

WHITE PAPER

Balancing Agricultural Productivity with Ground-Based Solar Photovoltaic (PV) Development

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Introduction

For centuries North Carolina farmers have made a major contribution to the state's economy by working the land and providing billions of pounds of agricultural and forestry products to meet demands for food and fiber. This resource serves as a foundational economic building block for the state. North Carolina's farming and forestry community provides North Carolinians and people across the world with food and fiber. That said, the demands of our growing, modern society require renewable forms of energy to begin to replace finite non-renewable energy resources that have traditionally provided the means for transportation, electricity, and much more.

Given that land and climatic conditions suitable for agriculture are finite, solar development may compete with agricultural land use. One use converts sunlight and fertilizer into food and fiber, while the other converts sunlight into electricity. The purpose of this paper is to explore the extent to which solar photovoltaic facilities and agricultural production compete for land use, as well as the extent to which agricultural production is affected by solar development. The paper is divided into two sections:

(1) Understanding the Context of Solar Development and Agriculture in North Carolina.

- (1.1) Developing Renewable Energy,
- (1.2) Landowner Land Use Choice,
- (1.3) Solar Facility Construction,
- (1.4) Duration of Solar Use,

(2) Weighing the Impact of PV Development on Agriculture

(2.1) Solar PV Land Use

(2.2) Impact on Agricultural Productivity

1. Understanding the Context of Solar Development and Agriculture in NC

This section provides some background on solar development in North Carolina. By illustrating the existing demand for renewable energy (1.1), touching on the state's political climate towards private land use (1.2), and highlighting two important considerations of PV development (1.3 and 1.4), the context surrounding the two competing land uses of solar development and agriculture can be better understood. As agriculture is and has been a dominant, established land use in this state for generations, discussion in this section will primarily focus on the increasing demands of land to be used for solar development.

1.1 Developing Renewable Energy

Currently, almost all of North Carolina's electricity is generated from fuels, such as coal, natural gas, and uranium, which are produced outside the state. Some coal plants in North Carolina are reaching the end of their useful lives and being retired.^{1,2} Alternative sources of energy, such as solar and wind, have become much more

economically attractive in the last several years, making it possible to economically replace some nuclear, coal, and gas electricity generation with these sources.³

More than three hundred privately financed utility-scale solar facilities operate in North Carolina under current electricity prices, regulations, and policies, with more planned for the future. As with any new technology, price drops and performance improvements may be expected over time as production volumes increase and experience is gained. Since 2009, the total cost to develop and build a utility-scale solar facility in North Carolina has dropped from over \$5 per watt to about \$1 per watt. This rapid cost reduction in utility-scale solar facilities has greatly improved the financial viability of solar projects; many solar projects are now being planned even without the North Carolina renewable energy tax credit that expired at the end of 2015.^{4,5}

In addition to the increasingly attractive economics, some of the shift towards solar energy has been driven by policy choices. Solar and other types of renewable energy have many benefits that have motivated support from policymakers. For instance, they do not use imported fuel, reducing our exposure to fuel price volatility. Solar energy also does not produce the air pollution and greenhouse gases emitted by fossil fuel-powered electricity generation, and it avoids some other environmental risks associated with fossil and nuclear fuels such as coal ash and radioactive waste disposal. Reduction of air pollution has been part of state and national policy for decades, and the U.S. has seen steadily improving air quality as a result⁶ Solar and other clean energy sources assist in this ongoing reduction in air pollution.

Solar energy offers many benefits to North Carolina. However, while solar development provides a source of clean in-state energy, it requires land to do so. This means that solar energy projects will sometimes compete with other potential land uses.

1.2 Landowner Land Use Choice

North Carolina policy generally leaves land use decisions in the hands of landowners. That said, the state, local, and federal governments can encourage or discourage specific landowner choices through the incentives or disincentives that they provide for particular uses, as well as through various forms of regulation, such as zoning rules and environmental restrictions. The balance of state-provided incentives for agricultural or solar energy production can, in some cases, be the determining factor in the decision to invest in solar or agriculture development. Also, the current grid infrastructure limits the sites feasible for solar development; it is only feasible to connect solar to certain locations in the grid and only to a limited density.

