some counties out there when it comes to opening up to larger energy developers because of what happened with the wind issue.

If the state and developers are perceived to be impeding tax revenue for local governments, this may result in more local government siting jurisdictions declining to allow renewable energy within their borders. Tax revenue represents another layer of complexity with scaling up renewable energy generation in Michigan.

Administrative scale: PA 116 workgroup and farmland preservation

There are several different types of farmland preservation programs. The most permanent are called “conservation easements.” In this type of program, farmers are paid market value for the development rights of their land. There is no way to unenroll from the program. The property can be sold but not developed. The city of Ann Arbor’s Greenbelt program, which is preserving farmland surrounding the city, is an example of a conservation easement program (City of Ann Arbor Greenbelt, n.d.). A conservation easement is one retirement plan for farmers that keeps the land in agricultural production. Solar energy projects, however, are incompatible with most easements, which restrict any development. A land lease for solar power production is another retirement option for farmers that would allow the land to go back into agricultural production after the solar project’s end of life, although this is not guaranteed.

Time-limited farmland preservation programs also exist. For example, since 1985, the Farm Service Agency under the USDA has run the Conservation Reserve Program, which pays a rental fee to farmers for 10 to 15 years (Farm Service Agency, n.d.). In exchange, farmers agree to remove the land from agricultural production and to plant grass and trees on the land with the goal of preventing soil erosion and regenerating soil. Twenty million acres are enrolled in the program (Farm Service Agency, 2019). Another example of a time-limited farmland conservation program is the Michigan Farmland and Open Space Preservation Act, or Public Act (PA) 116. Farmers can enroll in the program for a period ranging from 10 to 90 years (Michigan Department of Agriculture and Rural Development, n.d.-a).

There are 3 million acres enrolled in PA 116. Farmers receive a property tax credit on the land enrolled in PA 116 for the duration of the commitment, minus 3.5% of the farmer’s total household income (Michienzi, 2018). The program provided $53 million in tax credits in 2017 (Freedgood et al., 2020). When the program commitment ends, farmers can re-enroll the land in PA 116, or sell it, although selling it requires repayment of the last seven years of the tax credits with interest (Michigan Department of Agriculture and Rural Development, n.d.-a). The land cannot be sold until the contract ends, not even by repaying the tax credits. The only way to exit the contract before it expires is through death or disability that precludes farming.

To enable the scale-up of solar power in Michigan, it was important to allow solar development on PA 116 land. Assembly Solar, a 239 MW solar installation currently under construction in Shiawassee County, needed a portion of two plots of PA 116 land to proceed. PA 116 lands are typically patches of land within a larger farm or grouping of farms. In some cases, it is challenging to build around these patches of land, or to allow access to the farm equipment for farming that patch of land if it were excluded from the solar power plant. Furthermore, contracts for each PA 116 parcel may expire in different years, or even different decades. In some cases, the farmer may not even be aware the land is enrolled because their parents or grandparents enrolled it. Exceptions to PA 116 requirements had already been made for wind turbines, but the previous governor had opposed allowing solar power on PA 116 lands. Because Michigan is shifting from wind to solar development, amending the PA 116 rules became urgent.

In 2018, the Whitmer administration established a workgroup to allow solar power to be sited on farmland enrolled in PA 116. PA 116 is under the jurisdiction of a state agency called the Michigan Department of Agriculture and Rural Development (MDARD). Therefore, changes made to the PA 116 program were administrative policy changes, not changes to legislation.

The workgroup included stakeholders from the governor's office, MDARD, Michigan Townships Association, Michigan Farm Bureau, Michigan Agri-Business Association, Michigan Energy Innovation Business Council (EIBC) and Michigan Environmental Council. EIBC advocates for multiple energy companies, rather than representing a single company's interests. The workgroup met for approximately six months. According to interviewees, the Farm Bureau provided feedback from their members but did not take a position on the policy because the farming community was not in agreement on the issue. One workgroup participant said, "We didn't really have anybody that was committed to blocking it. Everybody [in the workgroup] was trying to work through it pretty collaboratively."

One barrier was that some stakeholders thought farmers would be "double-dipping" if they received both the PA 116 tax credit and a payment from a solar company for leasing this land exclusively for solar power generation. Because it is possible to farm or graze animals around wind turbines, farmers retain the PA 116 tax credit for wind (Michigan Department of Agriculture and Rural Development, n.d.-c). Therefore, the workgroup decided that the tax credits would be paused while the land was being leased for solar power. The participation in the PA 116 farmland will be paused for the duration of the solar lease (20 to 30 years), and the PA 116 contract will be finished once the solar panels are removed. The land remains categorized as farmland rather than being rezoned as commercial or industrial land. Farmers making a decision based purely on economics (not other values or considerations), would choose between the economic benefits of the tax credit versus the payments from the lease. Multiple interviewees reported that the solar lease is always more lucrative than the tax credit.

The workgroup also decided to require solar installations built on PA 116 land to include pollinator habitat; this will be discussed further in the pollinator habitat section.

Lingering confusion over the PA 116 decision

We identified several areas of confusion among stakeholders over the decision to allow solar development on PA 116 lands.

Project decommissioning: Some members of the public were concerned about whether the solar panels and other equipment would be removed at the end of the solar lease, especially if the developer went bankrupt, which would prevent the land from returning to agriculture. Workgroup members shared this concern. A policy (5) interviewee who participated in the workgroup stated:

> We ultimately ended up getting to what I think is a pretty solid policy where we not only allow solar on preserved farmland, but we figured out how to make sure that we keep the agricultural value by ensuring that there are bonds to [deconstruct the solar arrays and] return that land back

> to farmland.

Therefore, removal of the panels is not an issue because developers are required to issue a bond at the beginning of the project to finance the decommissioning and removal of all structures at the end of the project. Furthermore, the facility can be sold to a different operator if a company goes bankrupt.

Return to farming and soil quality: Another area of confusion identified from the interviews was whether the solar site would return to agriculture at the end of the 25- or 35-year lease. This question applies to both PA 116 farmland and other farmland used for solar power. There is not a definite answer for non-PA 116 lands. For PA 116 lands, the farmer must fulfill the remaining years on the PA 116 agreement, but the policy does allow them to enter into a subsequent deferment period after the first solar lease (Michigan Department of Agriculture and Rural Development, n.d.-a). The deferment period cannot exceed 90 years minus the years remaining on the PA 116 agreement. The PA 116 land would not be rezoned as commercial but would remain zoned as farmland, which makes it easier to convert it back to farmland. Additionally, it is possible that managers of conservation easements could exempt solar leasing, since the easement land is guaranteed to go back to agriculture at the end of the lease. Several interviewees used the fact that most farmers only wanted to lease, not sell, the land as evidence that they, or their family members, wanted to eventually farm the land again.

One key issue addressed regarding the return of the land to agriculture was how the solar installation would affect the soil. Some interviewees speculated that by allowing the soil to rest after decades of intensive tilling and planting, the soil quality would be improved by the end of the lease. There is scientific evidence that planting pollinator habitat on former agricultural land improves soil quality (increasing nitrogen retention, total nitrogen, and soil organic carbon) (Pérez-Suárez et al., 2014). The Conservation Reserve Program discussed earlier focuses on planting cover crops to reduce soil erosion and runoff of nutrients to improve water quality (Farm Service Agency, 2019). In MDARD’s written response to us, the agency argued that since the projects will include plans to prevent soil erosion, it will be easier to return to farming at the end of the lease. It is possible that with the inclusion of well-managed pollinator plantings, the soil quality would improve. Only one study has measured soil quality at solar power plant sites and did not find a clear improvement; however, the vegetation was grass, not pollinator habitat (Choi et al., 2020). Research is needed to measure changes in soil quality at solar sites with different types of vegetation. Interviewees who believed that solar power would improve soil quality framed solar development as minimally intrusive on the land, making a return to farming simple. For example, the developer of the Carroll Road Solar Farm stated in a public meeting, “Right when we decommission the project, it’s just taken right out of the ground, and it’s returned right back to farmland.”

People unconvinced that the soil would improve wondered whether the equipment used on the site would result in soil compaction and changes to drainage, making it too difficult to convert the land back to farming. One ag interviewee (2) stated:

> If these installations do a lot to soils—as in drainage or [reduced] productivity or installing foundations ... if it takes a lot to convert that back to crop production land, then is it really a 25-year investment, or is it permanent?

While developers take steps to address compaction, this is another area where research is needed to measure or model the effects of soil compaction when the land is returned to farming.

From the standpoint of sunk costs and infrastructural investment, it would make sense that future developers would want to replace the panels on the site and continue to use it. Members of the affected public would by that point in time be used to solar power within the landscape, and renewing a site permit would likely be easier than getting a new one. For example, most nuclear power plants have renewed their licenses for new equipment on an existing site rather than trying to site a power plant in a different place. This is partly because by the time a large infrastructural project comes up for renewal, the community has become accustomed to the tax revenue, jobs, and other benefits. Furthermore, 23 U.S. wind farms have been “repowered,” meaning that older wind turbines have been replaced with newer, more efficient turbines, prolonging the life of the installation (Wiser et al., 2018, p. 103). Many interviewees referenced the uncertainty of future energy innovation, suggesting perhaps very different energy alternatives will be available by the end of the first solar lease; therefore, it is uncertain whether the site will be repowered.

Only one interviewee (policy 6) acknowledged that the agricultural system might look very different in 25 to 30 years. They stated:

> Especially given that most solar leases that I’ve seen would be 20 to 30 years give or take, it’s really hard to know what agriculture’s going to look like in 20 years. Honestly, I struggle to believe that a farmer that took 500 acres of corn and put it into solar from a financial standpoint would ever see the value in going back to corn.

It is important to bear in mind that both the agricultural system and the energy system could change by the end of the lease.

Stakeholder perspectives on using farmland for solar development

Solar developers

Solar developers prefer agricultural land to other sites for several reasons. Previously tilled agricultural land provides hundreds or thousands of acres of flat and contiguous land. Siting solar power on contiguous land avoids the need for conducting O&M across multiple sites, significantly reducing the cost. Furthermore, a large solar site over 20 MW in capacity allows developers to benefit from economies of scale; purchasing lower-cost panels in bulk and mounting the panels on the ground is cheaper than mounting them on rooftops. Furthermore, agricultural land is devoid of rocks and trees that would need to be cleared, it is stable, and it is unlikely to be contaminated. These factors also reduce the cost of the required upfront surveys and the mounting. Additionally, agricultural land already has drain tile, or drainpipes, installed, which prevent the solar installation from flooding. Development on brownfields rather than greenfields can be beneficial but also comes with legal liability, engineering, and regulatory issues, which can increase costs. (This is further discussed later in the report.) Finally, solar power developed on agricultural lands usually has fewer impacts on the environment that could increase the cost of permitting (e.g., potential harm to endangered or threatened species). Figure 7 provides a visual of solar panels developed on Michigan farmland.

Figure 7: Assembly Solar, PA 116 parcel. Photo by Aubrey Wigner and Sharlissa Moore.

Moreover, agricultural land is often located near substations and transmission lines. Transmission lines take electricity from the power plant to where it is consumed. Many interviewees cited a rule of thumb that every additional mile required to reach a substation or tap into a transmission line adds $1 million to the project cost. Therefore, siting solar power near existing transmission lines is crucial.

Farmers and decisions to lease land for solar power

The main benefit to farmers of leasing or selling land for solar power is diversification of income to manage risk. For example, for Californian farmers suffering with yield loss due to drought, solar leases offer an alternate source of income (Roth, 2019). Since only 670,212 acres of Michigan's 9.7 million acres of farmland is irrigated (National Agricultural Statistics Service, 2018), most farmers have lower yields in dry years. Solar leasing would provide income to compensate for variable yield. An interviewee (ag 1) said that annual lease payments for solar power in Michigan are on average $800 per acre, ranging from $500 to $1,200. This payment exceeds crop sales from the land, especially when commodity prices are low. Furthermore, the lease payment remains constant, in contrast to the price volatility of agricultural crops. For smaller operations, solar leasing income could help keep the remainder of the farm in business. It could also provide capital to reinvest in the farm.[4]

In some cases, particularly for smaller projects, farmers could lease or sell marginal agricultural land to a solar company. The Fieldwork podcast featured a story about a Minnesota farmer who leased a 30-acre area near a substation with low agricultural yield for a community solar project (Johnson & Hora, n.d.).

[4] Evidence to substantiate this point is limited thus far. Grout et al. (2021) analyzed past farm income from energy leasing and found that it did not result in capital reinvestment in the farm. However, we footnote this because the evidence is dated (from 2014), and it therefore does not capture the growing trend toward solar leasing. The median lease payment was $6,000 per year, which is much lower than solar leasing payments would be.

Neighbors in the area were complaining that the farmer's fungicide spray was making the flowers in their gardens wilt. Unfortunately, one unhappy neighbor also does not like solar installations and has been driving golf balls into the solar field. While the change from farming to solar did not solve community conflict, the farm gained $1,000 per acre per year from the solar lease.

Leasing land for solar power can be an emotional decision for farmers, even when it makes financial sense to do so. As one interviewee pointed out, some farmers are reluctant to lease land for a purpose they do not perceive to be farming. As an energy stakeholder who works in farming communities (energy 2) expressed:

> For a lot of these people who have been farming for decades, some of these people have owned their land for more than a century. Their land is their identity. And if their crop yields are high, they're proud. And if their crop yields are low, they're frustrated, it's kind of who they are.

