ORIGINAL

0000178622

RECEIVED
AZ CORP COMMISSION
DOCKET CONTROL

2017 APR -3 P 1:52

Gilberto V. Figueroa
Attorney at Law
SBN 006115
P.O. Box 10248
Casa Grande, Arizona 85130
T- 520-876-0303
C- 520-705-0710
gvfigueroa@yahoo.com
Rodney Q. Jarvis
Earl, Curley & LaGarde, P.C.
Attorneys at Law
3101N. Central Ave.
Suite 1000
Phoenix, Arizona 85012
T- 602-265-0094
rjarvis@ecllaw.com

Arizona Corporation Commission
DOCKETED
APR 3 2017
DOCKETED BY GB

BEFORE THE ARIZONA POWER PLANT
AND TRANSMISSION LINE SITING COMMITTEE

IN THE MATTER OF THE APPLICATIONOF PINAL CENTRAL ENERGY CENTER LLC, IN CONFORMANCE WITH THE REQUIREMENTS OF ARIZONA REVISED STATUTES 40-360, ET SEQ., FOR A CERTIFICATE OF ENVIRONMENTAL COMPATIBILITY AUTHORIZING THE PINAL CENTRAL ENERGY CENTER 230KV GENERATION INTERTIE LINE PROJECT, WHICH INCLUDES THE CONSTRUCTIONOF A GENERATION TIE LINE ORIGINATING LESS THAN HALF A MILE TO THE SOUTHEASTOF PINAL CENTRAL SUBSTATION ON PRIVATE LAND UNDER JURISDICTION OF PINAL COUNTY AND THE CITY OF COOLIDGE, ARIZONA, AND TERMINATINGIN THE PINAL CENTRAL SUBSTATION IN PINAL COUNTY,ARIZONA.

Docket No. L-00000BBB-17-0073-00174

Case No. 174

MEMORANDUM OF LAW NUMBER ONE RE: THERMAL/RADIANT HEAT

I. INTRODUCTION

Pursuant Page 9, Paragraph 27, lines 25-27 of the March 23, 2017 Procedural Order signed by Chairman Thomas K. Chenal, Lynda Williams hereby submits her Legal Memorandum Number One as to the issue of whether this Committee has jurisdiction to consider whether Thermal or Radiant Heat generated by photovoltaic fields will adversely impact Ms. Williams personally. And whether her home and business will be adversely impacted by a "heat island effect" form those fields.

As the materials set forth below, including the three exhibits, demonstrate, there is sufficient evidence from learned articles and studies for this Committee to find it has jurisdiction and to Order the Applicant to conduct formal studies, such as CDF's and CAR's, before the Committee considers the Application for a CEC for the proposed project.

I. FACTS

NEE proposes to construct and operate a photovoltaic power plant on property which borders a 14.5 acre (approx.) acre property owned by Lynda Williams in Pinal County. The proposed NEE facility will occupy the entire northern boundary of Ms. Williams' land, and extends much further east. The proposed NEE facility will also occupy the entire western boundary of Ms. Williams' land, extends further south. Thus, Ms. Williams' land will be nearly surrounded by the NEE facility.

ISSUE:

Does the Arizona Power Plant and Transmission Line Siting Committee (the "Committee") have jurisdiction to consider the potential heating impact the proposed NEE facility will have on Ms. Williams' land?

RULE:

The environmental impact of a facility is relevant to and may be considered by the Committee. (ARS § 40-360.07(B))

APPLICATION:

Studies have been conducted which have established that solar energy plants have an impact on air temperature of adjacent properties. According to a Columbia University study, air temperatures can be raised as much as 3.42 degrees F. These increased temperatures require a distance of 300 meters to fully dissipate. This heating effect "may subsequently affect the thermal environment of near-by populations of humans and other species." (See page 1 of Exhibit A.) In another study from the University of Arizona, we learn that the increased temperatures may actually be increased 5.4 to 7.2 degrees F. (See page 1 of Exhibit B.) Furthermore, we learn that evening cooling is delayed by this heating effect and that heating effect is even greater in summer months. (See page 2 of Exhibit B.)

Clearly, an environmental impact of increased temperatures, perhaps more than seven degrees increase, may be created, radiating to adjacent areas as far as 300 meters away, and lasting into the nighttime. Such temperature issues will affect plant, animal and human life. ARS § 40-360-.07(B) states: In arriving at its decision, the commission… shall balance…the need for… electrical power with… the effect hereof on the environment and ecology of this state. Given the evidence of studies, and the obvious impact of heat increase on the environment and ecology, the Committee is clearly empowered to consider testimony and other evidence relating to the heating effect of solar energy power plants. Indeed, the Arizona Corporation Commission's website confirms that the Committee is to consider "the total environment of the area" when considering a CEC approval. (See page 2 of Exhibit C.)

CONCLUSION:

The Committee is permitted, indeed required, to consider environmental impacts to the surrounding area, such as the increase of temperatures. Immediately adjacent and relatively small, Ms. Williams' land will be enormously impacted by the heat radiating from the proposed NEE facility.

Respectfully Submitted this 3rd day of April, 2017

By ______________________
Gilberto V. Figueroa

The Original and 25 copies of the foregoing Notice of Appearance will be filed this 3rd day of April, 2017, with Docket Control.

A copy of the foregoing will be hand-delivered or e-mailed this 2nd or 3rd day of April, 2017, to the following individuals:

Chairman Thomas K. Chenal
Arizona Power Plant and Transmission
Line Siting Committee
Arizona Attorney General's Office
1275 West Washington St.
Phoenix, Arizona 85007
Thomas.chenal@azag.gov

Jeffrey W. Crockett
Crockett Law Group. PLLC
2198 E. Camelback Rd. Suite 305
Phoenix, Arizona 85016
Attorney for Pinal Central Energy Center, LLC

Tim LaSota
Interim Chief Counsel
Legal Division
Arizona Corporation Commission
1200 W. Washington St.

Phoenix, Arizona 85007
Counsel for Legal Division Staff
tlasota@azag.gov

Elijah Abinah, Acting Director
Utilities Division
Arizona Corporation Commission
1200 W. Washington
Phoeneix, Arizona 85007

____

Exhibit A

Analysis of the Potential for a Heat Island Effect in Large Solar Farms

Vasilis Fthenakis[1,2] and Yuanhao Yu[1]

[1] Center for Life Cycle Analysis, Department of Earth and Environmental Engineering, Columbia University, New York, NY

[2] PV Environmental Research Center, Brookhaven National Laboratory, Upton, NY

Abstract — **Large-scale solar power plants are being built at a rapid rate, and are setting up to use hundreds of thousands of acres of land surface. The thermal energy flows to the environment related to the operation of such facilities have not, so far, been addressed comprehensively. We are developing rigorous computational fluid dynamics (CFD) simulation capabilities for modeling the air velocity, turbulence, and energy flow fields induced by large solar PV farms to answer questions pertaining to potential impacts of solar farms on local microclimate. Using the CFD codes Ansys CFX and Fluent, we conducted detailed 3-D simulations of a 1 MW section of a solar farm in North America and compared the results with recorded wind and temperature field data from the whole solar farm. Both the field data and the simulations show that the annual average of air temperatures in the center of PV field can reach up to 1.9°C above the ambient temperature, and that this thermal energy completely dissipates to the environment at heights of 5 to 18 m. The data also show a prompt dissipation of thermal energy with distance from the solar farm, with the air temperatures approaching (within 0.3°C) the ambient at about 300 m away of the perimeter of the solar farm. Analysis of 18 months of detailed data showed that in most days, the solar array was completely cooled at night, and, thus, it is unlikely that a heat island effect could occur. Work is in progress to approximate the flow fields in the solar farm with 2-D simulations and detail the temperature and wind profiles of the whole utility scale PV plant and the surrounding region. The results from these simulations can be extrapolated to assess potential local impacts from a number of solar farms reflecting various scenarios of large PV penetration into regional and global grids.**

[illegible]

Index Terms – **PV, climate change, heat island, fluid dynamics**

I. INTRODUCTION

Solar farms in the capacity range of 50MW to 500 MW are being proliferating in North America and other parts of the world and those occupy land in the range from 275 to 4000 acres. The environmental impacts from the installation and operation phases of large solar farms deserve comprehensive research and understanding. Turney and Fthenakis [1] investigated 32 categories of impacts from the life-stages of solar farms and were able to categorize such impacts as either beneficial or neutral, with the exception of the "local climate" effects for which they concluded that research and observation are needed. PV panels convert most of the incident solar radiation into heat and can alter the air-flow and temperature profiles near the panels. Such changes, may subsequently affect the thermal environment of near-by populations of humans and other species. Nemet [2] investigated the effect on global climate due to albedo change from widespread installation of solar panels and found this to be small compared to benefits from the reduction in greenhouse gas emissions. However, Nemet did not consider local micro-climates and his analytical results have not been verified with any field data. Donovan [3] assumed that the albedo of ground-mounted PV panels is similar to that of underlying grassland and, using simple calculations, postulated that the heat island effect from installing PV on grassy land would be negligible. Yutaka [4] investigated the potential for large scale of roof-top PV installations in Tokyo to alter the heat island effect of the city and found this to be negligible if PV systems are installed on black roofs.

In our study we aim in comprehensively addressing the issue by modeling the air and energy flows around a solar farm and comparing those with measured wind and temperature data.

II. FIELD DATA DESCRIPTION AND ANALYSIS

Detailed measurements of temperature, wind speed, wind direction, solar irradiance, relative humidity, and rain fall were recorded at a large solar farm in North America. Fig. 1 shows an aerial photograph of the solar farm and the locations where the field measurements are taken.