North Carolina has granted local governments the power to regulate land use in their jurisdictions, although state and federal rules apply in many circumstances. This means that local governments can manage land development with the needs of the community in mind, while also safeguarding natural resources. These land-use regulations can put limits on the allowed uses for some land and thus limit landowners' options, in some cases affecting the viability of solar development. Some agricultural land has been exempted from certain regulations due to "grandfathering," and changing the land use to solar may remove these exemptions, which can affect the ability to return the land to agricultural use in the future.⁷

Land use regulations that may be relevant to solar development, depending on the location, can include (but are not limited to):⁸

- Local zoning and land use rules (fencing, buffer zones between buildings and roads, border shrubs/trees, etc.)
- Floodplain development rules

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- Erosion and sedimentation rules
 - Permitting regarding military and air traffic impact
 - Water quality rules (i.e. Neuse nutrient strategy rules, Coastal Area Management Act rules)
 - USDA wetlands impact rules

To determine whether these and other rules are relevant for a potential solar development, landowners and solar developers should consult their local government planning departments, the Soil and Water Conservation Division of the N.C. Department of Agriculture and Consumer Services, the USDA Natural Resources Conservation Service office, and the USDA Farm Services Agency.

1.3 Solar Facility Construction

Solar panels are supported by steel or aluminum racks. The racks are attached to galvanized steel posts driven 6-8 feet into the ground without concrete, although very occasionally, site conditions require the use of cement grout in the pile hole. The only concrete is generally at the inverter/transformer pads which are typically about 10' by 20' each. There is usually no more than one such pad per MW of AC capacity. At some sites these pads are precast concrete or steel skids that sit above grade on helical steel piers. Much of the wiring at the site is above-ground attached to the racking under the rows of panels. The rest of the wiring is 2 to 3 feet underground either as direct-bury cables or in 2"-6" PVC conduit. Most sites involve minimal grading of the land.

Every site provides access for vehicles, which requires roads, or "access aisles," to be constructed. These roads are sometimes improved with gravel, but they do not require application of concrete or asphalt. Many sites only use gravel close to the entry to the public Right of Way, as required by NCDOT regulation, with the rest

of the access aisles as simply compacted native soil. Some developers use reusable wooden logging mats to provide temporary stabilization during construction to avoid the need for the addition of gravel. A best practice when building a gravel access aisle is to strip the organic topsoil, place a geotextile fabric under the aggregate and redistribute the topsoil on site to assist in soil stabilization. This will provide stability for the aggregate, allow for more efficient removal of the gravel at the end of the project's life cycle by providing separation between aggregate and subgrade, while preserving the valuable topsoil on site for future agricultural use. Well-drafted leases will specify allowable construction techniques and locations of roads and other infrastructure. The NC Department of Environmental Quality (DEQ) requires soil erosion and sedimentation control plans and permits and inspects implemented measures on the site until vegetative groundcover is established.

1.4 Duration of Solar Use

Currently in North Carolina most utility-scale solar projects have a 15-year Power Purchase Agreement (PPA) with the local electric utility. Some developers prefer to purchase the land, while others prefer to lease, depending on the project's business model and financing arrangements. Typical land leases have a term of 15 to 30 years, often with several optional 5-year extensions.¹⁰ While specific lease rates are generally undisclosed, in our understanding lease rates often range between \$500 and \$1,000 per acre per year. Most solar PV panel manufacturers include a 25-year power warranty on their panels, which cover the panels to produce at least 80% of their original power output at the expiration of the warranty period.

Modern solar facilities may be considered a temporary, albeit long-term, use of the land, in the sense that the systems can be readily removed

from the site at the end of their productive life. At this point, the site can be returned to agricultural use, albeit with a potential for some short-term reduction in productivity due to loss of topsoil, compaction, change in pH, and change in available nutrients. Leasing farmland for solar PV use, particularly land that is not actively being farmed today, is a viable way to preserve land for potential future agricultural use. PV use is particularly valuable in this regard when compared to commercial or residential development, which require changes to the land that are very difficult to reverse. For landowners struggling to retain ownership of their land due to financial strains, solar leasing may provide a vital, stable income solution. It may also serve as a more appealing alternative to selling their land to buyers intending to use the land for other, more permanent non-agricultural uses.