Some farmers in Michigan prefer to continue farming or do not want their land locked into a long-term lease because they hope to soon pass it on to their children. There are farmers who do not perceive solar farms to be farming the land. This is a matter of lifestyle and pride. An interviewee from a community organization stated that "there are some who initially had been reluctant to it and think, 'Well, if you're not planting corn or soybeans or something on it, you're not farming it" (communities 1). An interviewee living in an agricultural community stated, "I thought that [a prospective solar lease] could potentially be a very good situation for [my neighbor's] farm [but] ... he enjoys farming so he didn't really want to stop doing that" (communities 2).

Farming is both a business and part of family heritage related to pride and identity. One interviewee (ag 2) anticipated that farmers will ask, "How does [solar leasing] fit into the long-term sustainability for my children or my grandchildren: that they're able to make a living on this farmland that's been in our family for multiple generations?" A solar developer explained that they have found that farmers who want to pass their farm on to their children are typically not interested in solar leasing. Alternatively, if children may be interested in inheriting the land but are young and not close to this decision point, leasing the land for solar can be advantageous compared to selling the land for a permanent use such as housing development. Furthermore, an interviewee involved in Michigan solar development reported they have generally found that farmers are interested in leasing, not selling, their land for solar power. Solar leasing is likely most attractive to farmers who are ready to retire and who are not passing on their land to their children. One interviewee (ag 6) stated, "If you're 65 and if you're looking to retire, and you don't have kids to take over the farm operation, [solar] might be the right thing for you." In sum, the decision about whether to lease, or to sell, farmland for solar production is partly a business decision but is also deeply rooted in land, identity and family heritage.

Climate change may have little or nothing to do with this decision. Several interviewees explained that many farmers do not believe in anthropogenic climate change because they already have long-term experience coping with climate variability. One interviewee (ag 2) stated:

> So, just over the course of a farmer's career, if he's an older person, he's seen 40 years of different growing seasons, so it's a little tougher for them to quickly agree to say that our climate is more variable now than it has been before because they've dealt with variability their whole career.

Another interviewee (ag 8) articulated this point of view:

> The climate is always changing. I mean, it's just the nature of the earth or creation, or however you want to say it, things are going to change. There's never a constant. So it brings us challenges, but farming is challenging every year. When you're relying on mother nature and the markets to determine your living, there's just going to be challenges. So I wouldn't say it's any more challenging now than when I was a kid….as far as solar just diversifying the income portfolio of the farm and adding a steady source of income, that is just going to help the farm solidify long-term gains if you can put that fixed income in there. I don't think it's going to affect climate change.

However, this climate skepticism does not necessarily lead farmers to oppose wind or solar leasing because it is a partly financial decision for them, and not a climate change mitigation choice. In fact, one farmer (ag 8) wanted to lease their land for wind energy, but local zoning ordinances prevented them from doing so.

Two competing paradigms: Private property rights versus farmland as a public good

Farmland and private property rights

A number of interviewees argued that the decision to lease or sell farmland for solar power is, or should be, completely a private property right of the landowner. Some mentioned they did not see why this would be an environmental issue or a policy or regulatory issue, since it was simply the right of the landowner to decide what to do with their land. Solar developers also advocated for private property rights. The developer of the Carroll Road Solar Farm stated in a public meeting that they chose this site "because there is a transmission substation on site that's state of the art, good solar resource, [and] willing landowners should have private property rights."

Interviewees who advocated for private property rights framed farmers both as people who should be able to do what they wish with their land and as good land stewards. For example, the Carroll Road Solar Farm developer stated in the public meeting:

> As far as I'm concerned, the best businesspeople in the world are farmers and the fact that they're willing to do this with their land speaks volumes to me. Most businesses worry about next quarter. Farmers worry about the next generation, and if folks there [are] thinking that long-term this is a good deal for them, who am I to argue? ... These are landowners that are exhibiting their private property rights and exhibiting what they feel is the best thing to do with their land.

Interviewees who supported private property rights also emphasized farmers' business acumen to substantiate solar power's appropriateness for agricultural land and its fit in the community and place. Similarly, an interviewee from the Michigan Chamber of Commerce queried, "How can you blame a farmer for wanting to look at a new revenue source? ... If a farmer wants to do that because it's good economics for him, we should get out of his way." Another interviewee (communities 1) stated:

> This is agribusiness. It is usually sophisticated stuff. ... So these are business people. ... So they are sensitive to the idea of what ways can I diversify my income? What ways can I stabilize my ability to stay in agribusiness if I have a bad year? What can I do?. They're going to look at all of

> those kinds of factors and say, 'This could be good for me. This could be good for me as a farmer, as an agribusiness person.'

In contrast, other interviewees focused on farmland as a public good. One interviewee (pub pol econ 9) who works in farmland conservation acknowledged the conflict between the two. They stated that their "head lives in private property rights" but also acknowledged the tensions of farmland as a public good.

> So we have such a well-defined system [in the United States] for the commodification of land and the ownership of it. So on the one hand, that's a brilliant and amazing thing to have accomplished juxtaposed against someone randomly having their farm taken from them. But then there comes all these inherent conflicts of the commodification of a resource that is basic like land.

An interviewee from the Michigan Farm Bureau explained that most land-use decisions are split; there are people who want farmland decisions to be based on private property rights, people who advocate for community input and oversight through planning and zoning, and people who fall in the middle of that spectrum. Another interviewee stated (ag 3), "So in agriculture as a whole, you have a wide variety of opinions of others on your property. And the how and the why around that is as diverse as [the number of people involved] in agriculture."

Farmland as a public good

Interviewees who saw farmland as a public good tended to view the development of solar power on farmland as placing energy in direct competition with agriculture since farmland is a finite resource. Despite the small fraction of Michigan's farmland that would be used, some interviewees worried not just about the overall footprint but also about whether solar panels would be built on high-quality soil. These interviewees tended to broadly use the term prime farmland to emphasize the scarcity of farmland and its inappropriateness for solar power. The U.S. Department of Agriculture defines "prime farmland" as land that has

> … the best combination of physical and chemical characteristics for producing food, feed, forage, fiber, and oilseed crops and is available for these uses ... prime farmland has an adequate and dependable supply of moisture from precipitation or irrigation, a favorable temperature and growing season, acceptable acidity or alkalinity, an acceptable salt and sodium content, and few or no rocks. The water supply is dependable and of adequate quality (U.S. Department of Agriculture, n.d.).

For example, one interviewee (community 3) stated that they wish for "the best land" to be "preserved for food production and agricultural production, and solar be sited on land that's not prime agricultural land."

These interviewees emphasized the importance of using marginal agricultural lands rather than prime farmland. Oregon, for example, capped utility-scale solar on class 1 and 2 farmlands at only 12 acres (Department of Land Conservation and Development, n.d.). An affected community member (5) stated, "You know, I really think that solar is the way. I think, also, that appropriating land that would otherwise be used to generate food is a kind of bargain with the devil." A farmer (ag 2) argued that "it seems most logical that we would preserve the best quality, most productive soils for crop production." Community member 3 argued that solar should be built on "agricultural land that's not prime, that is challenged by nutrient deficiencies, or is drier than prime agricultural land would ideally be, or the soil type isn't suitable for commercial production of the crops that are well suited to our climate." A farmer (ag 2) pointed out that this decision has not been made with urban development, as the Detroit metropolitan area was built on high-quality farmland, so a lot of prime farmland has already been converted in the state.

One expert interviewee (8) delineated his personal beliefs from his agricultural expertise stating, “As a person, I feel that replacing prime farmland with any other use is probably a giant mistake.” From a more analytical point of view, he argued that a full cost-benefit assessment is needed to compare the monetary return on investment, the direct services of energy production versus food production, the water quality and quantity benefits of both, what happens to the displaced crop production, and the habitat benefits of both farmland and solar power. From a developer perspective, completely avoiding prime farmland is difficult (some interviewees said “impossible”) because prime soils are not laid out in blocks, whereas solar power plants are.

Interviewees who focused on farmland as a public good emphasized the involved public policy and regulatory decisions, the environmental considerations of using farmland for solar power, and the effects on the surrounding community. Instead of focusing on the effects at the scale of the state of Michigan, they focused on the community scale. An interviewee (policy 2) stated:

> Farmers’ private property and farm production really affects small communities. It’s not just a couple farmers changing their land use. It may truly not be appropriate to have ... If you wanted to maintain the character of that farmland to have that [solar] use there.

Interviewees also addressed the aesthetic value of farmland for people living in the community. An interviewee (pub pol econ 7) stated:

> We need to be cognizant ... that farmland and agricultural land is truly a public good. It obviously has benefit for agricultural reasons, but it’s a natural amenity that people who don’t necessarily own the land drive by the land every day, or have just come to value it as open space, it factors into their sense of place.

Furthermore, they referenced a conversation they had with an expert who studies renewable energy siting, to explain how small farming communities can be impacted by land-use changes of any size:

> Well, what happens is, you may have a small farming community, and if you take 600 acres out of farm production, it may not seem like a lot. But what you don’t realize is that [the] community was sort of already at a tipping point. And maybe that was the thing that changed the amount of farmland that was maybe ... They took corn out of production. And that could have affected the local granary in town or some of those commodity markets.

Overall, the largest landowners in the community, who may already be the best off, are more likely to benefit from a solar power project than the smaller landowners, or people who do not own land, in the community.

Potential cost to farmers who lease farmland

On a local scale, if the cost of land increases as it is leased out for solar power, interviewees speculated that this could hurt people who lease their land for farming. The $800/acre average solar lease is much higher than the average agricultural land rental price in Michigan in 2019 of $127/acre (U.S. Department of Agriculture, 2020b). This suggests that landlords may be interested in switching from leasing land for agricultural purposes to leasing for solar energy. Of Michigan’s 9,764,090 acres of farmland, 3,631,000 acres are rented out by landlords (U.S. Department of Agriculture, 2014a). Landlords have signed 79,184 rental agreements with tenants on Michigan agricultural land; the figure measures the number of rental agreements rather than the number of tenants (U.S. Department of Agriculture, 2014b; National Agricultural Statistics Service, 2015). Overall, a large percentage of Michigan's agricultural land is operated by lessees, and they could be disproportionately harmed by landlords shifting leases from agricultural leasing to solar leasing.

Additionally, one interviewee (ag 1) found that dairy farmers in Michigan do not own the land on which they apply manure. "So, manure is generally viewed as a positive thing because it contains nutrients, but then it becomes a liability because trucking costs are more than the nutrients in the manure are worth." Therefore, if that land were leased for solar power, they would need to either treat and dispose of the manure, or they would end up paying more than what the nutrients are worth to truck it elsewhere.

Solar power as farmland preservation

In contrast to the argument that solar power will consume farmland, others argued that siting solar energy will in fact preserve agricultural resources. At the heart of the argument is the idea that agricultural land that a farmer leases for solar power is much more likely to return to farming at the end of the lease than land that a farmer sells to a housing developer.

Several interviewees also emphasized that the financial benefits to farmers of solar power qualifies it as part of farmland preservation. MDARD responded, "The point of farmland preservation is to keep the land in farming. If overall farm income, including solar land rental, helps the long-term financial sustainability of the farming operation then this income option helps." Similarly, a public policy interviewee (6) stated:

> We were also trying to show that it's normal that solar and ag can coexist. And for a lot of farmers and for me, farmland preservation in my mind isn't just about preserving the physical acreage of the land. Farmland preservation at its core should be about preserving the viability of a farm long term.

Sarah Mills has made a similar argument about wind power, which financially enables farmers to continue to farm the land around the turbines regardless of the return on investment from farming within the current agricultural commodity markets (Mills, 2018).

Interviewees who view solar as part of farmland preservation also speculated about whether solar power would play a similar role to the USDA Farm Service Agency's Conservation Reserve Program. More research is needed to determine the benefits and drawbacks in this regard.

Pollinator habitat: Goals, complexity and unanswered questions

The PA 116 workgroup decided to require solar installations built on PA 116 land to include pollinator habitat. The Michigan Environmental Council advocated for the pollinator habitat requirement because the organization wanted "to position [solar installations on PA 116 farmland] as a win-win." An interviewee stated:

> One of the concerns we'd hear a lot from local units of government and stakeholders or citizens within those units is that they don't want to look at a field of solar panels with gravel underneath. That's not visually appealing to them. So, by including this pollinator habitat, it obviously has a benefit ecologically. It also might help avoid some of that community pushback that you might have around the unsightliness of it.

Therefore, the assumption was made that pollinator habitat increases public acceptance. (Note that gravel is typically not used, especially outside of the southeast, but rather vegetative groundcovers such as turf grass. There is additional cost required to truck in gravel to a site.)

The workgroup required that a solar pollinator habitat scorecard developed by MSU Extension be used to gauge whether a habitat meets the requirements. MSU entomologists developed the scorecard before the PA 116 workgroup started its work and did not develop it for regulatory use. The experts who produced the scorecard played no role in the workgroup and were informed of the inclusion of the scorecard after the workgroup's conclusion. People involved in developing the scorecard heard rumors that their scorecard would be used to "get around PA 116" (expert interview 3) and were disappointed to discover this was true. By not consulting the scorecard developers, the workgroup treated the scorecard like an artifact rather than a living document that required interpretation by experts and stakeholders.