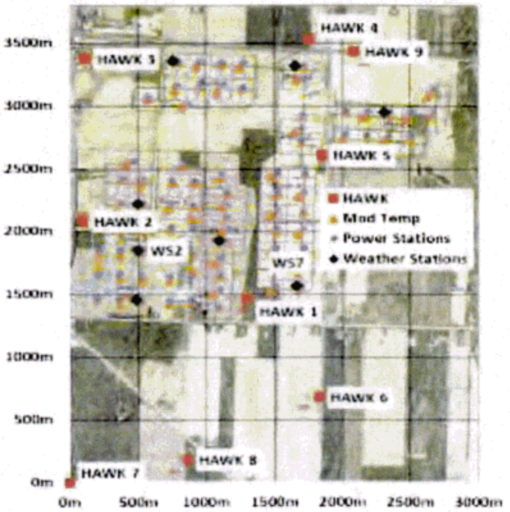


Fig. 1. A picture of the solar farm indicating the locations of the monitoring stations

The field data are obtained from 17 monitoring stations within and around the solar farm, including 8 weather stations (WS) and 9 Hawk stations (HK), all at 2.5 m heights off the ground. There also 80 module temperature (MT) sensors at the back-side of the modules close to each of the corresponding power stations. The WS and MT provide data at 1-min intervals, while the Hawk provides data every 30 minutes. The WS and MT data cover a period of one year from October 2010 to September 2011, while the Hawk data cover a period of 18 months from March 2010 through August 2011.

Hawk stations 3, 6, 7, 8 and 9 are outside the solar farm and were used as reference points indicating ambient conditions. The measurements from Hawk 3, 6, 8 and 9 agree very well confirming that their distances from the perimeter of the solar farm are sufficient for them to be unaffected by the thermal mass of the PV system; Hawk 7 shows higher temperatures likely due to a calibration inaccuracy. In our comparative data analysis we use Hawk 6 as a reference point and, since the prevailing winds are from the south, we selected the section around WS7 as the field for our CFD simulations. Figures 2 to 7 show the difference between the temperatures in Hawk 6 and those in the weather stations WS2 and WS7 within the field, and Hawks 1, 2, 4 and 5 around the solar field.

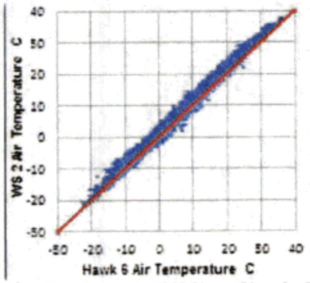


Fig. 2. Air temp WS2 vs. Hawk 6

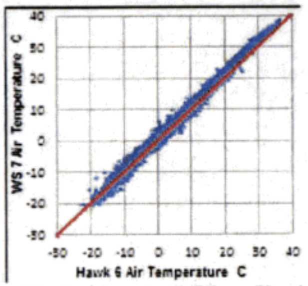


Fig.3. Air temp WS7 vs. Hawk6

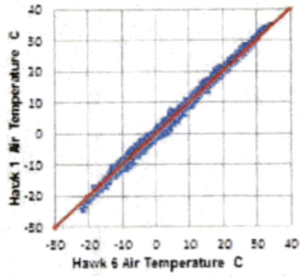


Fig. 4. Air temp Hawk 1 vs. 6

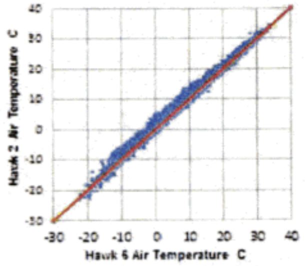


Fig. 5. Air temp Hawk 2 vs. 6

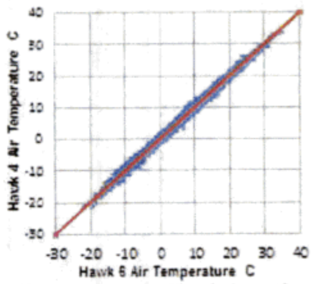


Fig. 6. Air temp Hawk 1 vs. 6

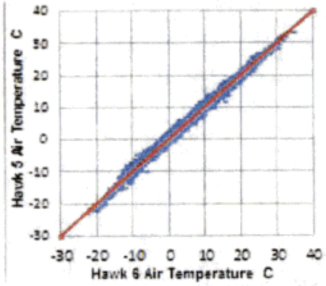


Fig. 7. Air temp Hawk 2 vs. 6

These figures and Table 1 show that with the exception of Hawk 4, the closer the proximity to solar farm the higher the temperature difference from the ambient (indicated by Hawk 6). The relative high temperatures recorded at Hawk 4, and also the relative low temperatures at Hawks 1 and 5 are explained by the prevailing wind direction, which for the time period used in our analysis (8/14/2010-3/14/2011) was Southerly (158°-202°). Hawk 4 is downwind of the solar farm, whereas Hawks 1 and 5 are upwind; the downwind station "feels" more the effect of the heat generated at the solar farm than the ones upwind.

Fig. 8 shows the decline in air temperature as a function of distance to solar farm perimeter. Distances for WS2 and WS7 are negative since they are located inside the solar farm site. WS2 is further into the solar farm and this is reflected in its higher temperature difference than WS7.

TABLE I

DIFFERENCE OF AIR TEMPERATURE (@2.5 M HEIGHTS) BETWEEN THE LISTED WEATHER AND HAWK STATIONS AND THE AMBIENT

Met Station	WS2	WS7	HK1	HK2	HK3	HK4	HK5	HK9
Temp Difference from H6 (°C)	1.878	1.468	0.488	1.292	0.292	0.609	0.664	0.289
Distance to solar farm perimeter (m)	-440	-100	100	10	450	210	20	300

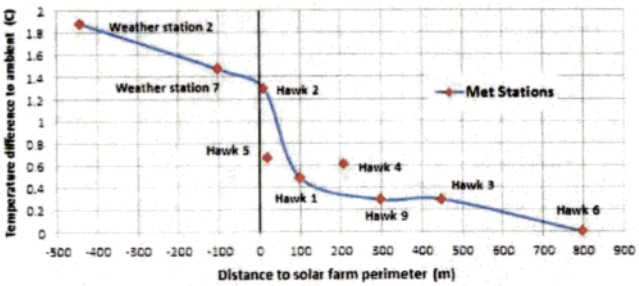


Fig. 8. Air temperature difference as a function of distance from the perimeter of the solar farm. Negative distances indicate locations within the solar farm.

We also examined in detail the temperature differences between the modules and the surrounding air. These vary throughout the year but the module temperatures are consistently higher than those of the surrounding air during the day, whereas at night the modules cool to temperatures below ambient; an example is shown in Fig. 9. Thus, this PV solar farm did not induce a day-after-day increase in ambient temperature, and therefore, adverse micro-climate changes from a potential PV plant are not a concern.

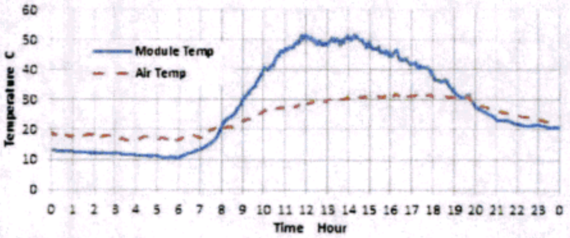


Fig. 9. Comparison of module temperature and air temperature 2.5 m off the ground on a sunny day (July 1, 2011)

III. CFD MODEL DEVELOPMENT

In preliminary simulations we tested the Ansys CFX and FLUENT computational fluid dynamics codes (CFD) and decided to use FLUENT in detailed simulations. FLUENT offers several turbulence schemes including multiple variations of the k-ε models, as well as k-ω models, and Reynolds stress turbulence models. We used the standard, renormalized-group (RNG), and realizable k-ε turbulence closure scheme as it is the most commonly used model in street canyon flow and thermal stratification studies [5]. FLUENT incorporates the P-1 radiation model which affords detailed radiation transfer between the solar arrays, the ground and the ambient air; it also incorporates standard free convection and wind-forced convection models. Our choice of solver was the pressure-based algorithm SIMPLE which uses a relationship between velocity and pressure corrections to enforce mass conservation and obtain the pressure field. We conducted both three-dimensional (3-D) and 2-D simulations.

A 3-D model was built of four fields each covering an area of 93-meters by 73-meters (Fig. 10). Each field contains 23 linear arrays of 73-meter length and 1.8-meter width. Each array has 180 modules of 10.5% rated efficiency, placed facing south at a 25-degree angle from horizontal, with their bottom raised 0.5 m from the ground and their top reaching a height of 1.3 m . Each array was modeled as a single 73 m × 1.8 m × 1 cm rectangular. The arrays are spaced 4 meters apart and the roads between the fields are 8 m. Fig. 10 shows the simulated temperatures on the arrays at 14:00 pm on 7/1/2011, when the irradiance was 966 W/m^2. As shown, the highest average temperatures occur on the last array (array 46). Temperature on the front edge (array 1) is lower than in the center (array 23). Also, temperature on array 24 is lower than array 23, which is apparently caused by the cooling induced by the road space between two fields, and the magnitude of the temperature difference between arrays 24 and 46 is lower than that between arrays 1 and 23, as higher temperature differences from the ambient, result in more efficient cooling.