While it is very difficult to predict the state of electricity, agriculture, and real estate markets 25 or more years into the future, existing circumstances can provide some insight into the likelihood of today's solar facilities continuing as solar facilities at the end of the initial PV modules' useful lifetime. The economics of existing solar facilities are such that many of the projects built today are likely to update some of their equipment after 20 or more years and continue to operate as a solar electricity facility for many more years. The ability to facilitate interconnection to the electric grid provides great value to a landowner. A parcel of land featuring this capability in today's market will likely also appeal to solar developers in the future due to the infrastructure cost savings.

2. Weighing the Impact of PV Development on Agriculture

The purpose of this section is to explore how the competing land uses of solar development and ag-

riculture interact and can coexist with each other. Subsection 2.1 provides analysis of data and metrics that quantify the current and potential amount of solar development on agricultural land in North Carolina. Subsection 2.2 explores the impacts that solar development could have on future agricultural production on the developed site and neighboring properties. Taken together, Section 2 of this factsheet provides several factors to consider when weighing the impact of PV development on agriculture.

2.1 Solar PV Land-Use

The NC Sustainable Energy Association (NCSEA) with the North Carolina Department of Agriculture and Consumer Services (NCDA&CS) used GIS software to quantify the amount of solar land use. As of December 2016, solar installations occupied 0.2 percent (9,074 acres) of North Carolina's 4.75 million acres of cropland.¹¹ NCDA&CS has provided an updated estimate; they estimate that 14,864 acres of cropland, or 0.31 percent of the total, were occupied by solar development at the end of the first quarter of 2017.¹² NCSEA and NCDA&CS were able to locate and quantify solar use for 318 of 341 currently-installed utility-scale facilities in North Carolina. A map of the solar installations in the state prepared by NCSEA is available at: <http://energyncmaps.org/gis/solar/index.html>.¹³ The researchers extrapolated the per-MW findings of the 318 sites found in aerial photos to generate an estimate for the remaining 23 projects not yet visible in the latest aerial photography. Across all projects, 79% of solar project area was formerly farmland, defined as land identified from aerial photography to have been used for crops, hay, or pasture before solar development. On average, the solar projects occupied 5.78 acres per MW_{AC}.

N.C. has been losing farmland to various forms of development for many years. Over the last decade, North Carolina has lost about one million acres of cropland to development and housing.

Since 1940, total cropland in N.C. has fallen from 8.42 million acres to 4.75 million acres (as of 2012). The North Carolina Department of Agriculture has identified farmland preservation as one of its top priorities since 2005.

As of the end of 2016, solar PV installations added 2,300 MWAC of solar generating capacity to North Carolina's electricity grid, making NC second in the nation for installed solar PV capacity. These installations generate enough electricity to power approximately 256,000 average N.C. homes, equaling 6.2% of all households in the state.¹⁴ NCSEA and NCDA&CS published the summary of their land-use analysis in February of 2017 and NCSEA released a report on this research in April of this year.¹⁵

If the current siting and production trends were to continue until ground-mounted solar produced, on average, an amount of electricity equal to 100% of N.C.'s current electricity use, solar facilities would cover about 8% of current N.C. cropland.¹⁶ This is an unrealistic extreme to illustrate the limited possible magnitude of land usage for solar even at very high solar generation levels, yet even this scenario would occupy only about half of the N.C. cropland acreage lost to development in the last 10 years. Even if solar were to provide all of our electricity, ground-mounted utility-scale solar will almost certainly not be the only source of electricity. As PV prices continue to decline it is likely that North Carolina will see more and more rooftop and parking lot canopies, reducing the need for green field development. A recent Department of Energy study found that rooftop systems have the technical capability to meet 23.5% of North Carolina's electricity demand.¹⁷

A more likely scenario, even assuming that fossil fuel and nuclear based electricity is entirely phased out, is that other sources of renewable electricity and technologies will meet a large portion of our electricity needs. A Stanford University study of the optimal mix of renewable energy sources for

each state to achieve 100% renewable energy found that North Carolina would get only 26.5% of its electricity from utility-scale solar plants.¹⁸ At this still highly expanded level of solar development, based off of the 8.3% land use for 100% solar figure calculated earlier, the amount of NC cropland used for solar would be around 2.2%.