Agricultural systems, ecosystems of which pollinators are a part, and electricity systems are all extremely complex, multifaceted and multi-scalar. Achieving multiple goals and benefits out of solar power development is a worthy goal, but the complexity of achieving successful outcomes should not be underestimated or significant loss of resources and opportunities could result.

Types of pollinators: Native versus managed

Interviewees identified three straightforward ecological benefits from planting pollinator habitat:

1. Providing additional habitat and forage on the landscape where the pollinators can nest and feed.
2. Providing areas for pollinators to forage where no insecticides are used.
3. Helping other wildlife, such as birds and butterflies.

How best to achieve these benefits and for what species is far more complicated. This is discussed in the remainder of the report.

Pollinator species are extremely diverse. Most broadly, pollinators can be distinguished between those that are native (or wild) and honey bees, which are not native and are managed for agricultural pollination and for honey production. Bumble bees are also sometimes produced and managed for pollination (Koppert, n.d.). Honey bees can travel farther for forage than native bees, up to 6.2 miles (10 kilometers), whereas native bees fly only between 50 feet and a half mile, depending on their body size (Kent, 1988; Natural Resource Conservation Service, 2017). Additionally, different types of pollinators need different plants. Specialized pollinators require a specific plant or plants, whereas generalist pollinators can collect nectar and pollen from numerous plants. Generalist native pollinators can often feed from the same forage as honey bees. However, specialized pollinators need specific plants such as bee balm, squash, or blueberries.

Competition between native bees and honey bees is currently an important area of research inquiry. Some expert interviewees emphasized that pollinator plantings can benefit both honey bees and generalized native pollinators. Native pollinators also benefit more from native plant species, but expert interviewee 3 explained that “there are cases where having a non-native cover crop would put food out there for lots of [species] and especially help the agricultural honey bees.” Expert interviewee 10 argued that the habitat could be partitioned between a cover crop for honey bees to get lots of nectar, and native plants that honey bees may visit infrequently for pollen. Others expressed concern that the native populations will compete with honey bees for forage if it is scarce. Expert interviewee 6 believed managed bees should not be kept on pollinator habitat developed for native bee conservation. Overall, research suggests that competition between native bees and honey bees is site specific and depends on overall availability of forage and the density of honey bee colonies (Herbertsson et al., 2016). More research is needed on this topic. There could be concern for areas with rare pollinator species. Solar developers should consult the US Fish and Wildlife Service and Michigan Natural Features Inventory.

Overall, it is important for developers of solar pollinator habitat to set goals for what pollinators they seek to benefit (which certainly will occur in tandem with consideration of economic energy production goals) and then select plants that meet those goals.

The monarch and agricultural communities’ perceptions of milkweed

One type of specialized insect that is often considered a pollinator is the monarch butterfly. Monarch caterpillars are dependent solely on milkweed for food, which they consume so that they taste bad to predators (Hopwood, n.d.). Michigan’s scorecard does not require milkweed, although it is included in some of the commercially available solar pollinator mixes and encouraged in some other states. Milkweed is controversial in agricultural communities because of previous traumatic experiences. An expert interviewee (4) explained that older farmers have “very strong memories of going into the field and pulling milkweed ... So in their mind, milkweed equals bad.” At the Carroll Road Solar Farm public meeting in fall of 2020, developers indicated that they would not plant milkweed because the local community had communicated to them it would be unacceptable. An expert interviewee (4) stated, “We’ve had a number of utilities who specifically said ... absolutely under no circumstances can we plant milkweed because that would really jeopardize the positive working relationship we have with our landowners.”

Social resistance to milkweed in agricultural communities also relates to rancher perceptions of milkweed as toxic to livestock (Borders & Lee-Mäder, 2014, p. 156). Milkweed is toxic only if eaten in large quantities. This is unlikely to occur because the plant is unpalatable, and cattle will avoid it if other types of forage exist in sufficient quantities (Hopwood, n.d.).

There are numerous species of milkweed, 10 of which are native to Michigan (Michigan Department of Natural Resources, 2017). None are listed as a noxious weed by states or the federal government (Hopwood, n.d.). Native species should be chosen, as non-native tropical species are invasive and harbor parasites that harm monarch caterpillars (Wade, 2015). That said, native milkweed seed can sometimes be difficult to source. Conservationists in Ohio collected milkweed pods by hand because the cost of native milkweed seeds doubled the overall cost of seed mix (Clark & Stevenson, 2017). The use of herbicides, such as glyphosate, in agriculture has reduced milkweed availability for monarch butterflies (Pleasants & Oberhauser, 2013). Expert interviewee 1 explained that in most situations, the continued use of glyphosate and other herbicides in modern farming operations typically prevent the spread of milkweed from becoming an issue.

An additional concern about milkweed is the added cost to the solar project if the monarch butterfly were to be classified as endangered. While the monarch butterfly has not yet been listed as endangered, in 2020, the U.S. Fish and Wildlife Service (USFWS) determined the monarch butterfly is eligible to be listed under the Endangered Species Act (U.S. Fish and Wildlife Service, 2020). Energy interviewee 12 explained what would happen if the monarch were listed:

> You're going to have an ESA, Endangered Species Act, issue. And they're not going to let you go build it anyways, because you're going to have to get a Section 7 and a biological opinion and all that, and the developers are going to walk away from it.

Where anticipated, this issue could be addressed using a Candidate Conservation Agreement with Assurances (CCAA) but it is a costly and time-consuming process.[5] The CCAA is a voluntary program with USFWS in which companies or other non-federal landowners volunteer to develop habitat to benefit species at risk of becoming threatened or endangered. In return, the company does not have to implement further initiatives if a species, such as the monarch butterfly, is later listed. However, if an already protected species establishes on a solar pollinator site, it could obstruct O&M on the site and increase costs.

Managed honey bees

Managed honey bees are used for pollination of agricultural crops and honey production. Many Michigan beekeeping operations are local, keeping their colonies in the state year-round. Most of the commercial beekeepers are migratory, meaning they move their hives across the country to pollinate crops, such as almonds in California. The USDA and IRS classify bees as livestock/food-producing animals, and veterinarians must be able to treat them (American Veterinary Medical Association, n.d.). In Michigan, only beekeeping operations with 300 or more colonies count as an agricultural use for tax purposes (Milbrath et al., 2021) Furthermore, local zoning may forbid keeping honey bees on one's property. Regulations differ in Oregon. Oregon has restrictive rules that solar power can only be developed on 12 acres of agricultural land with high-quality soil and 320 acres of low-quality soil without water rights (Department of Land Conservation and Development, n.d.). However, several solar facilities have been exempted from these restrictions for including apiaries. While a local county tried to deny bees counted as livestock and as an agricultural use, this ruling was overturned by the Oregon State Supreme Court (Jacob, 2014).

According to interviewees, one benefit for the beekeepers is that they could sign a 30-year lease to have their bees forage on a site free of insecticide use with diverse forage in between trips to pollinate agricultural crops. This is a new concept, with only a handful of examples. Energy interviewee 11 from a solar development company expressed interest in the concept stating:

> Livestock classification [of honey bees] is an interesting nuance. Land zoning and property taxes for things considered to be agricultural uses of a property—if honey bees are livestock and maintain the agricultural characteristic of the land, it could be seen as beneficial from the landowner perspective.

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[5] The Rights of Way as Habitat Working group has developed a monarch CCAA. See http://rightofway.erc.uic.edu/national-monarch-ccaa/

In order to fulfill this potential benefit, beekeepers would need to be ensured access to the solar site and sufficient room to drive in a large truck with hives on pallets and a forklift to move the pallets. Beekeepers would also need to be permitted inside the fenced area, often during the middle of the night because that is when bees are moved.

It is also important for solar developers to understand that beekeepers compete for forage for their bees. As one beekeeper (ag 5) stated, “A good bee yard is like your secret fishing hole. The last thing you want to see is another fisherman, or another beekeeper, nearby.” Therefore, when planning a pollinator habitat for managed bees, it would be important to consult with nearby beekeepers early in order to avoid conflict.

Urban honey

A nonprofit called Bees in the D had a large honey crop their first year managing honey bee hives at the urban Detroit O'Shea solar farm. DTE donated the honey back to the nonprofit organization.

Figure 8: Urban honey

Solar developers and beekeepers could produce honey and related value-added products (royal jelly, beeswax, honeycomb, mead or honey wine) (see Figure 8). These products could potentially be sold with labels that identify them as a solar product. A contract would be needed to determine whether some of the product or product revenue would go back to the solar producer.

However, research conducted at the University of Minnesota Bee Laboratory found that honey bees do not forage much off of native prairie plantings if a nectar-rich crop is available in the vicinity (Carr-Markell, 2020). Researchers placed hives near a prairie planting and then recorded the honey bees’ waggle dance, which provides other bees in the hive directions to forage. The bees gave directions to melliferous cover crops, and they used these cover crops to produce honey, rather than the native plantings. Native forage on the solar site would likely be helpful for providing diverse food sources for honey bees, but the sites are too small to support a hive’s honey production. Therefore, the honey would not come from native plants blooming on the solar site, but from the tens of thousands of acres that honey bees forage. It could be labeled solar honey for marketing purposes. If honey is marketed as solar honey, we recommend that the label should also provide correct information for educational purposes, and should inform consumers about the importance of forage for native bees and of forage diversity for honey bees.

Overall, while commercial beekeeping at solar facilities is an interesting option with potential benefits, some questions, such as the cost, state and local governments’ willingness to classify beekeeping as an agricultural use, and communities’ perceptions of beekeeping as an agricultural use, remain unanswered. Furthermore, careful planning is needed to allow access for beekeepers to the site and sufficient space for equipment, as well as consultation with nearby beekeepers to avoid conflict.

Uncertain benefits of pollinator habitat to agriculture

Not all crops require insect pollination. For example, most row crops do not require it, such as soybeans, corn, grains (e.g., wheat, oats, barley, rice, sorghum), sugar beets, cabbage and peaches. Many fruits and vegetables require insect pollination. Pollinator-dependent crops in Michigan listed in order of yield include apples, blueberries, cucumbers, squash, cherries, asparagus and pumpkins (U.S. Department of Agriculture, 2020a). Despite the large colony losses referenced in the introduction, beekeepers have been able to maintain a steady overall number of colonies. Therefore, the cost of pollination has not significantly increased for most crops, other than for almonds and plums, which have increased approximately 2.5 times since the early 1990s when adjusted for inflation (Ferrier et al., 2018, p. 54).

There are three ways that pollinator-dependent crops might benefit from solar pollinator habitat. One, there is some evidence that native bee populations located near these crops will aid in pollination, in addition to managed honey bees (Reilly et al., 2020). This may make it possible to truck in fewer honey bee hives, reducing the pollination services cost. Since most native pollinators only fly short distances (around a half mile), the solar pollinator habitat would need to be immediately adjacent to the pollinator-dependent crops. Bumble bees are one exception to this. Second, honey bees could hypothetically be located permanently next to pollinator-dependent crops, instead of being moved, and forage on the native habitat when the nearby crops are not in bloom. Third, as is occurring at relatively small solar sites in Oregon, the bees could be brought back to the solar pollinator habitat in between trips to pollinate monocrops.

However, there is a significant disconnect between where the most advantageous sites for solar power are and where pollinator-dependent crops are grown. There are good reasons for this. Fruits and vegetables are typically grown on higher-quality soils (Texas A&M AgriLife Extension, n.d.), and selecting these high-quality soils for solar power development would likely foster more conflict. Furthermore, these lands are more expensive. Row-crop agricultural land is cheaper and more suitable for solar power development. Furthermore, solar developers select land based on its distance to existing transmission lines with available capacity and areas with high-quality solar resources and willing landowners. Expert interviewee 3 stated:

> A lot of the places [solar developers are] looking at on the east [of Michigan]. There aren't any [large farms with] specialty crops there that would really benefit from an increase in native pollinators, and so it's really hard to say that it's an agricultural [benefit].

In addition, Bessette and Mills (2021) found greater resistance to wind energy siting in areas of the state along Lake Michigan, from Traverse City to Berrien County, known for fruit production. Overall, aligning solar power site selection with pollinator-dependent agriculture at any significant scale is unlikely to occur.

It may be possible with an amended PA 116 rule that a solar developer could fund pollinator habitat in areas adjacent to pollinator-dependent crops as a mitigation measure rather than under the panels on the utilized PA 116 land. Care would need to be taken so that the insecticides used in agriculture would not harm these native pollinators. The advantage of planting the habitat within the solar installation is that insecticides will likely not be used. None of our energy sector interviewees anticipated that insecticides (chemicals that kill insects) would be used and could not think of a reason they would be needed (see Figure 9). Herbicides are used to spot treat noxious and invasive plants. herbicides are overall less toxic than insecticides for most pollinators. If the planting were to occur in a different township or county, the mitigation measure would not benefit the affected

<u>Science-based trials of row crops integrated with prairie strips (STRIPS)</u>

Iowa State University studies the use of prairie strips in row crop farming. Researchers planted strips of prairie grasses in corn or soybean fields, to benefit the farm's soil and water, as well as provide wildlife habitat. Unlike typical perennial vegetation buffers, the strips include diverse native plant species. Researchers plant the strips in areas with low agricultural crop yields or land features that make farming difficult. The goal is to improve soil and water quality and provide habitat for pollinators. This is an example of pollinator habitat directly integrated into agriculture. However, some interviewees expressed concern that the pollinators would be affected by insecticide use on the adjacent crops (Iowa State University, 2019).