TABLE II
MODULES TEMPERATURE

Arrays	1	23	24	46
Temperature ℃	46.1	56.4	53.1	57.8

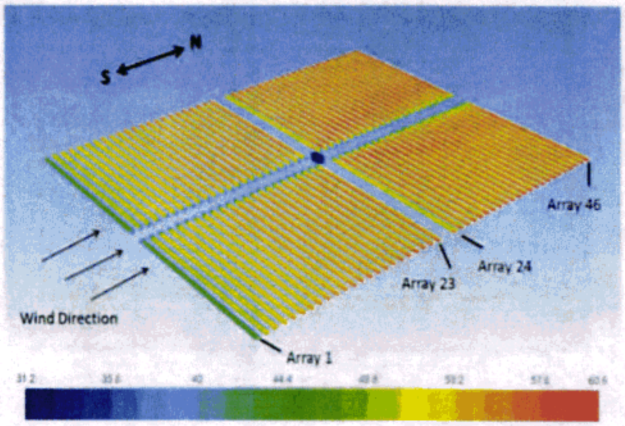
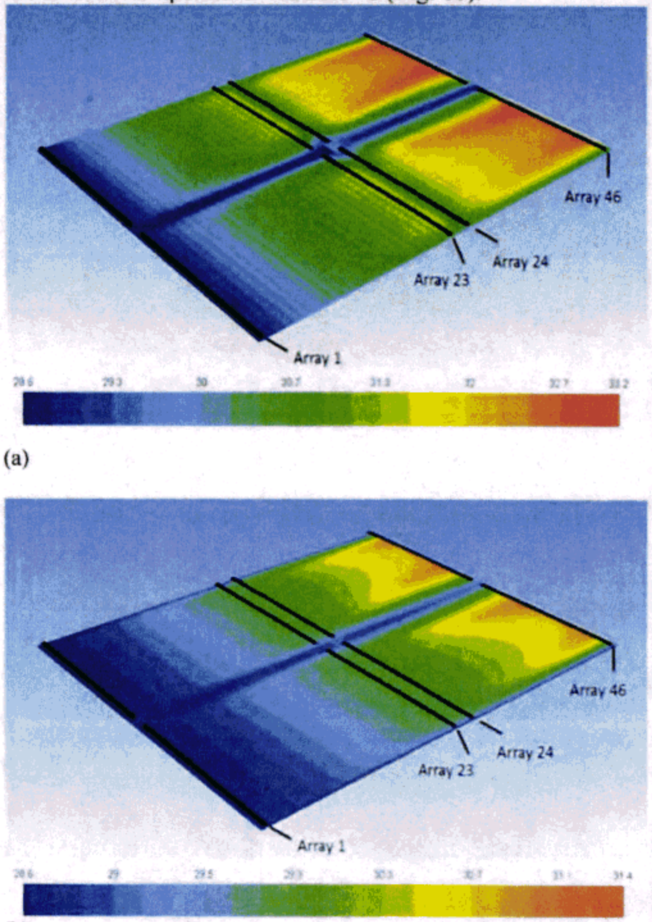


Fig. 10. Module temperatures from 3-D simulations of air flows and thermal exchange during a sunny day

Our simulations also showed that the air temperatures above the arrays at a height of 2.5 m ranged from 28.6 °C to 31.1°C; the ambient temperature was 28.6 °C (Fig. 11).



(a)

(b)

Fig. 11 Air temperatures from 3-D simulations during a sunny day. a) Air temperatures at a height of 1.5 m; b) air temperatures at a height of 2.5 m.

TABLE III
AIR TEMPERATURE

Temperature	Ambient (°C)	Low (°C)	High (°C)	Average (°C)
2.5m height	28.6	28.6	31.1	30.1
1.5m height	28.6	28.6	33.2	30.8

These simulations show a profound cooling effect with increasing height from the ground. It is shown that the temperatures on the back surface of solar panels is up to 30 °C warmer than the ambient temperature, but the air above the arrays is only up to 2.5°C higher than the ambient (i.e., 31.1°C). Also the road between the fields allows for cooling, which is more evident at the temperatures 1.5 m off the ground (Fig. 11a). The simulations show that heat build-up at the power station in the middle of the fields has a negligible effect on the temperature flow fields; it was estimated that a power station adds only about 0.4% to the heat generated by the corresponding modules.

The 3-D model showed that the temperature and air velocity fields within each field of the solar farm were symmetrical along the cross-wind axis; therefore a 2-D model of the downwind and the vertical dimensions was deemed to be sufficiently accurate. A 2-D model reduced the computational requirements and allowed for running simulations for several subsequent days using actual 30-min solar irradiance and wind input data. We tested the numerical results for three layers of different mesh sizes and determined that the following mesh sizes retain sufficient detail for an accurate representation of the field data: a) Top layer: 2m by 1m, b) Middle layer: 1.5m by 0.6m, c) Bottom layer: 1m by 0.4m. According to these mesh specifications, a simulation of 92 arrays (length of 388m, height 9m), required a total of 13600 cells. Figures 12-15 show comparisons of the modeled and measured module and air temperatures.

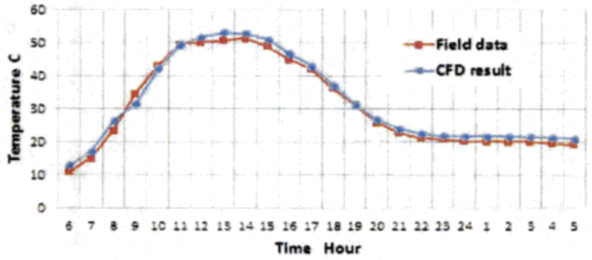


Fig. 12. Comparisons of field and modeled module temperatures; a sunny summer day (7/1/2011); 2-D simulations.

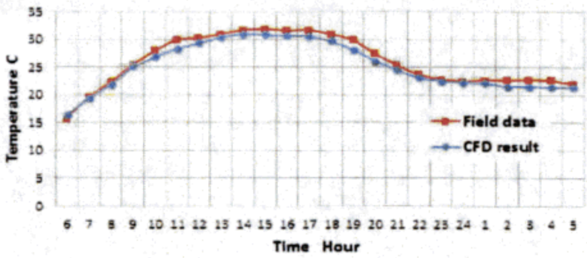


Fig. 13. Comparisons of field and modeled air temperatures at a height of 2.5 m; a sunny summer day (7/1/2011); 2-D simulations.

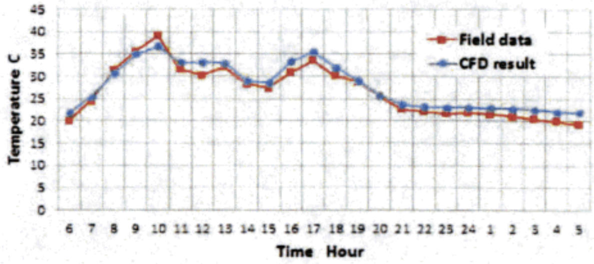


Fig. 14. Comparisons of field and modeled module temperatures; a cloudy summer day (7/11/2011); 2-D simulations.

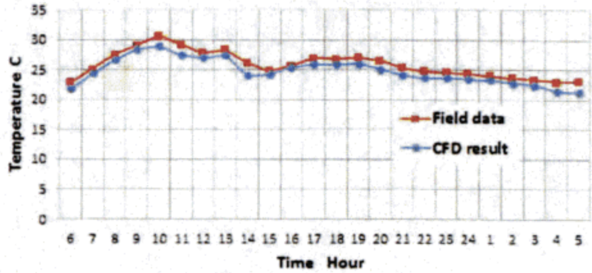
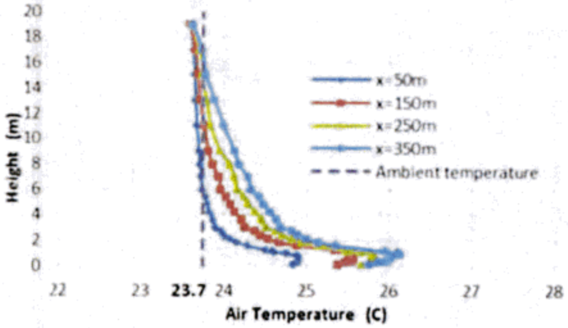
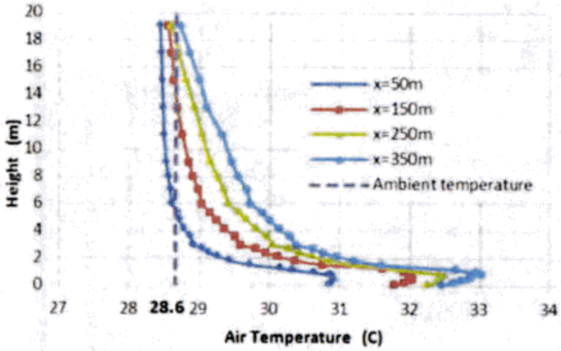


Fig. 15. Comparisons of field and modeled air temperatures at a height of 2.5 m; a cloudy summer day (7/11/2011); 2-D simulations.

Figures 16a and 16b show the air temperature as a function of height at different downwind distances in the morning and afternoon during a sunny summer day. At 9 am (irradiance 500 W/m2, wind speed 1.6 m/s, inlet ambient temperature 23.7°C), the heat from the solar array is dissipated at heights of 5-15m, whereas at 2 pm (irradiance 966 W/m^2, wind speed 2.8m/s, inlet ambient temperature 28.6°C , the temperature of the panels has reached the daily peak, and the thermal energy takes up to 18 m to dissipate.



(a) 9:00 am



(b) 2:00 pm

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

IV. CONCLUSION

The field data and our simulations show that the annual average of air temperatures at 2.5 m of the ground in the center of simulated solar farm section is 1.9°C higher than the ambient and that it declines to the ambient temperature at 5 to 18 m heights. The field data also show a clear decline of air temperatures as a function of distance from the perimeter of the solar farm, with the temperatures approaching the ambient temperature (within 0.3°C), at about 300 m away. Analysis of 18 months of detailed data showed that in most days, the solar array was completely cooled at night, and, thus, it is unlikely that a heat island effect could occur.

Our simulations also show that the access roads between solar fields allow for substantial cooling, and therefore, increase of the size of the solar farm may not affect the temperature of the surroundings. Simulations of large (e.g., 1 million m^2) solar fields are needed to test this hypothesis.

ACKNOWLEDGEMENT

We are grateful to First Solar for providing data for this study.

REFERENCES

[1] D. Turney and V. Fthenakis Environmental, "Impacts from the installation and operation of large-scale solar power slants," *Renewable and Sustainable Energy Reviews*, vol. 15, pp. 3261-3270, 2011.

[2] F.G. Nemet. "Net radiative forcing from widespread deployment of photovoltaics," *Environ. Sci. Technol.*, vol. 43, pp. 2173-2178, 2009.

[3] M. Donovan, "Memorandum: impact of PV systems on local temperature, " *SunPower,* July 6, 2010. http://www.rurdev.usda.gov/SupportDocuments/EA_5_17_13_RUS_PartA.pdf

[4] Y. Genchi, M. Ishisaki, Y. Ohashi, H. Takahashi, & A. Inaba, "Impacts of large-scale photovoltaic panel installation on the heat island effect in Tokyo, " *in Fifth Conference on the Urban Climate*, 2003.