More realistically, in the next decade or two, solar electricity may grow to provide around 5 – 20% of North Carolina's electricity, which would allow solar to meet, or nearly meet, the full requirements of the North Carolina Renewable Energy and Energy Efficiency Portfolio Standard. At the 12.5% REPS requirement, this is about 13 GW_{AC} of PV, which will require about 75,000 acres of land at the average historic density found in the NCCETC/NCDA study. This is not an insignificant amount of land, but if split between agricultural and non-agricultural land at the same ratio as the first 2.3 GW installed in NC this represents about 1.1% of cropland in the state. NCSEA projects that by 2030, utility-scale solar will provide 5.03% of North Carolina's electricity and use 0.57% of available cropland.¹⁹

Solar energy's land use requirements are comparable to those of existing energy sources. According to an MIT study, supplying 100% of U.S. electricity demand in 2050 with solar would require us of about 0.4% of the country's land area; this is only half the amount of land currently used to grow corn for ethanol fuel production, and about the same amount of land as has been disturbed by surface coal mining.²⁰

For landowners interested in solar development, it is important to understand the agricultural value of the land before entering into a solar lease agreement. Careful due diligence in the siting phase can help mitigate the use of the most valuable farmland. Landowners can contact their county tax office for property value information. The following online resources can assist landowners and developers in assessing the agricultural value of land

before selecting the final footprint for solar development:

- www.nrcs.usda.gov/wps/portal/nrcs/main/national/technical/nra/dma/ The USDA Natural Resources Conservation Service provides several tools in this link to identify soil types on property.
- www.ncmhtd.com/rye/ The North Carolina Realistic Yields Database provides landowners with a useful mapping and soil analysis tool that produces realistic productivity yields for expected crops given the landowner's property location and soil type.

2.2 Impact on Agricultural Productivity

This subsection provides an overview of impacts that solar development may have on agricultural land. The discussion of these impacts is divided into the following subtopics: construction grading and soil preservation, compaction, erosion, weed control, toxicity, and pollinators, followed by a brief discussion of decommissioning. The subtopic discussions illustrate that solar development, with proper planning and implementation, results in a small but manageable impact on the future agricultural productivity of the land on which it is sited. Further, these discussions also illustrate that solar development is unlikely to significantly affect the agricultural productivity of neighboring properties now or in the future.

Construction Grading and Soil Preservation

The amount of grading necessary to prepare a parcel for a utility-scale solar facility is dependent on the slope of land and the type of solar mounting used. In much of N.C., fixed-tilt mounting of PV requires little to no grading for installation of the PV system. Single-axis tracking systems that

slowly rotate each row of panels to track the sun's path across the sky generally require flatter land (typically less than 8% grading) and thus more often require grading of the site, particularly for projects in the Piedmont region or farther west.²¹ Typical construction practices require that topsoil be stripped and stockpiled prior to cut/fill operations. The stockpiled topsoil will be redistributed across graded areas, to assist in growing adequate ground cover as quickly as possible to provide ground stabilization. The stripping, stockpiling and redistribution of topsoil in this manner will have some impact on the amount of organics and nutrients that remain in the soil immediately after placement. However, proper ground stabilization practices include soil testing to determine the appropriate levels of lime, fertilizer and seed to be applied to establish ground cover. Proper installation practices require these additives to be tilled into the soil, which effectively reduces the compaction of the upper soil stratum, typically to a depth of 8"-12". Typical solar projects will not remove any topsoil from the project site, partly due to financial implications, but more importantly due to its value in establishing ground cover as quickly as possible²² (removing soil also requires a mining permit).²³ Most landowners steer solar projects to their least productive soils on a given piece of property to the extent practical.²⁴

Soil Quality

Modern agriculture relies on regular additions of lime and fertilizer to maintain soil pH and fertility. Solar facilities maintain vegetative ground covers that can help build soil quality over time, which may require lime and fertilizer to be applied. When the vegetation is cut, the organic matter is left in place to decompose which adds valuable organic matter to the soil. A facility operation and maintenance schedule should include a plan for maintenance of sufficient plant groundcover to protect soil from erosion. Maintaining healthy plant cover will require monitoring of soil fertility and may call for the addition of fertilizer or lime to ensure sufficient

nutrients are available for plant growth and that soil pH is adequate. Vegetation mixes may help balance soil nutrient needs, but will need to be managed. Species composition will change over time.²⁵ NREL and others are researching and using vegetation mixes that include many native grasses with deep root systems; many include some nitrogen fixing plants as well. According to a study published in July 2016 that measured soil and air microclimate, vegetation and greenhouse gas emissions for twelve months under photovoltaic (PV) arrays, in gaps between PV arrays and in control areas at a UK solar sited on species-rich grassland, UK scientists found no change in soil properties among the three locations. After a solar project is removed, a routine soil test (available from the North Carolina Department of Agriculture) should be obtained to determine fertility requirements, including lime, for optimum crop production.