Figure 9: STRIPS project

community. In Michigan, where solar facilities are permitted at the local rather than the state level, it seems unlikely that local communities would prefer this option.

Potential benefits to specific crops

Soybeans are self-pollinated and therefore do not require insect pollination to grow. One study speculated that siting solar pollinator habitat next to soybean farms would increase crop yield through greater insect pollination, adding millions of dollars of value (Walston et al., 2018). The study did not empirically investigate increased soybean yields due to solar pollinator habitat. However, there are a number of studies that illustrate that pollinators increase soybean yield (da Rosa Santos et al., 2019; de O. Milfont et al., 2013; Esquivel et al., 2021). Providing nesting areas for bees near soybean fields has also been shown to increase yield (Cunningham-Minnick et al., 2019). Whether this increase in yield occurs is dependent on the site, and the soybean cultivars differ from the ones grown in Michigan. Furthermore, studies should be conducted to see whether solar pollinator habitat would result in increased soybean yield (and if so, at what habitat size and specifications).

From a stakeholder perspective, an interviewee from a soybean advocacy group doubted that this benefit, even if it applied in Michigan, would appeal to soybean farmers in the state. He said, “I don’t see it as a negative, but I don’t see it as something that soybean growers would get really excited about.” It is important to note that increased soybean yield will not automatically secure the support of soy farmers for leasing land for solar power integrated with pollinator habitat. This issue needs future interview research.

In response to a question about whether solar pollinator habitat would measurably benefit agriculture, an interviewee who works in farmland conservation and supports developing some solar power on agricultural lands said, “That sounds like a concern of someone who just doesn’t want to burn a bridge with the ag community and say that our development has some secondary or tertiary benefit to you continually in the ag community.” It is important for all parties involved in solar siting to bear in mind that benefits advertised without robust evidence can backfire with skeptical communities. The benefits of pollinator plantings to agriculture are likely limited due to the most appropriate solar sites being located near crops that are not dependent on pollinators.

Numerous energy interviewees discussed prospects for benefitting blueberries likely because they are a high value crop and perhaps because there are numerous myths about blueberry pollination. There is a myth that honey bees are inefficient at pollinating blueberries, but this has been disproven (Hoffman et al., 2018). Managed bumble bees can also be used to pollinate blueberries. Furthermore, both managed honey bees and wild bumble bees can play a role in blueberry pollination (Miñarro & García, 2021). Many energy company interviewees thought it would be unlikely that a solar power plant would be developed near fruit production because soil in fruit production regions tends to be high quality. Therefore, the land is probably more expensive, but more importantly, local residents who do not want prime farmland to be used for solar power would likely strongly oppose the solar power plant. It is also unlikely that solar developers could plant blueberries next to solar installations because blueberries require acidic soil that would not be found near row crops. Native vegetation planted nearby—specifically vegetation that blooms while wild bees that pollinate blueberries, such as *Andrena carolina* (Graham et al., 2021), are active—might benefit the pollinators in providing them with diverse forage. Overall, blueberries and solar pollinator habitat are an instructive example of how intertwining the challenge of clean energy development with the challenge of addressing pollinator decline to achieve win-win outcomes is complex and not as simple as a reasonable stakeholder might initially presume.

Pollinator habitat design choices and scorecards

Types of scorecards

Pollinator scorecards for assessing solar pollinator habitat or pollinator habitat on rights-of-way (e.g., transmission corridors, roads, pipeline corridors) vary across states and organizations. Minnesota was the first state to develop a solar pollinator scorecard, and Michigan's scorecard is very similar. MSU Extension developed the scorecard by request from an environmental NGO but did not receive funding for this work. It was not developed for policymakers or for policy implementation. This process took multiple years. The goal was to ensure that pollinator habitat was not just developed for aesthetic value but for tangible benefit to pollinator species. No academic energy experts were involved in the development of either scorecard.

We examined several scorecards but did not conduct a national assessment of all scorecards. The Electric Power Research Institute (EPRI) has done this work and has a report forthcoming. In most states, scorecards exist as a labeling and certification mechanism to prevent developers from falsely labeling their site as pollinator friendly. However, it is possible that other states, like Michigan, or local governments will begin requiring solar pollinator habitat that meets scorecard requirements.

We identified three main categories of scorecards. Scorecards that:

- Inform the upfront development of the site
- Conduct a biological assessment based on a snapshot of what has grown on the site
- Gauge the long-term success of the habitat

Interviewees who focused on a biological assessment argued that it was important for the scorecard not only to focus on planning but to also measure what actually grows on the site. For example, an expert interviewee (4) stated about their biological-assessment scorecard:

> But I think what we've really tried to do with [our] scorecard is really focusing on: if you were to go out on that site today, what would you see and what did that mean as far as an indicator of the presence of habitat? ... Do you see milkweed? Do you see nectar plants? Are there other habitat resources on site? So you really don't get credit in that scorecard for your maintenance practices. Or let's say you use a really fancy seed mix, if none of those flowers blooms, you don't get credit for that.

Michigan's scorecard also focuses on a biological assessment snapshot, but with an emphasis on preparation of the site rather than assessment after the establishment. Several interviewees explained that people marketing a site as pollinator friendly often assume that if there are flowers on a site then pollinators will benefit. The scorecard developers sought to ensure that developers deployed a biological assessment of the plants' benefits to pollinators.

Stakeholders disagree over whether including pollinator habitat that meets scorecard requirements should be mandatory or voluntary. In some states, such as Indiana, certain counties have required minimum pollinator scores, or other specific requirements for pollinator habitat (Randolph County Indiana, 2020; Graham et al., 2021). It is possible this will occur in Michigan in the future, especially owing to its decentralized local siting process.

One of the creators of the MSU scorecard stated that “the goal of having a minimum is that people will aspire to be higher than it, so that’s really how it was set up.” In contrast, expert interviewee 4 argued that if a minimum is required then companies will only meet the minimum. However, if pollinator habitat requirements are voluntary, companies are more likely to exceed the minimum requirements. We do not have any evidence that justifies one assumption over the other, but it is something that could be measured in the future.

In the following section we discuss the requirements of the MSU scorecard and the considerations for developing pollinator habitat that is designed for specific sites.

Pollinator habitat design choices

Renewable energy siting is “site-specific in nature,” as all facets of development prior to the transmission of the electricity are concentrated on the project site (Apostol et al., 2017). Apostol et al. (2017) state that “this characteristic concentrates the associated environmental impacts and often leads to land use and visual conflicts” (p. 258). Pollinator habitat is part of the site-specific nature of renewable energy development. Each project will be unique and must be tailored to the local landscape, ecology and needs. Furthermore, the stressors on specific pollinators are somewhat specific to the local area. As expert interviewee 1 put it, “There isn’t a one size fits all [solution for pollinator habitat development], because every soil situation is different, and the hydrology of that site and the shade of that site will all influence which plants establish and thrive.” To follow, we discuss the factors that influence pollinator habitat design processes.

Size of habitat

The Michigan scorecard provides more points for higher percentages “of [the] site planned to be dominated by wildflowers” (Figure 10). One group of interviewees argued that some pollinator habitat is better than none, while others argued that pollinator habitat must be sufficiently large, or connected to other pollinator habitat, in order to matter. For example, an expert interviewee (3) stated:


7. PERCENT OF SITE PLANNED TO BE DOMINATED BY WILDFLOWERS**

☐	0 - 25%	0 pts
☐	26- 50 %	+3 pts
☐	51-75 %	+8 pts
☐	More than 75%	+15 pts

Projects may have different species mixes under the solar array panels and in the perimeter. Flower cover should be averaged across the entire site.

Figure 10: MSU scorecard, percentage of site dominated by wildflowers

> The habitat loss in Michigan and all the other agriculture states is so profound that a lot of times our messaging is, ‘Just put something ... flowers on the ground. We’ve just gotten rid of so many flowers, don’t focus on making it perfect, just put flowers on the ground.’

Expert interviewee 4 stated:

> You would have the purist who would say, absolutely not, you shouldn’t consider a clover field [pollinator habitat]. Pollinator habitat needs to be much more diverse and native and so forth. But others, I think, can take a more pragmatic approach that, well, it’s better than nothing.

Similarly, expert interviewee 9 stated, “Some food resources are better than no food resources. So I think that’s obvious.” Ag interviewee 4 emphasized that quality should be prioritized over quantity: “One of the philosophies that I operate by is that when we get an acre of habitat, we have to make it the best acre of habitat it can be because we don't have enough acres going around."

In contrast, several interviewees argued that only sufficiently large pollinator habitats would benefit pollinators. For pollinators, expert interviewee 6 stated:

> …the bigger the better. The more habitat that you can create, the more likely it is that you're going to attract some of those rare species and increase [the] diversity of pollinators. But is there any minimum threshold where it's just not even worth it? After, let's say, you get down to a hectare [2.45 acres] or something like that, I would say, the answer is a pretty resounding no. We know even from urban gardens that are like the size of this room that I'm in right now, if you have those plantings out there, they can actually make a difference.

However, this interviewee saw small pollinator habitats as advantageous if they are connected to other habitats to form pollinator corridors (see also Figure 11). They stated:

> If that agricultural land that you put a pollinator planting [on] is in a particularly good location—so let's say that there's really no other habitat around there—but having that land could serve as a corridor between this site that's over here that has some habitat and that site over there that has some habitat, maybe it could be really good.

Furthermore, smaller habitats are far less likely to benefit the rare pollinators that need more habitat the most. Expert interviewee 3 explained that "some of those really common [pollinators] would easily move in just because they're probably in the area, ... It just may not be a place where the more rare ones could survive, unless you knew they were [already] there." Therefore, developers should set goals for which pollinators their habitat aims to benefit.

Overall, it is unclear how much of a site needs to be planted with wildflowers in order to ensure a tangible benefit. It depends on (1) the type of pollinators the developers seek to benefit, (2) the proximity of the site to other pollinator habitats and (3) the type of pollinators that already exist in the area. While more pollinator habitat is better, solar developers are not required to plant every square foot; rather, they are incentivized to plant more by the point system in Figure 10.

Connectivity for pollinators through small habitats

Bees in the D was created the Detroit Bee Highway by enrolling businesses and homeowners in the creation of small waystations with food, water and shelter for native and managed pollinators moving around southeast Michigan, including Detroit and Ann Arbor. Food can be as simple as flower plots in community members' backyards. Shelter includes bee boxes available at many stores, and people can leave out water bowls with rocks in them to quench bees' thirst (Brooker, 2020).

Figure 11: Connectivity for pollinators

Importance of site preparation

Site preparation is often the most important and expensive aspect of developing pollinator habitat at a solar power plant site. Site preparation mainly involves clearing any species—invasive, non-native and native—from the site so that the seed mix can successfully germinate and take root without competition. If the site is not properly prepared, the investment in a high-quality seed mix will be lost as invasive species and grasses overtake the pollinator plants.

Farm interviewee 4 explained:

> If you're ever in a situation where you're four or five years into the project, and [you're] like, I don't know, 'this is not really what I thought it was going to look like,' it almost always goes back to site prep ... And it's a frustration because we don't have a time machine to go back and redo it.

2. HABITAT SITE PREPARATION PRIOR TO IMPLEMENTATION

☐	Measures taken to control weeds during season prior to seeding	+10 pts
☐	No weed control	-20 pts

Figure 12: Habitat site preparation prior to implementation, MSU scorecard

One difference between the Minnesota and Michigan scorecards is that Michigan's scorecard explicitly requires weed control prior to seeding as part of site preparation (see Figure 12). Most often, this requires applying herbicide to the site. However, some citizens are fearful of the use of herbicides in site preparation. Energy interviewee 6 explained that "I've had people call me in townships where solar was going to be installed, and they were terrified of their water being polluted by the vegetation management spray." This concern was also raised by a member of the public at the Carroll Road Solar Farm public hearing who expressed concern about adding farm runoff water pollution with herbicides. The response from the company was that herbicides would only be used in site preparation and not for the duration of the project. There are non-herbicide means of preparing a site such as solarizing the site (covering it to block the sun) and planting a cover crop such as soybeans to take over the existing vegetation (Berthelsen, 2021). However, these methods cost more and take years to establish. It will be important for developers to communicate with affected members of the public about the amount and duration of expected use of herbicides on the site. Ideally, proper site preparation and pollinator habitat will greatly reduce the need for herbicide use on the site in the long term.

Seed mix and pollinator plant type

Once the site is prepared, a seed mix would be applied. Many expert interviewees emphasized that the seed needed to be tailored to the specific site and its characteristics, such as weather, rainfall, and soil type. Many state scorecards, including the Michigan scorecard, require the application of native plant seeds. This is a contested and complex area of solar pollinator habitat development, which affects the cost.

Native versus non-native seed mixes

Expert interviewees disagreed about whether native or non-native seed mixes were preferable for solar pollinator habitat, across a variety of measures. Both Minnesota's and Michigan's scorecards provide points for sourcing local wildflower seeds (within 150 miles of a site for Michigan (see Figure 13) and 175 miles for Minnesota) and increase points for including greater diversity of plant species (see Figure 14). Experts who advocated for native seed mixes, such as perennial tall or short grass prairie, emphasized that these plants are adapted to the local

8. SEEDS USED FOR WILDFLOWER AREAS

☐	Mixes are seeded using at least 40 seeds/square foot	+5 pts
☐	All wildflower seeds are from a source within 150 miles of the site	+5 pts

Figure 13: Seeds for wildflowers, MSU scorecard

environment and are therefore unlikely to require irrigation or fertilizer. Furthermore, native seed mixes are more beneficial to native bees (as opposed to honey bees) because they prefer a wide variety of pollinator plant species instead of a single crop. One interviewee's research is yielding positive results for pollinators from simply using turfgrass with clover and other flowers embedded in it.