[5] Theory Guide, *ANSYS Fluent HELP 13.*

Exhibit B

The Photovoltaic Heat Island Effect: Larger solar power plants increase local temperatures

Item type	Article
Authors	Barron-Gafford, Greg A.; Minor, Rebecca L.; Allen, Nathan A.; Cronin, Alex D.; Brooks, Adria E.; Pavao-Zuckerman, Mitchell A.
Citation	The Photovoltaic Heat Island Effect: Larger solar power plants increase local temperatures 2016, 6:35070 Scientific Reports
Eprint version	Final published version
DOI	10.1038/srep35070
Publisher	NATURE PUBLISHING GROUP
Journal	Scientific Reports
Rights	© The Author(s) 2016. This work is licensed under a Creative Commons Attribution 4.0 International License.
Downloaded	10-Mar-2017 16:43:12
Link to item	http://hdl.handle.net/10150/621943

www.nature.com/scientificreports

SCIENTIFIC REPORTS

OPEN

The Photovoltaic Heat Island Effect: Larger solar power plants increase local temperatures

Received: 26 May 2016
Accepted: 23 September 2016
Published: 13 October 2016

Greg A. Barron-Gafford[1,2], Rebecca L. Minor[1,2], Nathan A. Allen[3], Alex D. Cronin[4], Adria E. Brooks[5] & Mitchell A. Pavao-Zuckerman[6]

While photovoltaic (PV) renewable energy production has surged, concerns remain about whether or not PV power plants induce a "heat island" (PVHI) effect, much like the increase in ambient temperatures relative to wildlands generates an Urban Heat Island effect in cities. Transitions to PV plants alter the way that incoming energy is reflected back to the atmosphere or absorbed, stored, and reradiated because PV plants change the albedo, vegetation, and structure of the terrain. Prior work on the PVHI has been mostly theoretical or based upon simulated models. Furthermore, past empirical work has been limited in scope to a single biome. Because there are still large uncertainties surrounding the potential for a PHVI effect, we examined the PVHI empirically with experiments that spanned three biomes. We found temperatures over a PV plant were regularly 3–4 °C warmer than wildlands at night, which is in direct contrast to other studies based on models that suggested that PV systems should decrease ambient temperatures. Deducing the underlying cause and scale of the PVHI effect and identifying mitigation strategies are key in supporting decision-making regarding PV development, particularly in semiarid landscapes, which are among the most likely for large-scale PV installations.

Electricity production from large-scale photovoltaic (PV) installations has increased exponentially in recent decades[1–3]. This proliferation in renewable energy portfolios and PV powerplants demonstrate an increase in the acceptance and cost-effectiveness of this technology[4,5]. Corresponding with this upsurge in installation has been an increase in the assessment of the impacts of utility-scale PV[4,6–8], including those on the efficacy of PV to offset energy needs[9,10]. A growing concern that remains understudied is whether or not PV installations cause a "heat island" (PVHI) effect that warms surrounding areas, thereby potentially influencing wildlife habitat, ecosystem function in wildlands, and human health and even home values in residential areas[11]. As with the Urban Heat Island (UHI) effect, large PV power plants induce a landscape change that reduces albedo so that the modified landscape is darker and, therefore, less reflective. Lowering the terrestrial albedo from ~20% in natural deserts[12] to ~5% over PV panels[13] alters the energy balance of absorption, storage, and release of short- and longwave radiation[14,15]. However, several differences between the UHI and potential PVHI effects confound a simple comparison and produce competing hypotheses about whether or not large-scale PV installations will create a heat island effect. These include: (*i*) PV installations shade a portion of the ground and therefore could reduce heat absorption in surface soils[16], (*ii*) PV panels are thin and have little heat capacity per unit area but PV modules emit thermal radiation both up and down, and this is particularly significant during the day when PV modules are often 20 °C warmer than ambient temperatures, (*iii*) vegetation is usually removed from PV power plants, reducing the amount of cooling due to transpiration[14], (*iv*) electric power removes energy from PV power plants, and (*v*) PV panels reflect and absorb upwelling longwave radiation, and thus can prevent the soil from cooling as much as it might under a dark sky at night.

Public concerns over a PVHI effect have, in some cases, led to resistance to large-scale solar development. By some estimates, nearly half of recently proposed energy projects have been delayed or abandoned due to local opposition[11]. Yet, there is a remarkable lack of data as to whether or not the PVHI effect is real or simply an issue

[1] School of Geography & Development, University of Arizona, Tucson, AZ, USA. [2] Office of Research & Development; College of Science, Biosphere 2, University of Arizona, Tucson, AZ, USA. [3] Nevada Center of Excellence, Desert Research Institute, Las Vegas, NV, USA. [4] Department of Physics, University of Arizona, Tucson, AZ, USA. [5] Department of Electrical and Computer Engineering, University of Wisconsin-Madison, Madison, WI, USA. [6] Department of Environmental Science & Technology, University of Maryland, College Park, MD, USA. Correspondence and requests for materials should be addressed to G.A.B.-G. (email: gregbg@email.arizona.edu)

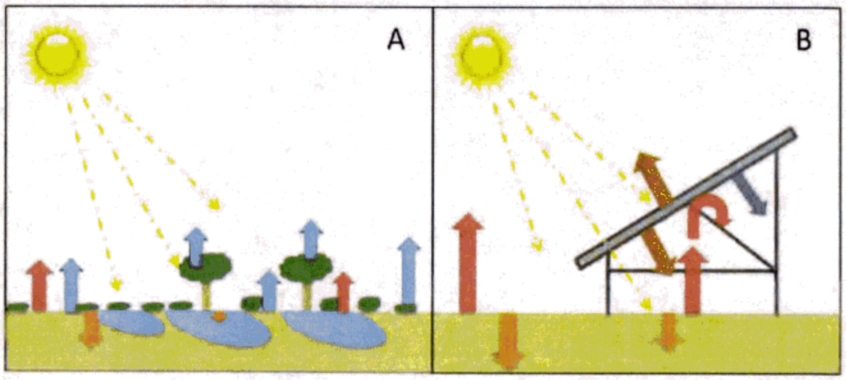


Figure 1. Illustration of midday energy exchange. Assuming equal rates of incoming energy from the sun, a transition from (**A**) a vegetated ecosystem to (**B**) a photovoltaic (PV) power plant installation will significantly alter the energy flux dynamics of the area. Within natural ecosystems, vegetation reduces heat capture and storage in soils (orange arrows), and infiltrated water and vegetation release heat-dissipating latent energy fluxes in the transition of water-to-water vapor to the atmosphere through evapotranspiration (blue arrows). These latent heat fluxes are dramatically reduced in typical PV installations, leading to greater sensible heat fluxes (red arrows). Energy re-radiation from PV panels (brown arrow) and energy transferred to electricity (purple arrow) are also shown.

associated with perceptions of environmental change caused by the installations that lead to "not in my backyard" (NIMBY) thinking. Some models have suggested that PV systems can actually cause a cooling effect on the local environment, depending on the efficiency and placement of the PV panels[17,18]. But these studies are limited in their applicability when evaluating large-scale PV installations because they consider changes in albedo and energy exchange within an urban environment (rather than a natural ecosystem) or in European locations that are not representative of semiarid energy dynamics where large-scale PV installations are concentrated[10,19]. Most previous research, then, is based on untested theory and numerical modeling. Therefore, the potential for a PHVI effect must be examined with empirical data obtained through rigorous experimental terms.

The significance of a PVHI effect depends on energy balance. Incoming solar energy typically is either reflected back to the atmosphere or absorbed, stored, and later re-radiated in the form of latent or sensible heat (Fig. 1)[20,21]. Within natural ecosystems, vegetation reduces heat gain and storage in soils by creating surface shading, though the degree of shading varies among plant types[22]. Energy absorbed by vegetation and surface soils can be released as latent heat in the transition of liquid water to water vapor to the atmosphere through evapotranspiration – the combined water loss from soils (evaporation) and vegetation (transpiration). This heat-dissipating latent energy exchange is dramatically reduced in a typical PV installation (Fig. 1 transition from A-to-B), potentially leading to greater heat absorption by soils in PV installations. This increased absorption, in turn, could increase soil temperatures and lead to greater sensible heat efflux from the soil in the form of radiation and convection. Additionally, PV panel surfaces absorb more solar insolation due to a decreased albedo[13,23,24]. PV panels will re-radiate most of this energy as longwave sensible heat and convert a lesser amount (~20%) of this energy into usable electricity. PV panels also allow some light energy to pass, which, again, in unvegetated soils will lead to greater heat absorption. This increased absorption could lead to greater sensible heat efflux from the soil that may be trapped under the PV panels. A PVHI effect would be the result of a detectable increase in sensible heat flux (atmospheric warming) resulting from an alteration in the balance of incoming and outgoing energy fluxes due to landscape transformation. Developing a full thermal model is challenging[17,18,25], and there are large uncertainties surrounding multiple terms including variations in albedo, cloud cover, seasonality in advection, and panel efficiency, which itself is dynamic and impacted by the local environment. These uncertainties are compounded by the lack of empirical data.

We addressed the paucity of direct quantification of a PVHI effect by simultaneously monitoring three sites that represent a natural desert ecosystem, the traditional built environment (parking lot surrounded by commercial buildings), and a PV power plant. We define a PVHI effect as the difference in ambient air temperature between the PV power plant and the desert landscape. Similarly, UHI is defined as the difference in temperature between the built environment and the desert. We reduced confounding effects of variability in local incoming energy, temperature, and precipitation by utilizing sites contained within a 1 km area.

At each site, we monitored air temperature continuously for over one year using aspirated temperature probes 2.5 m above the soil surface. Average annual temperature was 22.7 + 0.5 °C in the PV installation, while the nearby desert ecosystem was only 20.3 + 0.5 °C, indicating a PVHI effect. Temperature differences between areas varied significantly depending on time of day and month of the year (Fig. 2), but the PV installation was always greater than or equal in temperature to other sites. As is the case with the UHI effect in dryland regions, the PVHI effect delayed the cooling of ambient temperatures in the evening, yielding the most significant difference in overnight temperatures across all seasons. Annual average midnight temperatures were 19.3 + 0.6 °C in the PV installation, while the nearby desert ecosystem was only 15.8 + 0.6 °C. This PVHI effect was more significant in terms of actual degrees of warming (+3.5 °C) in warm months (Spring and Summer; Fig. 3, right).