Compaction

Soil compaction can negatively impact soil productivity and will occur to some degree on every solar site. Soil compaction can also limit water infiltration into the soil environment, and lead to greater surface water runoff during rain events.²⁷ In addition to the roads built in and around solar project sites, the construction of the facility itself as well as regular use of lawn mowers compacts the soil, decreasing the ability of plant roots to grow. However, use of land as a solar site will avoid agriculture-related activities that can induce compaction, such as tillage. There are no data available on the degree of compaction common at solar facilities, but it is possible that some sites could experience heavy compaction in frequently used areas. In cases of heavy compaction, hard pans in the soil will form that can take decades to naturally free up; however, tractor implements such as chisels and vibrators designed to break up hard pan can often remove enough compaction to restore productivity. To prevent damage to soil due to compaction, landowners can negotiate for practices that will result in the least amount of compaction

and for roads to be constructed on less productive land. Additionally, maintaining healthy groundcover, especially varieties with deep root systems, can serve to keep the soil arable for potential future agricultural use. The appropriate use of alternative vegetative maintenance strategies, such as grazing with sheep, can reduce the use of mowing equipment onsite and therefore the compaction that may result from using this equipment.²⁸ Furthermore, livestock grazing works to cycle nutrients in the pasture ecosystem onsite and improve the soil.

Erosion

According to its current Stormwater Design Manual, the N.C. Department of Environmental Quality allows solar panels associated with ground-mounted solar farms to be considered pervious if configured such that they promote sheet flow of stormwater from the panels and allow natural infiltration of stormwater into the ground beneath the panels.²⁹ For solar development, an erosion control and sedimentation permit is required, which involves on-site inspections and approval by the North Carolina Department of Environmental Quality. The permit requires establishment of permanent vegetative ground cover sufficient to restrain erosion; according to DEQ staff, the site must be “completely stabilized,” although this does not require a specific percentage of ground cover.³⁰ In-depth information on erosion control and sedimentation laws, rules, principles, and practices is available at the NC DEQ’s website, at <http://deq.nc.gov/about/divisions/energy-mineral-land-resources/energy-mineral-land-permit-guidance/erosion-sediment-control-planning-design-manual>. Once permanent vegetation is established it will be necessary to maintain soil pH and fertility as mentioned above in order to ensure sufficient, healthy, and continuous ground cover for erosion control.

Weed and Vegetation Control

Maintenance of vegetation on site can be accom-

-plished using several options, including but not limited to the following: mowing, weed eaters, herbicides, and sheep. Reductions in fertilizer use on the site will slow growth of vegetation and weeds. Mowing allows the landowner to have the option of laying cut grass or vegetation on grounds of site to decompose and improve long-term soil fertility. In some cases, landowners have used grazing animals, normally sheep, to frequent the solar site grounds and control the vegetation and weeds, which also returns organic matter to the soil on site.

Like most lawns and parks, many utility-scale solar facilities in N.C. use a combination of mowing and herbicides to maintain the vegetation. When using herbicides, applicators are advised to be mindful of label instructions and local conditions. Herbicide persistence is affected by the organic matter content and moisture level of the soil. The importance of complying with legal responsibilities in using the treatments cannot be stressed enough, especially for land located near surface water, land where the surface is near the water table, or where application might carry over to other neighboring lands.