If native seeds are selected, it is important to contract with a native plant specialist in the state or even the specific local area where the project is being built. Michigan has a number of these contractors. However, according to interviewees, many seed companies treat the seed mix cost as proprietary. Furthermore, the cost of seed often varies significantly by region, making it challenging to estimate the project costs in advance.

Site preparation would likely be more important and intensive for native seeds, compared to clover, for example, because native plants take longer to establish. Therefore, the threat of invasive species taking over the site as the seeds establish is greater (expert 4). Clover grows more aggressively and quickly than native plants, so site preparation requirements are less stringent for clover-based seed mixes than native seed mixes. A combined advantage and disadvantage of native species is that they grow deeper roots (two to four feet or more), which improves erosion control and likely increases carbon sequestration in the soil (Kell, 2011; Pett-Ridge et al., 2018, p. 15). However, the time spent growing deeper roots means that it takes longer—up to four years—for the plants to establish than a non-native cover crop. Another disadvantage of native plants is that many species grow taller than non-native crop cover such as clover, requiring an increase in panel height, which will be discussed later.

FLOWERING PLANT SCORES

5. FLOWERING PLANT SPECIES SEEDED IN PERIMETER AREA (species with more than 1% cover)

☐	5-10 species	+1 pts
☐	10-15 species	+3 pts
☐	16-20 species	+8 pts
☐	>20 species	+10 pts

Exclude invasive plant species from total

Figure 14: Flowering plant scores, MSU scorecard

Some interviewees emphasized the potential benefits of non-native plant species. An expert interviewee (9) queried, "How should you treat flowers? Should you treat non-natives different than natives? The dirty secret is that a lot of these non-native species are excellent forage resources for pollinators, so it really depends on how you're looking at it." For example, honey bees feed on many weeds. An interviewee who works in conservation (ag 4) stated, "I'm a prairie guy. Part of my business is local eco-type seed. I'm all about it, but prairie restoration is not necessarily appropriate in a solar project."

Non-native species can be advantageous for managed bees and honey production. Honey bees prefer to forage on a single crop (see examples in Box 1, in contrast to native pollinator species, which prefer diverse forage. Expert interviewee 3 stated:

> There are cases where having a non-native cover crop would put food out there for lots of pollinators, and be especially helpful to the agricultural honey bees ... If someone planted [solar sites] with clover or buckwheat or a high nectar plant, you would absolutely have [beekeepers] clambering for that, because you could actually make a honey crop of it.

Examples of plants beneficial to honey bees

- Basswood tree
- Buckwheat
- Dandelions
- Goldenrod
- Lotus corniculatus (birdsfoot trefoil)
- Melilotus (weedy sweet clover)
- Trifolium (white clover)

Box 2: Beneficial plants to honey bees

The expert explained that while grassland habitat is "mildly useful" for honey bees, it would not be a boon to honey bees or allow for significant agricultural benefit to adjacent farms. Figure 15 provides examples of small projects and their benefits. If non-native plants are used, it will be important to ensure that none of the species will be invasive in the local region. However, restoring native habitat can provide various ecosystem services. Expert interviewee 3 also explained, "If you were looking at a habitat restoration native plant, you would bring back a lot of ecosystem services, especially related to other animals, and also related to soil stabilization and water runoff."

Honey bees on prairie habitat

There are some examples of honey bees being kept on small native prairie sites that have been planted in Michigan. Examples include:

- **Fiat-Chrysler Automobiles (FCA) Factory**: FCA planted a meadow of pollinator friendly plants, and Bees in the D keeps four hives on site (Roff, 2020).
- **Phillis Haehnle Memorial Audubon Society**: A beekeeper keeps hives at this location. The area is beautiful and free of insecticides ("Giving back–the Sandhill," n.d.).

While bees produce limited honey on such sites, their value is natural beauty, education and public relations.

Figure 15: Honey bees on prairie habitats

Planting a diversity of plants is directly related to the diversity of pollinator species that the project seeks to benefit. For example, to target a particular species of conservation concern (e.g., the rusty patched bumble bee, which is thought to be extinct in Michigan), it is important to plant species beneficial to that specific pollinator. For a list of endangered pollinators see: fws.gov/midwest/endangered/insects/rpbb/plants.html.

It is also important for the seed mix to include forage that will bloom in each season. If there are only flowers during one month, the insects could later starve. Additionally, some native bee species only appear for several weeks of the year and therefore need host plants during that time period. It is important to ensure that the planting thrives overall, regardless of whether it is a hot, cold, wet or dry year. An interviewee (farm 4) stated, "So the first rule of thumb that you can take to the bank: it's proven and documented in research is the more diversity you have, the more pollinator species you benefit, the more different species you'll benefit." Furthermore, it could be beneficial to identify communities of plants that together have more resilience to invasive species (expert 8).

The cost of seed mix

All pollinator plant seeds are more expensive than standard turf grass seeds. From the interviews, we determined that seed mix costs range from $100 or $200 per acre to over $1,000 per acre. Interviewees had significantly different opinions about what cost of seed is reasonable. This is partly related to the differing opinions previously discussed about native versus non-native plants. For example, a conservation biologist (expert interview 9) explained that a honey bee mix (which is non-native) was "maybe a sixth or a seventh the price of the native bee high divers[ity] mix." A beekeeper (ag 5) argued that "there's a well-intentioned but misplaced interest in the native seed mixes. For one, nothing is really native to under solar panels. And for 10% of the cost, you can buy traditional cover crops." One interviewee worked on a project in Virginia where native plant species requirements increased the cost of the seed mix from $70 per acre to $1,780 per acre.

At the lower end of the range, the Bee and Butterfly Habitat Fund produces a monarch butterfly mixture including a minimum of 40, and more commonly 65, wildflower species, and a honey bee seed mixture that consists of five or six species of traditional cover crops rather than native seeds. The average cost for the seed mixture at the Bee and Butterfly Habitat Fund is $150. The cheaper seed mix costs $75 and the more expensive mix costs $250. Another seed mix (called CP42) for the Conservation Reserve Program sold online by Millborn Seeds costs $110/acre for Michigan, $125/acre for Illinois, and at least $130/acre for Iowa (Millborn Seeds, n.d.). Ernst Conservation Seeds in Pennsylvania sell as a mix for $288 per acre (American Solar Grazing Association, n.d.).[6] Minnesota's required solar pollinator seed mix is mid-range in cost, from $500 to $600 per acre. More expensive seed mixes often include rarer plant species.

On the higher end, Cardno, an environmental consulting firm that has a laboratory focused on studying pollinator habitat, sells a solar field pollinator habitat mix that costs $955 per acre. A landscape architect who quoted the highest price we heard said that for "workhorse species that will bloom well and grow well, I don't think that it's out of line to expect $2,500 an acre, plus the mulch." The mulch that the seed is applied with, such as newspaper, straw or engineered mulch, can also make a difference in seed establishment and affect the cost. If the seeds overwinter, then mulch must be applied to prevent erosion.

A high-cost seed mix can also be overtaken by invasive species and require replanting, especially if the site was not properly prepared. Replanting adds to the cost as well. An expert interviewee (4) explained:

> If you have not done proper site prep, you might have a situation where you've planted this fantastic seed mix. But then you come back next year, and it's been completely overtaken by an invasive grass or some other invasive plant species. And basically, it feels like a loss of your investment, if you've particularly invested in one of those high dollar seed mixes.

In addition to the wasted cost of the high-dollar seed mix, developers also would incur the costs of replanting.

Finally, concern has been raised about future seed availability. The seed for both native and non-native low-growing plants appropriate for solar installations is in high demand, with numerous large solar projects under development. There are also shortages of supply due to drought conditions in the areas where these plants.

[6] Note that this seed mix aims to benefit both pollinators and grazing livestock and does not meet scorecard requirements.

Pollinator plant species and cost

The selection of plant species for a pollinator habitat has the unique restriction of panel height. Solar developers voiced several practical concerns about tall vegetation growing under the solar panels. For example, if the vegetation shades the solar panels, it will reduce the energy generation. While interviewees generally did not see vegetation as a fire risk, a company interviewed for this study had a fire that destroyed a facility. While the reason for the fire remains under investigation, they suspect it was due to a tall invasive grass getting into the wiring. Some interviewees suggested that taller vegetation could be planted outside of the panel field or within the setback zones, while a low-growing cover crop could be planted under the panels. Additionally, some energy sector interviewees worried that maintenance workers could be stung walking through tall vegetation with bees. Expert interviewees noted that this is not a real (objective risk), and ticks and snakes pose a more objective risk. According to webinars, paper wasps, which can sting multiple times if they feel threatened, have taken hold at some solar projects. Paper wasps also prey on monarch larvae (Baker & Potter, 2020), and they prey on harmful pests (Mitchell, 2018).

An interviewee (ag 4) used the metaphor of a toolbox to describe the problem of choosing a seed mix at a solar site, saying, “When a project comes to me and they say they have an 18-inch or a 24-inch vegetative height restriction, I open the toolbox and I have a roll of duct tape and a rusty screwdriver.” In other words, there are not a lot of good choices. Several other interviewees cited a slightly higher ideal pollinator plant height of 36 inches. Not only must the plants be short, they also need to be resistant to invasive species, commercially available, suitable for stormwater management, able to establish quickly, and be able to be maintained over the 20- to 30-year lifespan of the plant. Additionally, some mixes advertised online as solar mixes include plants that grow higher than the average panel clearance. Therefore, the mix needs to be customized, which increases the costs. Furthermore, standard seed mixes might not meet the requirements of scorecards that require native species.

Incentives, operations and maintenance, and monitoring

Incentives for developing pollinator habitat can be divided into the metaphorical categories of carrots (incentives) and sticks (penalties). A government requirement from the national, state or even local level to construct pollinator habitat in order to be allowed to develop a project is a stick approach. A potential carrot would be a carbon credit for the carbon sequestration value of the habitat. Currently, the carbon sequestration value has not been measured, and programs do not exist. However, it could provide an avenue for funding the habitat costs. Government funding could also provide incentives for pollinator habitat development (Burkle et al., 2017).

Another potential carrot is the reduction in operations and maintenance (O&M) costs in the long run. O&M costs include, for example, mowing and vegetation management, preventative maintenance, labor, inverter replacement, repairs, replacing damaged panels or racking, land leasing, taxes, and security (Feldman et al., 2021). However, the benefits of pollinator habitat to O&M remain uncertain, as the additional upfront cost needs to be compared to the long-term O&M costs. For example, O&M costs for pollinator habitat can be higher than for turfgrass in the first five years but are expected to drop thereafter. One O&M cost is the control of invasive species. While this is sometimes achieved through controlled burns, burns are not safe on a solar site because of the electrical wiring. Therefore, herbicides may need to be applied as grass begins to take back over the site. As mentioned earlier, reseeding with the pollinator mix may also be required. These remain unknowns that will affect the long-term costs. Since most solar sites with pollinator plantings are only several years old, empirical data on long-term O&M costs are lacking.

For large-scale installations over 50 MW, mowing the turfgrass under the panels adds significant cost. An interviewee from a large utility company (energy 8) said that vegetation management composes 40% to 50% of the overall O&M costs of solar power plants. While native pollinator habitat needs to be mowed for the first two to five years, it may not require mowing after that, resulting in significant cost savings. While mowing will be reduced, there needs to be sufficient space to fit a riding mower between the panels for the first several seasons.

A shift away from mowing requires some worker adjustment. Several interviewees indicated that employees who do much of the mowing (especially for state agencies) prefer to remain in their air-conditioned cab while mowing. If their job changes to maintaining pollinator plantings in the field, they could be disgruntled. An expert interviewee (4) explained:

> It's a really sweet job if you get to be on mow duty in the summer because you're in an air-conditioned cab, and you can just mow and mow for hours. So, this idea of someone saying we're not going to have you mow anymore and instead you're going to plant these pollinator plantings requires a little bit of adjustment of mindset.

Furthermore, an interviewee (expert 6) indicated that reducing mowing will require clear communication between the solar company and the company responsible for maintaining the vegetation to ensure that the pollinator plants are not accidentally mowed.

One gap in Michigan's pollinator requirement on PA 116 lands is that there are not currently any concrete plans to monitor the pollinator habitat. An expert interviewee (3) explained:

> The biggest complaint from the solar companies is when they really look at this ... The seeds are expensive, the prep is expensive, the maintenance is super expensive, And if there's nobody making sure that they actually do that, it's really hard to see that it would actually happen without some sort of manag[ement] or enforcement, just because it's a lot of work.

Monitoring could entail ensuring the plants that the company planted actually grow. It could also include measuring what pollinator species are utilizing the habitat and their relative abundance. An expert interviewee (1) stated, "As far as I know they don't have a lot of expectation in the PA 116 for anybody to go back to these sites and check on whether the scorecard was actually followed." MDARD reported to us that "there are no requirements for evaluation of the habitat ... The pollinator habitat is subject to monitoring by MDARD or subcontractor staff. The landowner will be notified for corrective action if the pollinator habitat does not meet the required standards." However, it remains unclear how often the sites will be monitored, over what duration, what the stick is for noncompliance, and even what noncompliance would mean since the standard is planting in accordance with the scorecard not a measure of benefit to pollinators. Monitoring requires funding for MDARD, which would require appropriations from the state legislature rather than administrative action alone. Furthermore, there are no standards of success in terms of the benefits to pollinators, and setting them would likely be unfair given the uncertainty of pollinator benefit.