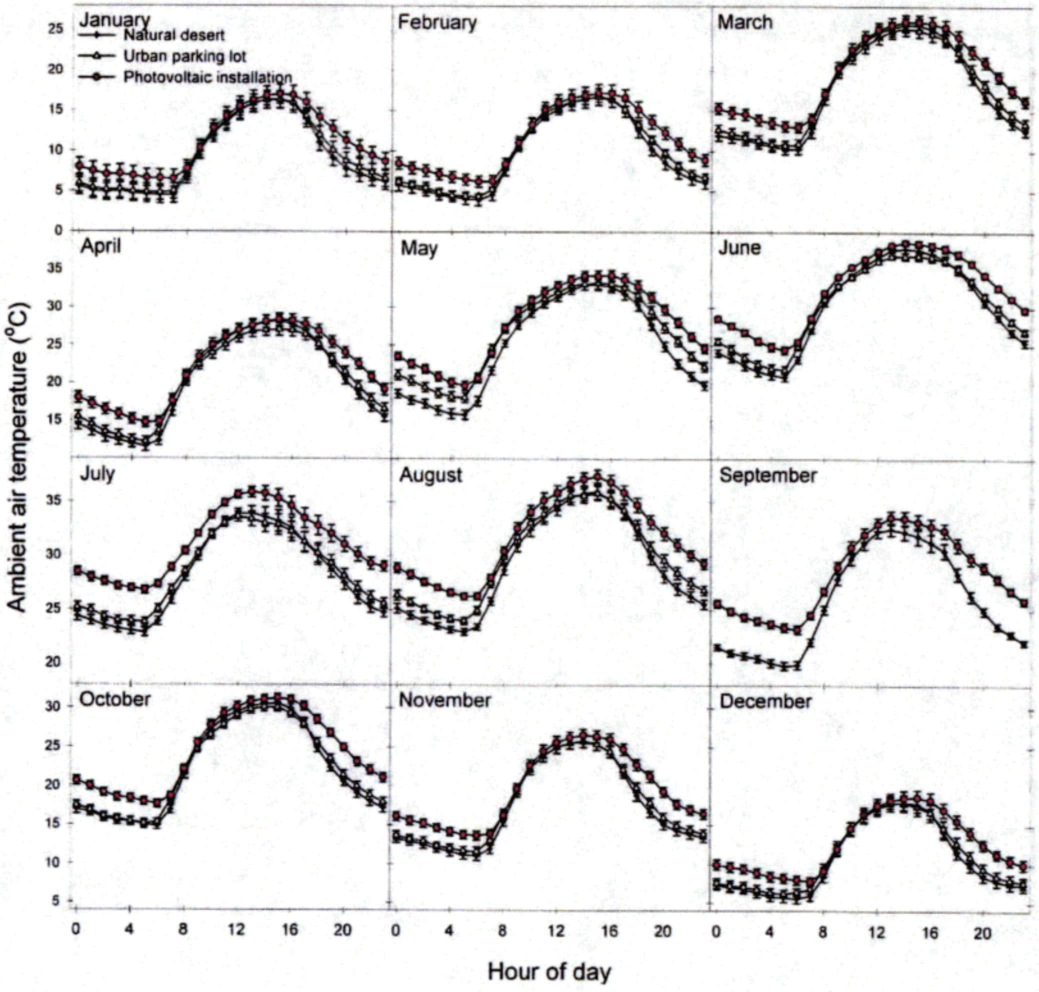


Figure 2. Average monthly ambient temperatures throughout a 24-hour period provide evidence of a photovoltaic heat island (PVHI) effect.

In both PVHI and UHI scenarios, the greater amount of exposed ground surfaces compared to natural systems absorbs a larger proportion of high-energy, shortwave solar radiation during the day. Combined with minimal rates of heat-dissipating transpiration from vegetation, a proportionally higher amount of stored energy is reradiated as longwave radiation during the night in the form of sensible heat (Fig. 1)[15]. Because PV installations introduce shading with a material that, itself, should not store much incoming radiation, one might hypothesize that the effect of a PVHI effect would be lesser than that of a UHI. Here, we found that the difference in evening ambient air temperature was consistently greater between the PV installation and the desert site than between the parking lot (UHI) and the desert site (Fig. 3). The PVHI effect caused ambient temperature to regularly approach or be in excess of 4 °C warmer than the natural desert in the evenings, essentially doubling the temperature increase due to UHI measured here. This more significant warming under the PVHI than the UHI may be due to heat trapping of re-radiated sensible heat flux under PV arrays at night. Daytime differences from the natural ecosystem were similar between the PV installation and urban parking lot areas, with the exception of the Spring and Summer months, when the PVHI effect was significantly greater than UHI in the day. During these warm seasons, average midnight temperatures were 25.5 + 0.5 °C in the PV installation and 23.2 + 0.5 °C in the parking lot, while the nearby desert ecosystem was only 21.4 + 0.5 °C.

The results presented here demonstrate that the PVHI effect is real and can significantly increase temperatures over PV power plant installations relative to nearby wildlands. More detailed measurements of the underlying causes of the PVHI effect, potential mitigation strategies, and the relative influence of PVHI in the context of the intrinsic carbon offsets from the use of this renewable energy are needed. Thus, we raise several new questions and highlight critical unknowns requiring future research.

What is the physical basis of land transformations that might cause a PVHI?

We hypothesize that the PVHI effect results from the effective transition in how energy moves in and out of a PV installation versus a natural ecosystem. However, measuring the individual components of an energy flux model remains a necessary task. These measurements are difficult and expensive but, nevertheless, are indispensable in identifying the relative influence of multiple potential drivers of the PVHI effect found here. Environmental

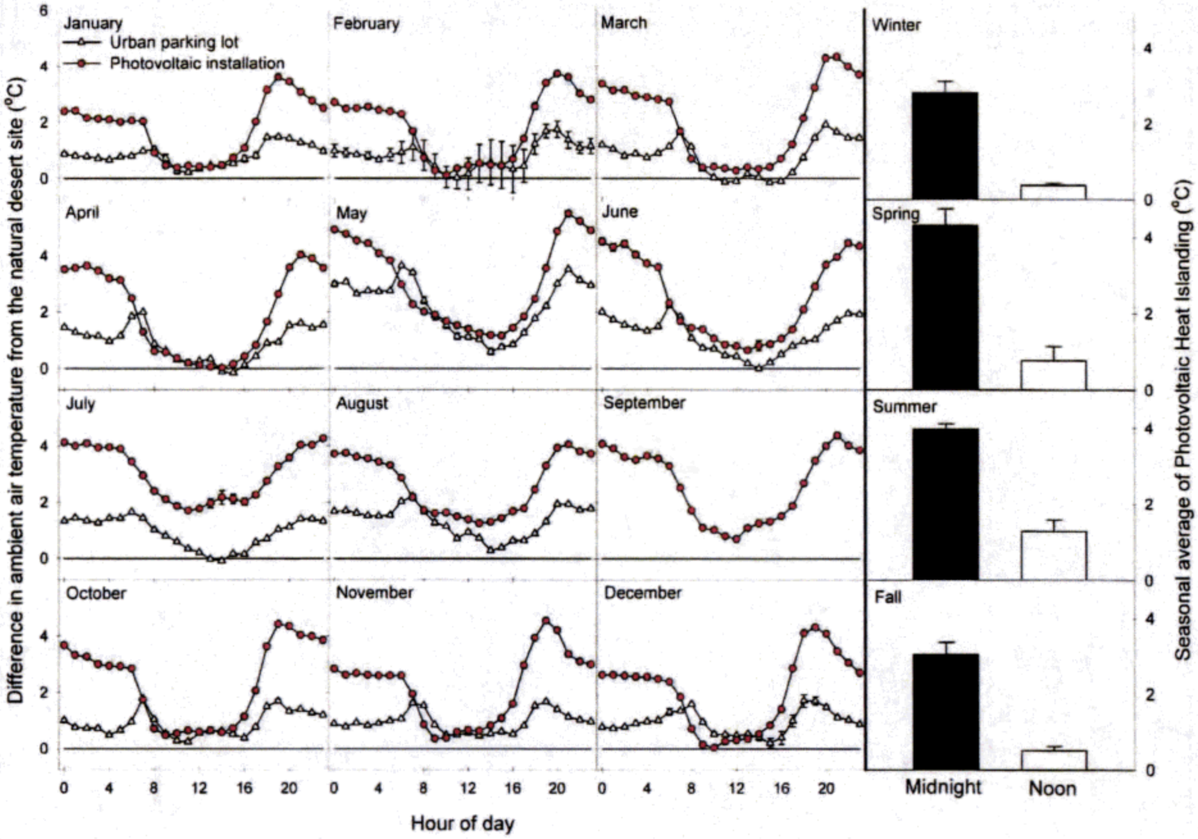


Figure 3. (Left) Average monthly levels of Photovoltaic Heat Islanding (ambient temperature difference between PV installation and desert) and Urban Heat Islanding (ambient temperature difference between the urban parking lot and the desert). (Right) Average night and day temperatures for four seasonal periods, illustrating a significant PVHI effect across all seasons, with the greatest influence on ambient temperatures at night.

conditions that determine patterns of ecosystem carbon, energy, and water dynamics are driven by the means through which incoming energy is reflected or absorbed. Because we lack fundamental knowledge of the changes in surface energy fluxes and microclimates of ecosystems undergoing this land use change, we have little ability to predict the implications in terms of carbon or water cycling[4,8].

What are the physical implications of a PVHI, and how do they vary by region?