Herbicide use at solar facilities is typically similar to that in agriculture, and the types of herbicides used are similar between the two uses. As such, the impact of herbicides used at solar facilities on neighboring land and the environment is likely to be no more than that of conventional agriculture. Herbicide use differs widely among different crops and farming techniques, so the change in herbicide appliance between agricultural and solar use will vary in individual cases, but in the aggregate, there is no reason to believe that solar facilities will result in more herbicide impacts on neighboring lands than do current agricultural uses.³¹ Herbicide use can be discontinued 1-2 years before decommissioning of a site, minimizing any residual impact on crop production at former solar sites.³²

A number of sites use sheep at low densities to

maintain vegetation during the growing season, although the sheep do not fully replace the need for mowing and/or herbicide use. The sheep are leased from sheep farmers, and the demand for sheep at solar facilities has been beneficial for North Carolina's sheep industry.³³ The grazing of sheep at solar facilities incorporates local farmers into the management of the sites, engaging the local community with solar development. The growth of solar farms represents a huge opportunity for the North Carolina sheep industry, with thousands of acres that are fenced well for sheep, and allow North Carolina farmers to diversify into new agricultural products for which there is increasing demand.³⁴

Toxicity

There is no significant cause for concern about leaking and leaching of toxic materials from solar site infrastructure.³⁵ Naturally occurring rain is adequate to generally keep the panels clean enough for good electricity production. If panels do need to be washed, the washing process requires nothing more than soap and water. Additionally, the materials used to build each panel provide negligible risk of toxic exposure to the soil, environment, or people in the community. Details about toxicity for aluminum and zinc are described below, and more information on the potential for human toxicity can be found in the [NCSU Health and Safety Impacts of Solar Photovoltaics white paper](#).

Aluminum

Aluminum is very common in soils around the world, including those common in North Carolina. In fact, the earth's crust is about 7% aluminum, and most soils are over 1% aluminum!³⁶ The aluminum is generally unavailable to plants as long as the soil pH is above about 5.5. In acidic soils many forms of aluminum become more bio-available to plants; this can be toxic to many plant species.³⁷ This effect is one of the major reason many plants

do not tolerate very acidic soils. The use of aluminum building materials releases negligible amounts of aluminum during their useful life because the material is so corrosion resistant.³⁸ The aluminum frames of PV modules are anodized which adds a very thin hard coating of aluminum oxide to the exterior of the aluminum that greatly improves aluminum's already-high resistance to corrosion. Therefore, any minute amount of aluminum that could be released by corrosion from aluminum construction materials during the life of a solar project will not materially add to the thousands or millions of pounds of aluminum naturally present in the soil of a typical N.C. solar facility. The common practice of liming soils to maintain appropriate soil pH for crop systems alleviates most, if not all, concerns about aluminum impacting crop growth in the future.

Zinc

Zinc from galvanized components, including support posts for solar panels, can move into the soil.³⁹ Zinc from building material stockpiles has been previously noted as a localized problem for peanut production in some North Carolina fields.⁴⁰ While it is difficult to predict in advance the degree to which this will occur, it is relatively simple to collect soil samples and monitor this situation in existing installations. Analysis of zinc is included in routine soil testing procedures used by the NC Department of Agriculture & Consumer Services Agronomic Services Division Laboratory. Awareness of zinc concentrations in the soil, and any spatial patterns noted with depth and distance from structures, should allow producers to determine if the field is adequate for desired crops as is. If zinc limitations exist, awareness of concentrations and spatial distribution patterns may indicate the potential for deep tillage, liming, or crop selection alternatives required for successful agricultural use. Of the agronomic crops grown in NC, peanuts are the most sensitive crop to

zinc toxicity. Based on information from the N.C. Department of Agriculture and Consumer Services, there is risk of toxicity to peanuts when the zinc availability index (Zn-AI) is 250 or higher, particularly in low-pH situations. Risk increases with increasing soil test levels, especially if pH management through a liming program is not followed. For most other crops, zinc toxicity does not become problematic until the Zn-AI index reaches 2,000-3,000.⁴¹

Pollinators

Solar projects with appropriate vegetation can provide habitat for pollinators, as well as other wildlife.⁴² Rather than planting common turf grasses, some solar facilities are starting to use seed mixes of native grasses and pollinator-friendly flowering plants as ground cover in solar facilities.^{43,44} This provides habitat for pollinators, which can be beneficial to neighboring farms. Minnesota passed the country's first statewide standards for "pollinator friendly solar" in 2016. According to Fresh Energy, a clean energy nonprofit in St. Paul, more than 2,300 acres of these plants took root near solar panels last year, according to Fresh Energy.⁴⁵ Solar facilities can also cooperate with commercial beekeepers to facilitate honey production, although this may conflict with providing habitat for wild pollinators.^{46,47} Pollinators provide benefits for agricultural production at nearby farms where insect-pollinated crops are grown.⁴⁸