It will be crucially important moving forward for the experts and stakeholders from both areas of expertise to work more closely together in the future. The interviews we conducted with the stakeholders working on the ecological aspects of solar pollinator habitat almost exclusively had not spoken with academic experts in energy transitions or energy policy. The next sections further illustrate why assumptions about the simplicity of developing pollinator habitat could backfire in some cases.

Does pollinator habitat reduce public resistance to solar?

As previously addressed, the governor's workgroup on PA 116 assumed that pollinator plantings on PA 116 land utilized for solar development would increase public acceptance of solar power. They assumed communities oppose literally seeing renewable energy and that pollinator habitat will improve the aesthetic appeal of solar power and thus increase public acceptance. Assumptions about increasing public acceptance because of visual impacts are just that: assumptions. These assumptions require validation. Furthermore, stakeholders should bear in mind our previous discussion explaining why aesthetic opposition to renewable energy is not simply about literally seeing renewable energy on the landscape. While it was not within the scope of this study to fully explore whether pollinator habitat increases public acceptance of utility-scale renewable energy, preliminary results are mixed. There is a risk of public misperception about pollinator habitat if it is not carefully approached and combined with education.

Figure 16: O'Shea solar project in Detroit, August 2019, appears messy but is pollinator habitat.

Most importantly, the visual appeal of the habitat is not always borne out. A high-value habitat to native pollinators does not necessarily look like a well-manicured, colorful landscape with showy blooms. Interviewees who are experts in creating public pollinator habitat were acutely aware of this issue and frequently referenced public expectations that the habitat will look like a pristine landscape on a nature-themed calendar. For example, one interviewee (farm 4) said, "There is a perception that it's going to look like the photo on the calendar in the month of July—quickly." Similarly, another interviewee (communities 5) stated, "People have an idea of a meadow from some calendar that was sent by [a nonprofit organization], and that is a very rare situation to get those kinds of landscapes." An ecologist, Dr. Guy Parker, took widely circulated pictures of a solar pollinator habitat in the UK at the 4.5 MW Southill Solar Farm and the 5 MW Westmill Solar Park, which both have significant aesthetic appeal (Davis, 2020). However, not every habitat in every location will look like this.

Second, the habitat will likely take longer to establish than members of the public assume. An interviewee (farm 4) with significant experience developing pollinator habitat stated:

> The more high-diversity mixture with all the native species in there is going to follow the mantra of: the first year it sleeps, the second year it creeps, and the third year it leaps. So it's really important to set the expectations.

During a tour of the Assembly Solar facility in May 2021, tour participants noticed that only dandelions were growing within the newly seeded pollinator habitat. One tour participant noted that they expected to see wildflowers. The guide explained that dandelions benefit pollinators early during the spring when other forage is lacking and that other flowers will take longer to establish. However, without this expectation, public confusion could result.

Michigan's and other states' scorecards have taken one step to address this by requiring that solar pollinator sites include a sign that is visible from 40 feet away. Expert interviewee 1 explained this decision:

> In the first two or three years these plantings don't look like very much. They're mostly, well they mostly look like a weedy field if they're native wildflowers. The signage was a way to try and give people that sort of aspirational view of what we hope it's going to look like in the long run. If you then say you're going to do this in a pollinator friendly way and people envision that it's going to look beautiful in the first year and all they get is weeds, that could be a negative even more that the company and developer has to deal with.

The signage is an important step, but insufficient. As with solar power, pollinator habitat would require education, as one interviewee (communities 4) expressed:

> If it looks unkempt, then [the public is] going to think that they're not taking care of that site. So, there, again, it's a change of mindset that we have to educate that, 'this is what a natural prairie would look like.'

In Michigan, a proposed solar project in the Upper Peninsula has already been rejected by communities despite a robust plan for pollinator habitat. An interviewee (energy 4) familiar with the project stated, "Pollinator habitat just didn't seem to carry a lot of weight with the locals who were standing in opposition to the project."

In an example from outside of the state, the Oregon Winegrowers Association opposed solar installations because they thought solar would interfere with tourism. They were not assuaged by pictures of pollinator habitat. An interviewee (farm 5) explained:

> And then a group that I didn't really suspect was one of our loudest adversaries, was the Oregon Winegrowers Association of all people. And they kind of helped propagate the myth that solar will take all that land. And then, they argued before the board that consumers won't come to their

> wineries if they have to look at solar panels, and so I showed him pictures of these arrays that are just full of wildflowers—that they're actually beautiful.

It will be important to conduct further research to better understand the relationship between pollinator habitat and public acceptance of utility-scale solar power.

Stakeholders should also distinguish between members of the public who are concerned about pollinator decline and informed about it, and those who place greater value on aesthetics. A state landscape designer (from outside of Michigan, communities 5) explained:

> We have a relationship with the statewide garden club association, and they are interested in the aesthetics. Not for pollinator value, but they have asked that we include some flowers in the seed mix, and they don't really care, or have not been influential in, trying to persuade the agency that the important flowers are the native plants. They want to see a splash of color, and frankly, the pollinators are opportunistic.

In this case, the pollinator habitat benefitted pollinators and had not only aesthetic appeal but also had advocates who promoted it for aesthetic reasons.

There is a risk that members of the public more invested in pollinator benefits than aesthetics will see the habitat as greenwashing, which could detract from overall public support. While solar companies can benefit from advertising themselves as pollinator friendly, some interviewees viewed these claims as a form of greenwashing called "bee-washing." Greenwashing generally refers to attempts by corporations to appear environmentally friendly when in fact their initiatives provide little concrete benefit to the environment; it can also refer to the use of environmental initiatives to deflect attention from a corporation's environmentally unfriendly practices (de Freitas Netto et al., 2020). Bee-washing is a subgroup of this category. It is defined as "a form of greenwashing where a product, service or organization is advertised as being more 'bee-friendly' than it actually is" (bee-washing.com). A Twitter feed and website feature examples of bee-washing in corporate advertising. As greenwashing becomes more common, so does consumer mistrust of corporate claims (de Freitas Netto et al., 2020). For example, expert interviewee 3 pointed out that *Rudbeckia hirta* (black-eyed Susan) are often used in solar pollinator marketing, but the bees do not prefer the plant for forage. An interviewee (communities 2) who is a hobby beekeeper in a rural area in Michigan expressed concern about a nearby solar developer using pollinator habitat to provide positive PR for a project, without concrete explanation of how the project will benefit bees.

Public engagement in renewable energy development is indelibly shaped by the expectations of all stakeholders at the beginning of the project. The relationships between expectations and engagement in a project are iterative, shaping one another over time (Walker et al., 2011). This process can also be conceived as a cycle between promises made by developers and expectations of the public (van Lente, 2000). As these promises about new technologies circulate, they become cemented expectations of the public. When these expectations are disappointed, it can damage trust between affected communities and solar energy developers. The key takeaway point is that if reasonable expectations are not established, solar pollinator habitat development could backfire rather than increase public acceptance. It will be important, also, for people involved in solar development to distinguish between the consent of the landowners versus the general public. Landowners farming nearby might see pollinator habitat as beneficial to their crops; this might increase landowners' acceptance, but it would do little to increase the acceptance of neighbors who are not financially benefiting from the project.

As addressed earlier, milkweed can garner opposition to projects. There are other potential types of opposition. Expert interviewee 4 discussed a pollinator habitat project planned for a tollway that people in an adjacent suburb strongly opposed because they feared it would become a breeding ground for mosquitoes. Although the concern was most likely unsubstantiated, the project was nevertheless withdrawn. A local nonprofit organization that raises bees generally has no resistance to their projects because they carefully locate them. They communicate early and often about the siting of hives and have opted not to develop some projects out of respect for concerned neighbors. The only area where they have faced resistance is in a suburban neighborhood where honey bees were using swimming pools to drink water and neighbors were afraid they would be stung. In urban areas, neighbors have been excited to see bees in their gardens again and have enjoyed increased yield. Furthermore, the organization enjoys interacting with neighbors because it allows for formal and informal education.

From interviewees with experience with pollinator habitat, we learned there can be pushback from people who misperceive that an area is not being cared for because it is not being mowed. In some cases, a public agency receives numerous complaints from the public who perceive they have forgotten to mow, and the agency complies with the request to mow to appease the taxpayers (Melathopoulos, 2019). It is possible that the public could misperceive that the solar pollinator habitat is land that the solar company is not maintaining.

Michigan utility experience with solar pollinator habitat

Consumers Energy has experience planting pollinator habitat on natural gas pipeline corridors. The company has developed some small solar power plants at Grand Valley State University and Western Michigan University, with a third under construction in Cadillac. They are required to bid as one potential developer on their own project RFPs. The company views pollinators as compatible with their triple bottom line approach to sustainability (maximizing benefits to economics, environment and society), but there is still the question of the best design for the habitat. An interviewee stated:

> You want to have vegetation that does not require a lot of maintenance, but of course it’s also not going to interfere with the operations of the solar facility. And if it can accommodate enhancing the environment, then that’s great as well… It’s got to be good for the people that are operating and maintaining it, the community that’s living around it, has to be good for the environment and it has to help reduce cost and make it more affordable for the customers.

DTE has experience with larger solar projects, since it developed, with a contractor, the 52 MW solar project in Lapeer. It also developed the 2.5 MW O’Shea facility in Detroit, which includes pollinator habitat for managed honey bees. DTE interviewees also emphasized that it is important to select solar-specific plantings rather than simply a local Michigan pollinator seed mix. An interviewee stated, “You’ve got to be very selective in what you decide to plant to make sure that you don’t have overgrowth issues.” Like Consumers, DTE interviewees emphasized the triple bottom line and the importance of reducing solar maintenance costs and the environmental impact of mowers, which burn fuel.

The Upper Peninsula Power Company (UPPCO) bids its projects out to developers and therefore sees the specifics of plans for pollinator habitat as being outside of its purview:

> We were a bit of an arm's length away from the details that were being developed and proposed by the developer, so again keep in mind that we had a contract with the developer for the offtake of whatever energy capacity they ultimately could produce. But the details of the project were theirs to manage, and we needed to be careful to not get too close to that.

Wolverine is a supplier of electricity generation to rural electric cooperatives and a nonprofit utility company. The company has experience planting pollinator habitat in its rights-of-way. It generally develops smaller renewable energy projects and is less concerned with the cost of O&M and pollinator habitat for these smaller (1 MW scale) projects. They saw mowing costs as minimal and the upfront costs of pollinator habitats as insignificant.

Even across different utility types in the state of Michigan, perceptions of pollinator habitat and pollinator habitat cost differ. This is partly because of differences in utility cultures but also because of differing business models described below.

Costs of pollinator habitat in context

In summary, the costs of pollinator habitat include the size of the site, site preparation, seed mix selection with mulch and application, and O&M (e.g., controlling invasive species, mowing, potentially reseeding). Furthermore, any delay in transferring the site from the engineering, procurement and construction contractor to the project operator, including delays associated with the planting, adds significant cost. Partly at issue is the question of whether the costs add to the project, or are balanced out by O&M: a point on which developers disagree.

For taller growing plants, the increased costs relate to the additional cost of steel for the pilings with the solar panel attached, which developers drive into the ground. There are also increased labor costs because at some panel heights, workers are required to get on a ladder, scaffold, or aerial lift to install the panels, and there are increased rental costs for larger equipment. A cost estimate provided to a major developer by a consulting company showed the increased costs of higher pile heights. However, this estimate did not disclose the percentage increase in the overall project cost because this is proprietary. NREL has a model for estimating the costs of increased pile heights compared to the system cost. They used it to estimate the capital expenditure costs for a 100 MW single-axis tracker solar photovoltaic installation using this cost estimate. Increasing the panel clearance

- from 18 to 24 inches increases pile costs by 33% and project costs by .5%.
- from 18 inches to 36 inches increases pile costs by 100% and project costs by 1.5%,
- from 18 inches to 48 inches increases pile costs by 167% and project costs by 2.51%,
- from 18 inches to 60 inches (5 ft) increases pile costs by 248% and project costs by 4%
- from 18 inches to 96 inches (8 ft) increases pile costs by 677% and project costs by 11%.

These costs should be taken as highly preliminary and uncertain. It is important to consider the pile costs in the context of the broader project costs and the bidding process. Broader project construction costs include land acquisition and rental costs, system hardware (modules/panels, inverters, balance of system costs), sales tax, mounting or racking, piles and tracking, developer overhead costs, installation labor, transmission interconnection, construction permits, and return on investment (Feldman et al., 2021). The specific solar resources on the selected site (sunlight, temperature, cloud cover, length of day) also affect project costs.

The cost of increasing the panel height to accommodate taller vegetation is a major concern for energy developers. In contrast, some advocates of pollinator habitat suggest the cost is low. For example, a pollinator advocate speaking in a public webinar asserted that “The cost has been described to me as ‘budget dust.’” This is yielding confusion among stakeholders, including regulators, utility companies, experts and public interest groups who are puzzled by the disagreement on the costs. The confusion can partly be cleared up by understanding the different companies involved and their business models, as well as how utility RFPs work.