The size of an UHI is determined by properties of the city, including total population[26–28], spatial extent, and the geographic location of that city[29–31]. We should, similarly, consider the spatial scale and geographic position of a PV installation when considering the presence and importance of the PVHI effect. Remote sensing could be coupled with ground-based measurements to determine the lateral and vertical extent of the PVHI effect. We could then determine if the size of the PVHI effect scales with some measure of the power plant (for example, panel density or spatial footprint) and whether or not a PVHI effect reaches surrounding areas like wildlands and neighborhoods. Given that different regions around the globe each have distinct background levels of vegetative ground cover and thermodynamic patterns of latent and sensible heat exchange, it is possible that a transition from a natural wildland to a typical PV power plant will have different outcomes than demonstrated here. The paucity in data on the physical effects of this important and growing land use and land cover change warrants more studies from representative ecosystems.

What are the human implications of a PVHI, and how might we mitigate these effects?

With the growing popularity of renewable energy production, the boundaries between residential areas and larger-scale PV installations are decreasing. In fact, closer proximity with residential areas is leading to increased calls for zoning and city planning codes for larger PV installations[32,33], and PVHI-based concerns over potential reductions in real estate value or health issues tied to Human Thermal Comfort (HTC)[34]. Mitigation of a PVHI effect through targeted revegetation could have synergistic effects in easing ecosystem degradation associated with development of a utility scale PV site and increasing the collective ecosystem services associated with an area[4]. But what are the best mitigation measures? What tradeoffs exist in terms of various means of revegetating degraded PV installations? Can other albedo modifications be used to moderate the severity of the PVHI?

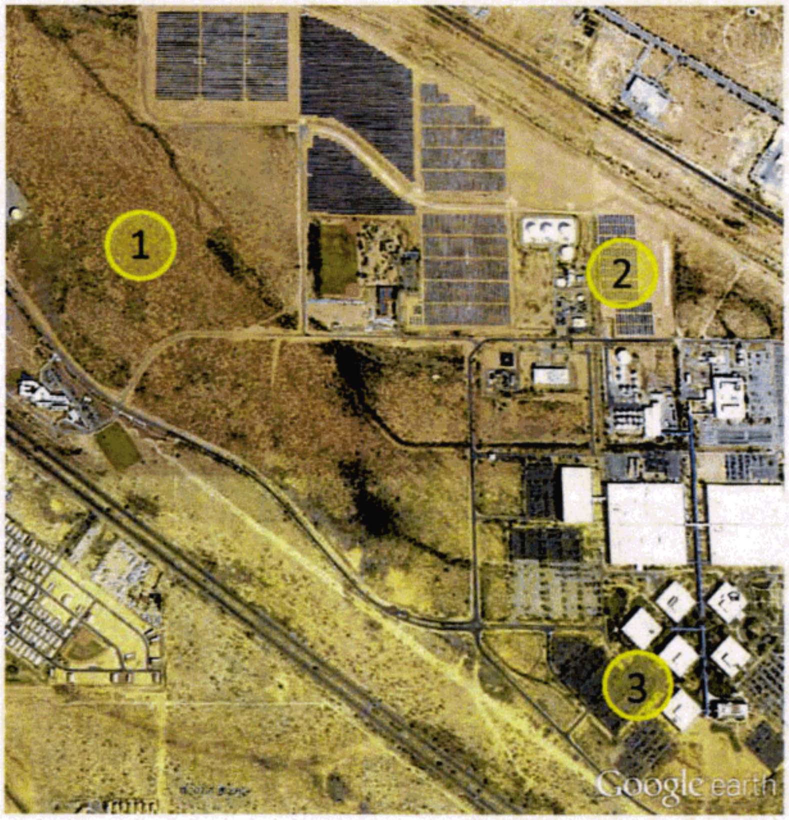


Figure 4. Experimental sites. Monitoring a (1) natural semiarid desert ecosystem, (2) solar (PV) photovoltaic installation, and (3) an "urban" parking lot – the typical source of urban heat islanding – within a 1 km² area enabled relative control for the incoming solar energy, allowing us to quantify variation in the localized temperature of these three environments over a year-long time period. The Google Earth image shows the University of Arizona's Science and Technology Park's Solar Zone.

To fully contextualize these findings in terms of global warming, one needs to consider the relative significance of the (globally averaged) decrease in albedo due to PV power plants and their associated warming from the PVHI against the carbon dioxide emission reductions associated with PV power plants. The data presented here represents the first experimental and empirical examination of the presence of a heat island effect associated with PV power plants. An integrated approach to the physical and social dimensions of the PVHI is key in supporting decision-making regarding PV development.

Methods

Site Description. We simultaneously monitored a suite of sites that represent the traditional built urban environment (a parking lot) and the transformation from a natural system (undeveloped desert) to a 1 MW PV power plant (Fig. 4; Map data: Google). To minimize confounding effects of variability in local incoming energy, temperature, and precipitation, we identified sites within a 1 km area. **All sites were within the boundaries of the University of Arizona Science and Technology Park Solar Zone** (32.092150°N, 110.808764°W; elevation: 888 m ASL). Within a 200 m diameter of the semiarid desert site's environmental monitoring station, the area is composed of a sparse mix of semiarid grasses (*Sporobolus wrightii, Eragrostis lehmanniana*, and *Muhlenbergia porteri*), cacti (*Opuntia* spp. and *Ferocactus* spp.), and occasional woody shrubs including creosote bush (*Larrea tridentata*), whitethorn acacia (*Acacia constricta*), and velvet mesquite (*Prosopis velutina*). The remaining area is bare soil. These species commonly co-occur on low elevation desert bajadas, creosote bush flats, and semiarid grasslands. The photovoltaic installation was put in place in early 2011, three full years prior when we initiated monitoring at the site. We maintained the measurement installations for one full year to capture seasonal variation due to sun angle and extremes associated with hot and cold periods. Panels rest on a single-axis tracker system that pivot east-to-west throughout the day. A parking lot with associated building served as our "urban" site and is of comparable spatial scale as our PV site.

Monitoring Equipment & Variables Monitored. Ambient air temperature (°C) was measured with a shaded, aspirated temperature probe 2.5 m above the soil surface (Vaisala HMP60, Vaisala, Helsinki, Finland in the desert and Microdaq U23, Onset, Bourne, MA in the parking lot). Temperature probes were cross-validated for precision (closeness of temperature readings across all probes) at the onset of the experiment. Measurements of temperature were recorded at 30-minute intervals throughout a 24-hour day. Data were recorded on a data-logger (CR1000, Campbell Scientific, Logan, Utah or Microstation, Onset, Bourne, MA). Data from this instrument array is shown for a yearlong period from April 2014 through March 2015. Data from the parking lot was lost for September 2014 because of power supply issues with the datalogger.

Statistical analysis. Monthly averages of hourly (on-the-hour) data were used to compare across the natural semiarid desert, urban, and PV sites. A Photovoltaic Heat Island (PVHI) effect was calculated as differences in these hourly averages between the PV site and the natural desert site, and estimates of Urban Heat Island (UHI) effect was calculated as differences in hourly averages between the urban parking lot site and the natural desert site. We used midnight and noon values to examine maximum and minimum, respectively, differences in temperatures among the three measurement sites and to test for significance of heat islanding at these times. Comparisons among the sites were made using Tukey's honestly significant difference (HSD) test[35]. Standard errors to calculate HSD were made using pooled midnight and noon values across seasonal periods of winter (January-March), spring (April-June), summer (July-September), and fall (October-December). Seasonal analyses allowed us to identify variation throughout a yearlong period and relate patterns of PVHI or UHI effects with seasons of high or low average temperature to examine correlations between background environmental parameters and localized heat islanding.