Temperature Effects

Solar PV facilities can cause changes in the air and surface temperature of the space in which they are located. The effect of solar PV facilities on surface and air temperatures is different. Solar panels shade the ground on which they are located, reducing the surface (ground) temperature from what it would be without solar panels present.⁴⁹ However, solar panels absorb solar radiation more effectively than do typical

agricultural land surfaces due to their darker color, leading to an increase in air temperature directly above the solar panels as the absorbed radiation is released as heat. The decrease or increase for surface and air temperatures, respectively, is around 2-4 degrees Celsius (3.6-7.2 degrees Fahrenheit), depending on the type of land cover in the area.^{50, 51}

Temperature effects on land outside the solar facility are much smaller. One study found that an air temperature increase of 1.9 degrees Celsius directly over a solar farm dissipated to 0.5 degrees Celsius at 100 meters in horizontal distance from the solar farm, and less than a 0.3 degree increase at 300 meters.⁵² Another study found that a temperature difference of 3-4 degrees Celsius directly above a solar farm was dissipated to the point that it could not be measured at a distance of 100 feet from the solar farm's edge.⁵³ Meteorological factors can affect the range and size of any temperature effect on land nearby a solar facility, but even under very conducive circumstances the possible temperature increase for nearby land would be on the order of tenths of degrees. Studies have varied on the time at which temperature differences are most pronounced; one study noted as taking place in a desert landscape found that temperature differences were larger at night,⁵⁴ while another study found larger temperature differences during midday;⁵⁵ differences in weather and landscape between the study locations may be responsible for the different results.

Decommissioning

If land used for a solar facility is to be returned to agricultural use in the future, it will be necessary to remove the solar equipment from the land. This process is known as decommissioning. Decommissioning is basically the construction process in reverse; it involves removal of the solar panels, breakup of support pads, removal of access roads, replacement of any displaced

soil, and revegetation.

Solar development often takes place on leased land, although it also occurs on land owned by solar companies. When leased land is involved, it must be determined whether the landowner or the solar developer bears responsibility for decommissioning. Responsibilities for decommissioning are lease-specific in North Carolina. It is important for landowners to consider decommissioning when setting lease terms, although landowners may choose in some cases to accept decommissioning responsibility themselves. Although state rules on solar decommissioning do not currently exist in North Carolina, local jurisdictions can choose to adopt regulations pertaining to decommissioning.

The materials recovered in the decommissioning process have significant economic value, which can help pay for the costs of decommissioning. Some engineering analyses have indicated that the salvage value of recovered materials is more than enough to pay for the removal of all the materials and to return the site to its pre-construction state.^{56,57,58,59}

NCSU has produced several resources that provide more information on decommissioning. They include:

- [Health and Safety Impacts of Solar Photovoltaics](#)⁶⁰
- [Template Ordinance for Solar Energy Development in North Carolina](#)⁶¹
- [Working Paper: State Regulation of Solar Decommissioning](#)⁶²
- [Landowner Solar Leasing: Contract Terms Explained](#)⁶³

Summary

The purpose of this paper is to explore the extent to which competition exists between solar development and agriculture and the extent to which

the agricultural productivity of land is affected by solar development. Discussion on this topic was divided into two sections: (1) Understanding the Context of Solar Development and Agriculture in North Carolina and (2) Weighing the Impact of PV Development on Agriculture. In these sections, information and tools were provided to aid in understanding the impact of solar development on agricultural land. Equipped with the information and tools provided by this paper, landowners may be able to better evaluate the viability of solar development on their land.

¹ Tonya Maxwell. *Duke plans to retire Asheville coal plant, replace with natural gas*. Citizen-Times. May 19, 2015. Accessed August 2017. <http://www.citizen-times.com/story/news/local/2015/05/19/duke-plans-retire-asheville-coal-plant/27571083/>

² Duke Energy News Center. *Duke Energy's fleet modernization allows two coal plants to retire early*. February 1, 2013. Accessed August 2017. <https://news.duke-energy.com/releases/duke-energy-s-fleet-modernization-allows-two-coal-plants-to-retire-early>.

³ Reuters, *Solar Power is Finding its Day in the Sun*, July 5, 2016, Accessed August 2017, <http://fortune.com/2016/07/05/solar-power-is-finding-its-day-in-the-sun/>.

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