When a utility company seeks to add solar power and other types of electricity generation to its portfolio, it typically issues a request for proposals, more commonly called an RFP, for projects. Companies that develop utility-scale solar power plants then estimate the project costs and submit a bid for a power purchase agreement for a specific cost per kWh of electricity produced by the power plant (e.g., 7 cents/kWh). These bidders can include the utility company itself; for example, Consumers Energy is bidding to develop its own projects. The cost of project add-ons, such as pollinator habitat or aesthetically pleasing fencing, increases the cost estimate, unless costs can be cut elsewhere within the project. This includes the previously discussed cost of increasing the panel height. The process is very competitive; therefore, companies seek to place a bid at the lowest cost possible while meeting their targeted return on investment.

Several utility company interviewees emphasized that the cost per kWh is the most important factor in selecting the bidder. While RFPs sometimes include “qualitative factors” aside from cost, which sometimes includes pollinator habitat, these factors provide a minimal increase in the ranking of the bids. The utility and the company that wins the bid then sign a power purchase agreement (PPA), in which the utility company agrees to purchase the electricity for the bid price per kWh for the lifetime of the power plant.

This process represents a race to the bottom rather than a process that offers incentives to develop the most environmentally friendly project possible. While utility-scale solar power is now economically feasible, the return on investment is slim, between 4% and 9%, according to interviewees. The priority placed on bidding at the lowest cost per kWh provides a perverse incentive for companies to budget less than is required for a high-quality pollinator habitat. For example, the company might skimp on site preparation.

It is also important to understand that some engineering, procurement and construction contractors only develop the project and sell it to an operator once construction is complete. This means their incentive is simply to win the bid, not to ensure that the pollinator habitat will be successful or that the operator’s O&M costs will be lower in the long run. Furthermore, some of the larger developers provide their own financing for the projects, which avoids the interest costs that companies borrowing the money must pay. However, compared to smaller companies, these companies typically require higher rates of return to consider a project to be economically feasible. This is partly why some companies perceive pollinator add-ons as extremely expensive while others see them as affordable. Expert interviewee 2 stated that local or state governments in many states are requiring add-ons, such as pollinator habitat, after the utility company has accepted the bid. This is an even worse situation for the solar developer because these requirements cut into the company’s profit margin per kWh since they cannot change their bid price.

Several interviewees representing energy developers questioned why it was fair for them to be required to help reverse pollinator decline, since they were not responsible for the problem. A commenter during a public forum on pollinator habitat developer stated expressed this frustration while still supporting pollinators. “Yes to pollinators at solar projects, but why only solar? Make that a requirement for all development. As a solar developer, it is frustrating to be held to a different standard than other, more invasive land uses."

An interviewee from Argonne National Laboratory addressed the challenges of a state mandating pollinator habitat if there is a net cost to the developer:

> It's great and awesome—if you want to do a pollinator scorecard—to do voluntary [actions]. But if you're starting to require these mandates [then]: if this land is going to be used for [solar power], you need to make sure that the soil or that the plant types have been pre-vetted [and] that there isn't a net cost to the solar provider. Or that needs to be included in the rate-making process, which is never a popular thing.

The rate-making process refers to the process in which public utility commissions (e.g., the MPSC) approve increases in electricity costs in the state for investor-owned utility monopolies. Passing off additional costs to consumers is challenging because it requires a complex request to the MPSC to increase rates. Furthermore, the affordability of electricity is important for economic equity, as low-income consumers already pay a disproportionate share of their income on utility bills (Brown et al., 2020). Affordable electricity is also important for economic competitiveness, although some large companies (e.g., Amazon, Google) are demanding renewable electricity access as a condition of locating part of their production in Michigan (Moore & Anctil, 2018).

Who, then, should pay for solar pollinator habitat? While the companies that both develop and manage projects may be able to budget for reduced O&M costs later in the project, some companies see the potential reductions as uncertain. Companies may also be able to find cost efficiencies elsewhere within the project to compensate for the pollinator costs, but this is also uncertain. A public policy interviewee (5) argued that the developers should bear the costs:

> It may very narrowly impact the revenue, but I think if the company has the ability to do so, I would like the companies to pay for it. If it truly is cost prohibitive and someone can show me exactly what that math looks like given that this is something that we value, we'd be happy to look at what the options are there.

There are several challenges associated with providing these cost estimates, and there is no exact math. One is that cost estimates are proprietary because of the competitive bidding process. The base total project costs used by NREL were much lower than those a solar developer shared with us. Another challenge is the previously referenced site-specific nature of solar power development and pollinator habitat, including the size of the planned habitat and the amount of PA 116 land included in each project. The costs of the power plant and the pollinator habitat differ based on the specific project. Furthermore, costs will differ based on the type of companies bidding on the projects and whether they both develop and operate the projects. Large developers that use their own capital to finance projects save interest costs but require a higher rate of return on investment on their capital. Smaller developers can accept a lower rate of return on their capital but also have higher project financing costs and potentially less experience with large projects. These factors also constrain their financial situation.

We see both solar energy and pollinators as public goods. While there is a direct market for solar energy, there is unfortunately not a direct market for benefitting pollinators, particularly native pollinators, especially given the lack of evidence of a tangible agricultural benefit for solar pollinator habitat. Given this, it is reasonable to consider public funding for the public good of benefitting pollinators. Ideally the public funding would only be needed in the early years of developing pollinator habitat, as the industry becomes more experienced and finds ways to reduce the costs. The challenge of providing government funding for pollinator habitat in Michigan, however, is that the state legislature would likely need to appropriate the funding, which public policy interviewee 5 said would be unlikely given the current political makeup of the state legislature. It is possible that foundations and other charitable funders could fill the gap for early projects until clearer evidence is available about whether the pollinator habitat overall reduces costs or breaks even in the long run. State and local governments currently considering legally requiring pollinator habitat, especially with native seed mix requirements, should proceed cautiously, with a nuanced understanding of the RFP process, company business models, solar project economics and the potential for public and stakeholder misunderstanding explained in this report.

Agrivoltaics and grazing: Promising but uncertain

The field of agrivoltaics, also called stacked agriculture, explores growing agricultural crops under solar panels. While this is an exciting prospect, there are numerous feasibility issues to be addressed. The literature on the topic is quickly growing but small (see tables 1 and 2). While the studies show promise for growing crops under panels, they have been conducted on very small installations under 1 MW in size. Research is needed at sites that are 50 MW and larger utility-scale sites. Furthermore, studies have been conducted in only a handful of geographic locations. As with pollinator habitat, setting reasonable public and stakeholder expectations about the feasibility, benefits, and drawbacks of agrivoltaics will be essential.

There are conflicting goals involved in integrating agriculture and solar energy production. The most salient feasibility issue from an energy standpoint is increasing the height of the solar panels to accommodate crops. Raised panel height will increase costs from additional steel and increase installation time and safety issues for workers. This could impede the cost feasibility of solar generation. Furthermore, to maximize energy production, panels should be placed close together to maximize energy production per acre of land. To allow for agricultural production, the panels would need to be spaced apart to accommodate the size of agricultural machinery needed to maintain and harvest crops. Soybeans, for example, are harvested using 30-ft wide combines. Crops that are economically feasible for hand harvesting could obviate this need. Overall, agrivoltaics would avoid completely removing the land from agricultural production but likely reduce energy production.

The crops that can be grown under solar panels will differ based on regional climate and soil type. There is limited research on what crops would be best suited for cultivation under solar panels. Studies are in progress to gauge whether crops can be planted earlier or later than usual and whether additional shade and rainwater runoff from the panels will improve crops' water efficiency. Furthermore, microclimates can be created in different parts of the solar field based on sun orientation and shading, changing what can be planted in the area. While solar power plants are mostly being constructed on row crop farms, high-value agricultural crops that are worth the high cost of increasing panel height and spacing might be most suitable for agrivoltaic production. It could be possible to plant high-value commodity crops, such as borage (starflower), calendula (marigold), various oilseeds or pennycress (Goerge, 2018; Wyse & Jordan, 2017).

One stakeholder (pub pol econ 9) pointed out that, while intriguing, agrivoltaics could simply add to the complexity and risk inherent in the agricultural sector. They stated sarcastically, "It is like unicorns. Not every new and beginning young farmer, or old timer, or somewhere in between is saying, 'You know what I really prefer to do? Stacked ag—that sounds easy.'" This raises an important point of whether in the near term the economic opportunities presented by agrivoltaics offer sufficient economic benefit for farmers to find them stacked agriculture worth the effort. That cost-benefit calculus will likely change over time based on the amount of land used for solar production, the overall characteristics of the agricultural system, and the amount of land needed for agriculture.

In contrast, interviewees in favor of agrovoltaics depicted it as simple: merely a matter of lifting up panels. One interviewee (ag 1) said, “They just put the solar arrays up higher so they can run farming equipment underneath it.” This interviewee also argued that soybeans or corn could be grown under solar panels provided there was enough space for a combine in between the rows of panels, and believed the yield will be similar to non-agrivoltaic crops. Another interviewee (pub pol econ 3) stated, “The cost is not that high to increase the height of the panels.” Therefore, setting concrete expectations about the costs for projects that require increased panel height will be important.

One of the overlooked factors in making stacked ag work is whether the developer of the solar facility will also operate it, or if the developer’s business model is to sell it once they complete construction. The latter is common. In that case, developers have less incentive to invest in measures that reduce long-term maintenance, such as reducing mowing costs through grazing or by planting crops that do not require mowing. In this case, the additional cost of raising the solar panels would benefit the operator not the developer. There are other considerations that need to be accounted for, such as cab wiring, which is cheaper but does not necessarily allow for equipment access because it hangs two feet above the ground. Interviewees from utility companies explained to us that the utility RFP might include a bonus point for measures such as growing crops or raising sheep, but it is not a requirement or even a priority.

Grazing

Another area under exploration is using the land under or around solar panels to graze sheep. As mentioned in the literature review, there are no peer reviewed studies on solar grazing yet. Therefore, this information is preliminary. Peer-reviewed publications will likely become available soon.

At the public meeting of the Carroll Road Solar Farm, developers invited a rancher from Cabriejo Ranches in Missouri, which also operates across the Midwest, to discuss his experiences “running thousands of sheep across thousands of acres across a dozen states.” He depicted solar panels as a good fit for an idealized countryside, a perfect integration between agricultural communities and new technology. He stated:

> There is a lot of glass and so forth, but it’s surprisingly serene. And our animals are actually very comfortable on these sites. These inverter pads, we actually have to put small fencing around [them] because the sheep find them to be very comfortable places to lay around and ruminate. And so again, it’s a very, very natural setting even though it’s covered in technology.

While this rancher expressed techno-utopian visions of solar and ranching, a number of feasibility issues remain. There will be trade-offs from trying to simultaneously generate energy and graze livestock. The benefits of grazing for the solar company are avoiding mowing costs and reducing the use of herbicide for managing weeds, but these advantages would not compensate for the increased panel height requirement. The economic benefits to ranchers also need to be proven. The primary challenge for grazing animals under the panels, particularly large animals, is the panel height requirements. One interviewee (ag 1) in favor of solar grazing stated that panels would need to be raised a minimum of nine feet to allow cattle to graze. This is economically infeasible under current conditions. According to cost estimates obtained from NREL, an increase in the pile height from two feet to nine feet would increase the pile cost by 555% and the overall project cost by 12.44%.

According to interviewees, a Michigan rural electric cooperative is testing grazing sheep on agricultural land in order to reduce mowing requirements for a 1.2 MW site. This has occurred spontaneously because the installation is in an agricultural area, and ranchers inquired about grazing possibilities. Therefore, it does not represent a large-scale and scalable industry. One challenge they have encountered is access to water for animals, as there are often not wells or regular water sources on a solar site.

Researchers are also exploring the best animals to graze on solar sites. Animals that climb on the solar panels or gnaw on the cables, such as standard breed goats, are not suitable, and hogs damage the sites. One interviewee mentioned that farmers in New Zealand are exploring using dwarf goats who are too small to scramble up the panels. Another area being studied is whether grazing and pollinator habitat can coexist within a solar facility. Researchers at Cornell University are trialing seed mixes that can still flower despite widespread grazing. Cabriejo Ranch uses rotational sheep grazing on solar sites, which can enable pollinator habitat and grazing to coexist. This is an experimental industry with feasibility issues including cost, but the founders are working to professionalize and grow the industry.

Municipal perspectives and brownfield urban development options

A number of interviewees questioned why renewable energy is not being built in cities rather than on agricultural land. Several cities in Michigan have developed renewable electricity goals. For example, Traverse City set a goal in 2016 of reaching 100% renewable energy for municipal operations by 2020 (McBenge, 2016). Several years later, the municipal utility company, Traverse City Light and Power, set a 100% renewable electricity goal for the city by 2040, with an interim goal to achieve 40% renewable electricity by 2025 (Carruthers, 2018). The city of Petoskey has also set a 100% renewable energy goal by 2035 (Perkins, 2019). Grand Rapids set a 100% renewable energy goal for municipal operations by 2025 (Kransz, 2020). Finally, according to interviewees, Lansing has a new sustainability commission and sustainability director and is in the early stages of considering a renewable energy goal.