References

1. IPCC. IPCC Special Report on Renewable Energy Sources and Climate Change Mitigation. *Prepared by Working Group III of the Intergovernmental Panel on Climate Change* (Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 2011).
2. REN21. Renewables 2014 Global Status Report (Paris: REN21 Secretariat; ISBN 978-3-9815934-2-6, 2014).
3. U.S. Energy Information Administration. June 2016 Monthly Energy Review. U.S. Department of Energy. Office of Energy Statistics. Washington, DC (2016).
4. Hernandez, R. R. *et al.* Environmental impacts of utility-scale solar energy. *Renewable & Sustainable Energy Reviews* **29,** 766–779, doi: 10.1016/j.rser.2013.08.041 (2014).
5. Bazilian, M. *et al.* Re-considering the economics of photovoltaic power. *Renewable Energy* **53,** 329–338, doi: http://dx.doi.org/10.1016/j.renene.2012.11.029 (2013).
6. Dale, V. H., Efroymson, R. A. & Kline, K. L. The land use-climate change-energy nexus. *Landsc. Ecol.* **26,** 755–773, doi: 10.1007/s10980-011-9606-2 (2011).
7. Copeland, H. E., Pocewicz, A. & Kiesecker, J. M. In *Energy Development and Wildlife Conservation in Western North America* (ed Naugle, David E.) 7–22 (Springer, 2011).
8. Armstrong, A., Waldron, S., Whitaker, J. & Ostle, N. J. Wind farm and solar park effects on plant-soil carbon cycling: uncertain impacts of changes in ground-level microclimate. *Global Change Biology* **20,** 1699–1706, doi: 10.1111/gcb.12437 (2014).
9. Hernandez, R. R., Hoffacker, M. K. & Field, C. B. Efficient use of land to meet sustainable energy needs. *Nature Climate Change* **5,** 353–358, doi: 10.1038/nclimate2556 (2015).
10. Hernandez, R. R., Hoffacker, M. K. & Field, C. B. Land-Use efficiency of big solar. *Environmental Science & Technology* **48,** 1315–1323, doi: 10.1021/es4043726 (2014).
11. Pociask, S. & Fuhr, J. P. Jr. Progress Denied: A study on the potential economic impact of permitting challenges facing proposed energy projects (U.S. Chamber of Commerce, 2011).
12. Michalek, J. L. *et al.* Satellite measurements of albedo and radiant temperature from semi-desert grassland along the Arizona/Sonora border. *Climatic Change* **48,** 417–425, doi: 10.1023/a:1010769416826 (2001).
13. Burg, B. R., Ruch, P., Paredes, S. & Michel, B. Placement and efficiency effects on radiative forcing of solar installations. *11th International Conference on Ceonctrator Photovoltaic Systems* **1679**, doi: 10.1063/1.4931546 (2015).
14. Solecki, W. D. *et al.* Mitigation of the heat island effect in urban New Jersey. *Environmental Hazards* **6,** 39–49, doi: 10.1016/j.hazards.2004.12.002 (2005).
15. Oke, T. R. The energetic basis of the urban heat island (Symons Memorial Lecture, 20 May 1980). *Quarterly Journal, Royal Meteorological Society* **108,** 1–24 (1982).
16. Smith, S. D., Patten, D. T. & Monson, R. K. Effects of artificially imposed shade on a Sonoran Desert ecosystem: microclimate and vegetation. *Journal of Arid Environments* **13,** 65–82 (1987).
17. Taha, H. The potential for air-temperature impact from large-scale deployment of solar photovoltaic arrays in urban areas. *Solar Energy* **91,** 358–367, doi: 10.1016/j.solener.2012.09.014 (2013).
18. Masson, V., Bonhomme, M., Salagnac, J.-L., Briottet, X. & Lemonsu, A. Solar panels reduce both global warming and Urban Heat Island. *Frontiers in Environmental Science* **2,** 14, doi: 10.3389/fenvs.2014.00014 (2014).
19. Roberts, B. J. Solar production potential across the United States. *Department of Energy, National Renewable Energy Laboratory.* http://www.climatecentral.org/news/eastern-us-solar-development-18714. *19 September* (2012).
20. Monteith, J. L. & Unsworth, M. H. *Principles of Environmental Physics Third Edition* (Elsevier, San Diego, CA, USA, 1990).
21. Campbell, G. S. & Norman, J. M. *An Introduction to Eenvironmental Biophysics Second Edition* (Springer, New York, USA, 1998).
22. Breshears, D. D. The grassland-forest continuum: trends in ecosystem properties for woody plant mosaics? *Frontiers in Ecology and the Environment* **4,** 96–104, doi: 10.1890/1540-9295(2006)004[0096:tgctie]2.0.co;2 (2006).
23. Oke, T. R. *Boundary Layer Climates. Second Edition* (Routledge New York, 1992).
24. Ahrens, C. D. *Meteorology Today. An Introduction to Weather, Climate, and the Environment Eighth Edition* (Thompson, Brooks/Cole USA 2006).
25. Fthenakis, V. & Yu, Y. Analysis of the potential for a heatisland effect in large solar farms. *Analysis of the potential for a heatisland effect in large solar farms; 2013 IEEE 39th Photovoltaic Specialists Conference* 3362–3366 (2013).
26. Santamouris, M. Analyzing the heat island magnitude and characteristics in one hundred Asian and Australian cities and regions. *Science of The Total Environment* **512–513,** 582–598, doi: http://dx.doi.org/10.1016/j.scitotenv.2015.01.060 (2015).
27. Oke, T. R. City size and the urban heat island. *Atmospheric Environment* **7,** 769–779, doi: 10.1016/0004-6981(73)90140-6 (1973).
28. Wang, W.-C., Zeng, Z. & Karl, T. R. Urban heat islands in China. *Geophysical Research Letters* **17,** 2377–2380, doi: 10.1029/GL017i013p02377 (1990).
29. Nasrallah, H. A., Brazel, A. J. & Balling, R. C. Jr Analysis of the Kuwait City urban heat island. *International Journal of Climatology* **10,** 401–405 (1990).
30. Montávez, J. P., Rodríguez, A. & Jiménez, J. I. A study of the Urban Heat Island of Granada. *International Journal of Climatology* **20,** 899–911, doi: 10.1002/1097-0088(20000630)20:8<899::aid-joc433>3.0.co;2-i (2000).
31. Buyantuyev, A. & Wu, J. Urban heat islands and landscape heterogeneity: Linking spatiotemporal variations in surface temperatures to land-cover and socioeconomic patterns. *Landsc. Ecol.* **25,** 17–33, doi: 10.1007/s10980-009-9402-4 (2010).
32. White, J. G. A Model Ordinance for Energy Projects; Oregon Department of Energy. http://www.oregon.gov/ENERGY/SITING/docs/ModelEnergyOrdinance.pdf (2005).

33. Lovelady, A. Planning and Zoning for Solar in North Carolina. *University of North Carolina at Chapel Hill, School of Government* (2014).
34. Coutts, A. M., Tapper, N. J., Beringer, J., Loughnan, M. & Demuzere, M. Watering our cities: The capacity for Water Sensitive Urban Design to support urban cooling and improve human thermal comfort in the Australian context. *Progress in Physical Geography* **37**, 2–28, doi: 10.1177/0309133312461032 (2013).
35. Zar, J. H. *Biostatistical analysis, Prentice-Hall, Englewood Cliffs, p 215* (1974).

Acknowledgements

The authors thank Ken Marcus for access to the University of Arizona Solar Zone and the Science and Technology Park and to Tucson Electric Power for access to their PV installation. This research was supported by the University of Arizona Institute of the Environment and the Office of Research & Development through the TRIF-funded Water, Environmental and Energy Solutions initiative.

Author Contributions

G.A.B.-G., R.L.M. and N.A.A. established research sites and installed monitoring equipment. G.A.B.-G. directed research and R.L.M. conducted most site maintenance. G.A.B.-G., N.A.A., A.D.C. and M.A.P.-Z. led efforts to secure funding for the research. All authors discussed the results and contributed to the manuscript.

Additional Information

Competing financial interests: The authors declare no competing financial interests.

How to cite this article: Barron-Gafford, G. A. *et al.* The Photovoltaic Heat Island Effect: Larger solar power plants increase local temperatures. *Sci. Rep.* **6**, 35070; doi: 10.1038/srep35070 (2016).

Exhibit C

Arizona
Corporation Commission


Doug Little


Boyd Dunn


Tom Forese


Andy Tobin


Bob Burns

Utilities Division

Home Electric Gas Telephone Water / Sewer Consumer Services

Arizona Power Plant and Transmission Line Siting Committee

Click here to view the Proposed Form for CEC Transfer

Click here to view the Siting Committee Hearing Calendar

- What is the Arizona Power Plant and Transmission Line Siting Committee?
- Who is on the Arizona Power Plant and Transmission Line Siting Committee?
- Who presides over the Arizona Power Plant and Transmission Line Siting Committee?
- How long does the Committee have to evaluate a project?
- How does the Committee conduct business?
- How can I find out about power plants or transmission projects affecting my community?
- How can I view the documents pertaining to a specific power plant application?
- Can members of the public speak out about a particular project?
- How can I participate if I'm unable to attend the meetings of the Siting Committee?
- What factors are considered when the Committee reviews an application?
- Is a unanimous vote required?
- How does the Arizona Corporation Commission play a role in plant or line siting?
- Can the Committee impose conditions on a power plant or transmission line approval?
- After the Committee approves a plant, can the Commission amend the approval?

What is the Arizona Power Plant and Transmission Line Siting Committee?
In 1971, the Arizona Legislature required that the Commission establish a power plant and line siting committee. The Committee provides a single, independent forum to evaluate applications to build power plants (of 100 megawatts or more) or transmission projects (of 115,000 volts or more) in the state. The Committee holds meetings and hearings that are open to the public.

The Committee was created after the Legislature found that existing law did "not provide adequate opportunity for individuals, groups interested in conservation and the protection of the environment, local governments, and other public bodies to participate in timely fashion the decision to locate a specific major facility at a specific site." (Historical Notes, Laws 1971, Ch. 67. §1)

Who is on the Arizona Power Plant and Transmission Line Siting Committee?
Arizona Revised Statute 40-360.01B dictates who is on the Committee. Its members are:

State attorney general or the attorney general's designee. (Chairman of Committee)

Director of the Arizona Department of Water Resources or the director's designee.

Director of the Arizona Department of Environmental Quality or the director's designee.

Director of the energy office of the Arizona Department of Commerce or the director's designee.

Chairman of the Arizona Corporation Commission or the chairman's designee.

Six members appointed by the Arizona Corporation Commission to serve for a term of two years. Three of the members shall represent the public, one member shall represent incorporated cities and towns, one member shall represent counties and one member shall be actively engaged in agriculture

Who presides over the Arizona Power Plant and Transmission Line Siting Committee?
The attorney general or his/her designee chairs the Committee. The Chairman directs the flow of the meeting and makes procedural decisions in accordance with Arizona law. However, each member of the Committee, including the Chairman, has a single vote.

How long does the Committee have to evaluate a project?
ARS § 40-360.04 sets forth specific time frames for Committee action. In general, the Committee has 180 days from the date the application is filed to come to a decision.

How does the Committee conduct business?
The procedures for the Committee's activities are set forth in law and administrative regulations. After an application to build a power plant or transmission line is filed with the Corporation Commission, copies are sent to all members of the Committee. The chairman of the Committee sets a hearing date and provides public notice of the hearing date

and location. Any member of the public can attend the hearing. The hearing will include testimony and exhibits from the applicant, and testimony and exhibits from any groups or individuals who are granted party, or intervener, status. There is cross-examination of the witnesses by the parties. The Committee members also ask questions of the witnesses, and may ask for additional information. After all the information is before the Committee, the Committee members will discuss the matter and will take a vote on whether to grant or deny a "Certificate of Environmental Compatibility," which is a formal document that is necessary before the power plant or transmission line can be built. If granted, the Certificate is then forwarded to the Commission for review and action. If denied, the applicant may request that the Commission rehear the matter.

How can I find out about power plants or transmission projects affecting my community?
We find that local newspapers and radio stations are a great source of information about utility projects. They usually carry notices of public meetings and attend the proceedings. The Arizona Corporation Commission's website (www.azcc.gov) includes a link for information about Arizona Power Plant and Line Siting Committee meetings.

How can I view the documents pertaining to a specific power plant application?
As power plant cases move through the process, hundreds of pages of documents, testimony and technical data are filed in the Docket Control Centers at the Arizona Corporation Commission's Phoenix and Tucson offices. The Phoenix Docket Control Center is located at 1200 West Washington and the Tucson office is at 400 West Congress Street.