The city managers we interviewed were all open to importing renewable energy from outside the city's borders. For example, the Michigan Municipal Electric Association is a key stakeholder in the Assembly Solar project because its member utility companies are importing electricity from it. Traverse City Light and Power will be importing most of its renewable electricity from the Assembly Solar installation and the Stoney Corners and Pegasus wind farms (Traverse City Light and Power, 2021). The Lansing Board of Water and Light is also sourcing part of its renewable energy from Assembly Solar (see Figure 17) and Pegasus wind (Lansing Board of Water and Light, 2020, p. 68). Petoskey gets its electricity through the Michigan Public Power Agency (Perkins, 2019).

Cost-effective renewable energy played an important role in cities' decisions to import electricity. Traverse City, for example, has a 1 MW solar and wind power pilot project in town from which they pay a premium for electricity. Councilman Tim Werner recalled that he and other council members were conflicted about the cost premium.[7] However, he explained:

[7] Research ethics protocols differ for elected officials, recommending their names be used when reporting results.

> [The project] was important to show that we were serious about this, and it did jump-start the conversation. It had people essentially coming out of the woodwork to say that they were interested in working with the city [on] projects ... And so, it did what it was intended to do, in my opinion.

Werner, however, did not think that Traverse City should continue to pay a high premium for small, local projects rather than importing electricity from larger, cost-effective projects farther south in Michigan. He stated:

> After we approved the one-megawatt solar project, it’s like I shifted gears, if you will, that I tried to make it clear I was not interested in premium projects—to keep accumulating premium projects. But [I said], “Hey, let’s become part of bigger projects.” And Light and Power helped facilitate that [through the Michigan Public Power Association].

An interviewee from a city that does not yet have a renewable energy target expressed a similar view on paying cost premiums compared to gaining visibility and marketing, stating:

> I think that we’re very interested in renewable projects, but we want to look at the different opportunities and look at cost and maintenance and locations and choose projects based on their payoff as well. ... I think some of those smaller projects sometimes get a lot of attention and raise awareness, which isn’t a bad thing, but we want to make sure the projects that we choose are going to have the payback that we want to see too.

Werner is interested in recruiting a utility-scale solar project of approximately 20 MW to Northern Michigan to meet Traverse City and Petoskey’s goals. Such a project could provide benefits such as preserving farmland for the future—ensuring it is not developed for housing—and local education. He would also be interested in a 10 MW project near Traverse City’s airport. The main benefit would be the visibility of renewable energy for public education purposes. He stated:

> So, it’d be great if it was 10 minutes [away] for that visibility, because to me, it’s marketing in a way, but it’s a constant reminder of: ‘Here’s one place our electricity is coming from, but where’s the rest of my electricity coming from?’ And, it just plants [something] in people’s minds to think about, so there’s value in that. How much value? I’m not sure. I don’t even have a personal number necessarily. I know I’d be willing to pay some premium for that.

However, he has heard little interest from developers in building these projects, and he discussed that stakeholders in the area have differing opinions on how much of a premium they would be willing to pay for a smaller local project compared to the import of solar electricity. He stated:

> I hope I’m still involved when we get to have that final discussion someday, and we can come to some compromise that: ‘Okay. We’ll pay a penny and a half more if we can have it local versus 200 miles away.’

For now, he perceives that most residents and officials would rather import solar energy. He stated:

> Do people want to take somewhat low productive farmland, not our most valuable farmland, but lower productive farmland, or go clear cut forests, even if it is second growth forests [like] red pines [that are] grown as a crop anyhow? I mean, I can hear an answer is, ‘Well, none. None of the above. Let Ohio produce it; we’ll just get their electricity.’

While visibility is a potential benefit for education, as previously discussed, the aesthetics of renewable energy also drive opposition to projects.

Interviewees opposed to developing solar power on prime farmland, or even on farmland in general, also asked why solar was not being developed instead on brownfield sites, meaning contaminated areas and landfills. There are benefits to developing smaller projects on brownfield sites near factories, municipal buildings, malls and other large centers of energy demand. These projects provide clean energy close to where it is consumed, reducing transmission losses, and providing tax and other types of revenue to local cities. The drawbacks are that smaller projects have higher per MW costs, there are potential cost risks associated with the liability of developing contaminated land, and there are opportunity costs of using urban land for energy generation (Spiess and de Sousa, 2016). Landfills have additional “geotechnical” costs because these sites settle over time and the landfill cap cannot be penetrated. Therefore, the panels need to be mounted on a ballasted system, requiring a unique design to ensure the system is stable as the landfill settles over time (U.S. Environmental Protection Agency & National Renewable Energy Laboratory, 2013). These considerations all add to the cost of the project and the cost of electricity. Finally, Michigan’s constrained local tax situation also applies to urban siting, as municipalities want the limited undeveloped land under their jurisdiction to be used for redevelopment that yields higher tax revenue and greater economic value to the public, such as restaurants, shopping and housing.

Moreover, the current regulatory frameworks for utility companies in Michigan, both private and municipal, restrict a city’s ability to undertake cost-feasible urban projects. A solar installation that is not grid-connected and that provides a portion of an adjacent building’s electricity demand is called a behind-the-meter installation (Marsh, 2019). Utility companies restrict the size of these installations, typically to less than 1 MW or even 375 kW. Instead of allowing the building to generate its own electricity, the electricity is credited on its overall electricity bill for a low cost per kWh. For example, according to a source with experience on the regulatory structure, the Lansing Board of Water and Light reimburses at 3 cents per kWh. Under these circumstances, the city or private entity’s investment in solar power does not pay off over time; instead, the city must pay extra for the renewable energy, even though the project is otherwise market feasible. The city of Ann Arbor has been lobbying for these rules to be changed at the state level through a proposed program called Community Choice Aggregation.

The city of Ann Arbor studied whether it could meet all of its electricity demand from urban-based solar power. It found that in theory it could locate 78 MW of generation within the city. This is less than one-fourth of Ann Arbor’s overall 400 MW of electricity demand. The city is, however, undertaking a large (24 MW) solar project on a landfill (Stanton, 2021). Under the current regulatory framework, an interviewee explained that the city will pay 120% of the cost of the installation over time, despite being the main investor in the project and the sole consumer of the electricity. This illustrates the current regulatory challenges with developing ground mount solar power in urban areas. That said, even if urban solar development accelerates, some large-scale solar development will also be needed to reach renewable energy goals.

Overall, the challenge is that members of the public expect that solar power can be strategically located on low-value areas such as marginal agricultural lands, brownfields and rooftops. It is important for stakeholders to bear in mind that siting solar power farther from transmission lines increases cost—adding roughly $1 million per mile. Furthermore, developing new transmission lines is not only extremely costly but is also often strongly opposed by some stakeholders. Current transmission planning processes through the Midcontinent Independent System Operator do not account for placement of new transmission lines to coincide with solar power sites on the lowest-quality land with the highest levels of public acceptance. Energy interviewee 7 stated, “Given that solar developers are proposing sites to maximize their profits, we don't really see a link between social acceptance for siting solar and the need for transmission facilities." While the regional grid operator is studying how much renewable energy the grid can accommodate before more storage and more transmission lines are needed, it does not consider local land-use policies or local opposition to utilizing certain land types in its transmission planning process.

Conclusion

This report has explored solar development on agricultural lands in Michigan. Solar development is part of a complex challenge to transform electricity systems in the state to replace aging infrastructure that is causing air and water pollution and contributing to climate change. Scaling up renewable energy is already a very complex challenge because of land use, economic equity issues, state and local tax policies, Michigan's distributed energy permitting process, and the existing transmission infrastructure system that has high sunk costs. The new energy system is not being developed from scratch; rather, it is being retrofitted into the landscape of existing technological infrastructure, social perceptions, and longstanding policies and politics, such as local tax policy. By requiring the development of pollinator habitat or agrivoltaics to ensure solar development includes multiple land uses, the challenge of energy transformations is being intertwined with the equally complex agricultural system and the urgent need to reverse pollinator decline.

This report summarized the decision to allow solar power development on PA 116 lands in Michigan, which was important to enable utility-scale solar projects on contiguous land to proceed. As a compromise, stakeholders decided to pause the PA 116 tax credits during the solar lease and require developers to plant solar pollinator habitat. We identified several areas of confusion with this decision. One was fear that the solar facility would not be decommissioned at the end of its life. This is a misunderstanding since developers are required to issue a bond for decommissioning at the beginning of the project. Another area of confusion relates to whether soil quality will improve over the lifetime of the facility, which is an important area for further research. Additionally, the long lifespan of solar power plants, 30 years, makes it difficult for stakeholders to predict whether the lease will be renewed or the land will return to farming. Both energy and agricultural systems will change over the next three decades, which will influence this outcome.

Overall, we identified several different paradigms through which stakeholders in Michigan viewed the appropriateness of solar power development on farmland. Some stakeholders viewed solar siting as a decision that should be left to an individual landowner because they have private property rights. Moreover, solar leasing would help to diversify farmers' incomes, reducing the risks from seasonal and price volatility. Some stakeholders even saw solar leasing as part of farmland preservation, as it could enable a struggling farming operation to stay in business and a farmer to continue to own the land leased for solar rather than selling it for housing development. Other stakeholders saw farmland as a public good and opposed using prime farmland for solar power generation. These stakeholders often assumed that solar power could be targeted specifically toward low-quality agricultural land, or urban rooftops and brownfields rather than agricultural lands. For these stakeholders, inclusion of pollinator habitat and other multi-land uses tended to improve their opinion of solar power.

In order to identify solutions and improve regulations, it will be important for stakeholders from different fields—pollination, wildlife, and agriculture and farmland preservation—to more closely coordinate. For example, the University of Illinois at Chicago has a center called the Rights-of-Way as Habitat Working

Group that facilitates collaboration across energy companies, government agencies, interest groups and academic experts on developing habitat in rights-of-way. University experts also need to collaborate across disciplines. Most universities now have one or more experts on energy policy or energy in society that can help provide an energy system perspective on efforts to develop pollinator scorecards and related initiatives. State agencies and public utility commissions could play a role in facilitating this collaboration, as could land grant universities.

Achieving benefits to ecosystems from developing pollinator habitat and to agricultural systems from agrivoltaics and grazing is promising. However, this requires careful planning to address feasibility issues and complexity. Pollinator habitat is not a one-size-fits-all modular solution like solar panels are, but rather requires a clear goal and must be tailored toward the specific site. A pollinator habitat designed for native pollinators is different than one for managed honey bees and comes with different requirements. For managed honey bees that would produce honey and related products, non-native species would likely be selected. Furthermore, beekeepers would need access to the site, and conflict could occur with nearby beekeepers over forage accessibility. For native pollinators, requirements differ depending on the targeted species and their need for nesting and forage. For example, monarch butterfly caterpillars require milkweed. Once a goal is identified, careful consideration is required in preparing the site, selecting and applying seed, and maintaining the site.

We found that the development of pollinator habitat integrated into solar facilities has numerous feasibility issues and unknowns that require additional experimentation and experience. Site preparation is of crucial importance, but financial constraints could lead developers to skimp on preparation. Requirements and options for seed mix vary dramatically in cost, benefit and availability. Operations and maintenance costs over the long run compared to upfront investments are still being investigated. These include the cost of seed mix and application, the cost of potentially increasing pile height, and the difference between the reduced cost of mowing in the long run and the increased cost of site preparation. Despite these challenges, we view pollinator habitat as a goal worth achieving.

Since there is a market for renewable energy but generally not a market mechanism for benefitting native pollinators, and because the RFP process prioritizes the lowest cost bid, ***we recommend that public investment should be made in the early phases for the following:***

- Fund the costs of site preparation and seed mix for the solar developers who win some of the first RFP bids, with careful monitoring to develop future standards that help to ensure future success without public funding.
- Formally engage local publics in setting priorities and goals for the habitat, and educate them so that expectations are in line with reality. Conduct systematic social science research on how pollinator habitat relates to public acceptance of solar facilities.
- Fund the scientific monitoring of this habitat to measure its actual success. Well-defined goals for the habitat must be set in order to measure success. Goals should be varied across early pollinator sites to measure success related to different goals (e.g., benefitting threatened and endangered native species, benefitting native species in general, benefitting managed honey bees, increasing pollinator habitat connectivity).

Overall, we found no evidence that solar pollinator habitat will substantially benefit agriculture in most cases. Sites being identified for solar development are typically not sites with the more expensive and high-quality soils used for growing pollinator-dependent crops. Targeting these areas for large-scale solar development would likely only increase the issue of community opposition. One possible solution that could be further explored is the use of pollinator habitat as an environmental mitigation mechanism by requiring developers using PA 116 land to develop pollinator habitat near pollinator-dependent crops. This would avoid the need to increase panel height, but it could require land leases. The cost, feasibility and public perceptions of this option would need to be investigated further.

One goal for requiring pollinator habitat on PA 116 land was to assuage public opposition to solar power for aesthetic reasons. Decision-makers should bear in mind that aesthetic opposition is not merely about people seeing solar panels as ugly. It is deeper, relating to disruption of community, identity, and sense of place. Particularly in politicized processes in communities where trust is lacking, solar pollinator habitat development can itself fuel misunderstandings related to expectations about the time required for the habitat to establish, the perception that the habitat is messy, disappointed expectations about the aesthetic qualities of the site and disappointed expectations related to agricultural benefits.

Rather than assuming solar power will inevitably yield techno-utopian outcomes, stakeholders from different sectors and areas of expertise should collaborate closely to develop workable and site-specific solutions. Achieving multiuse land development for a new and cleaner but land-intensive energy system is not simple, but it is a laudable goal that is worth the time and effort of a careful and concerted approach.

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