Can members of the public speak out about a particular project?
Yes. The Legislature envisioned the plant and line siting process as a public process that benefits from public input. Time permitting, the Chairman of the Committee will call the meeting to order and allow time for public comment. If there are many people who wish to speak, the Chairman may impose a time limit for each person making public comment.

How can I participate if I'm unable to attend the meetings of the Siting Committee?
You can express your views by sending a letter and 25 copies to the Docket Control Center. It will be distributed by mail to all registered parties or interveners. Be sure to include the docket number (case number) to ensure that it is properly catalogued and distributed. Send to:

Docket Control Center
Arizona Corporation Commission
1200 West Washington
Phoenix, AZ 85007

What factors are considered when the Committee reviews an application?
Again, the statutes (ARS § 40-360.06) spell out the criteria for issuing a Certificate of Environmental Compatibility. These factors include:

Existing plans of the state, local government and private entities for other developments at or in the vicinity of the proposed site.

Fish, wildlife and plant life and associated forms of life upon which they are dependent.

Noise emission levels and interference with communication signals.

The proposed availability of the site to the public for recreational purposes, consistent with safety considerations and regulations.

Existing scenic areas, historic sites and structures or archaeological sites at or in the vicinity of the proposed site.

The total environment of the area.

The technical practicability of achieving a proposed objective and the previous experience with equipment and methods available for achieving a proposed objective.

The estimated cost of the facilities and site as proposed by the applicant and the estimated cost of the facilities and site as recommended by the committee, recognizing that any significant increase in costs represents a potential increase in the cost of electric energy to the customers or the applicant.

Any additional factors which require consideration under applicable federal and state laws pertaining to any such site.

Is a unanimous vote required?
No. The Committee needs only a majority decision of the total Committee to issue or deny a Certificate of Environmental Compatibility.

How does the Arizona Corporation Commission play a role in plant or line siting?
The Commission plays three important roles:

1. The Chairman of the Commission or his/her designee serves on the Committee.
2. The documents pertaining to a particular case are housed in the Commission's Docket Control Center (1200 West Washington in Phoenix) so members of the public can view the case files.
3. The Commission must either confirm, deny or modify the certificate granted by the Committee or if the Committee refused to grant a certificate, the Commission may issue a certificate. The Commission makes its decisions in public Open Meetings with opportunities for additional public comment.

Can the Committee impose conditions on a power plant or transmission line approval?
Yes. The Committee has fairly broad discretion and can require that a plant or transmission line conform to certain conditions.

After the Committee approves a plant, can the Commission amend the approval?
Within the parameters of the law, the Commission can also amend an application to include conditions it deems necessary for a project to be in the broad public interest.

Editors & News Directors:
To find out more about the statutes governing the Committee, please go to www.azleg.state.az.us and enter 40-360 under the section marked Arizona Revised Statutes.
The Rules of Practice and Procedure Before the Power Plant and Transmission Line Siting Committee can be found in R14-3-201 through 219 in the Arizona Administrative Code. To view the Rules, click here: RULE 14-3

QUICK LAUNCH

QUICK LAUNCH...

LIVE MEETING BROADCAST

eCorp

eDOCKET

AZ IN

Bloomberg Law Reports' Sustainable Energy

Siting Renewable Electric Infrastructure in the Southwest (Back to Top)

Contributed By: Albert Acken & Thomas Campbell, Lewis and Roca, LLP

I. Introduction

Renewable Energy, Why Now?

As it has in the past, renewable energy is again hailed as the future. In the 1970s, renewable energy was touted as one part of the solution for the energy crises. The movement lost momentum, however, when low oil prices reappeared in the 1980s.

Today, energy independence is again a driver for renewable energy, but it is not the only one. Concern about climate change is a second critical factor in the current renewable energy frenzy. Renewable energy development is being directly pursued through various state renewable portfolio standards, which mandate that public utilities acquire certain percentages of power from renewable sources. Given recent congressional proposals, such as the American Clean Energy and Security Act of 2009 (also known as the Waxman-Markey bill), it appears the federal government is likely to jump into the renewable portfolio standard business too. Additionally, the federal government also appears poised to facilitate renewable energy indirectly through greenhouse gas regulations and concomitant costs on conventional energy sources. The version of the Waxman-Markey bill that passed the House on June 26, 2009, mandates a reduction in greenhouse gas emissions to 17 percent below the 2005 levels by 2020 and 83 percent below the 2005 levels by 2050.[1] As a result, renewable energy sources will look more attractive when compared to conventional sources of power and provide a hedge against the uncertainty of the true cost of greenhouse gas regulation.

Additionally, renewable energy is viewed as a key economic development strategy. The recently enacted federal stimulus bill includes billions in grants and loans for transmission grid development and billions more in tax incentives and grants to facilitate renewable energy developments.[2] States are getting in the act as well. Using tax incentives, renewable energy portfolio standards, and other mechanisms, southwestern states are competing for the jobs and tax base that renewable plants and associated manufacturing facilities will bring. These additional factors suggest renewable energy will finally begin to fulfill its potential.

Challenges

However, despite the current momentum, many obstacles remain. The focus of this article is on one of those challenges, the licensing processes that utility-scale renewable energy projects in the Southwest must navigate.

Despite the climate-friendly nature of these projects, they do have real environmental impacts given the size and location of the plants. A typical concentrated solar power plant requires at least five acres per MW, so a 200 MW plant requires 1,000 acres of land. Additionally, the transmission lines to move power from remote generation to urban areas needing the power also have environmental impacts and are frequently opposed by those who live nearby.

Finally, land in the Southwest is a checkerboard of federal, state, and private lands. Each brings unique challenges and benefits and many projects will cross multiple types of lands and, therefore, require multiple, parallel approvals. This article summarizes the licensing approvals required and the considerations that come into play when deciding whether to use federal, state, or private lands.

II. Licensing Approvals

A. Federal Land Managers

In the Southwest, federal lands are managed by a number of federal agencies including the Bureau of Land Management, Forest Service, and the Fish and Wildlife Service, among others. Each of these federal land managers has its own process for processing right-of-way applications to construct and operate renewable energy facilities and the transmission lines needed to serve them.

While the processes are not identical, they share one common bond: all require compliance with the National Environmental Policy Act ("NEPA"). NEPA requires the federal government to assess the environmental impact of "major Federal actions significantly affecting the quality of the human environment."[3] Federal licensing for utility-scale renewable projects and the transmission lines necessary to carry generation to loads certainly fit the bill of actions that significantly affect the environment and, therefore, NEPA compliance is required. Complying with NEPA's procedural requirements and obtaining federal rights-of-way is typically a multi-year process.

B. State Trust Land Departments

When the federal government established territories and states in the western United States, it reserved some lands to be held in trust, primarily for the benefit of education. These lands, commonly referred to as state trust lands, occupy a significant portion of the southwestern landscape. For example, New Mexico has approximately 13 million acres in trust. Arizona holds approximately nine million acres.

To site a plant or transmission line on state trust lands, approval must be obtained from the state land department.[4] Each state has different processes that work in similar ways. Unlike the federal process, which focuses primarily on the environmental impact, the focus of the state land process is to maximize revenues and preserve trust assets for the trust's beneficiaries.

C. State Public Utility Commissions

In addition to the authorization needed to use federal lands and state trust lands, approvals must also be obtained from state public utility commissions.

1. Federal Siting Authority

Historically, states have had the exclusive authority to site electric transmission lines. The Energy Policy Act of 2005 was an effort to change the status quo. Section 1221 provided the Federal Energy Regulatory Commission ("FERC") with the authority to site electric transmission lines in designated National Interest Energy Transmission Corridors in the event a state siting commission either lacked the authority to approve a transmission project or withheld approval for more than one year.[5] This authority is generally referred to as "backstop" siting authority.

In rules promulgated to implement the new statutory authority, FERC determined that it would also exercise jurisdiction over projects in which a state commission denied a transmission line application.[6] However, in February 2009, the Fourth Circuit concluded that FERC's rule was unlawful, casting into doubt the efficacy of FERC's backstop authority.[7] Congress is considering various legislative proposals that would give FERC additional jurisdiction over interstate electric transmission lines (as FERC currently has with respect to interstate natural gas pipelines).

At this time, the state utility commissions still have primary responsibility for siting transmission lines within their state borders. The following brief summary of the siting process for Arizona and Nevada demonstrates that these two states are actively promoting the development of renewable generation.

2. Arizona Corporation Commission

Transmission lines of 115 kV or more, and power plants of 100 MW or greater (with limited exceptions)[8] must receive state commission authorization through a two-step process. First, projects must obtain a certificate of environmental compatibility ("CEC") from the Arizona Power Plant and Transmission Line Siting Committee (the "Committee) following an evidentiary hearing.[9] **Interested parties, including landowners, members of the public, environmental groups, municipalities and others, may intervene and participate in the process, which participation may include presenting witnesses, cross-examining the applicant's witnesses, and filing legal memoranda.**[10] After the Committee decides whether or not to grant a CEC, the Arizona Corporation Commission ("ACC") reviews the Committee's decision.[11]

The environmental factors that must be considered by the Committee are set forth in A.R.S. §40-360.06 and include: existing land use plans of the state, local government and private entities for other developments at or in the vicinity of the proposed site; biological resources; visual impacts; and cultural impacts. Another environmental factor is set forth in A.R.S. §40-360.13, which requires that the Committee consider the availability of groundwater and the impact of the use of groundwater for facilities within the service areas of the city or town in an active management area.

Ultimately, the CEC must be approved by the ACC under the standard set forth in A.R.S. §40-360.07(B):

> In arriving at its decision, the commission shall comply with the provisions of section 40-360.06 and shall balance, in the broad public interest, the need for an adequate, economical and reliable supply of electric power with the desire to minimize the effect thereof on the environment and ecology of this state.

It is important to note that the state utility commission authorization does not eliminate the need to obtain land use and zoning approvals from local municipalities. Localities have zoning ordinances and general plans that must be addressed if the project is sited on private land and often require some environmental analysis. In addition, other state or local environmental agencies often have oversight with respect to environmental impact.

3. Nevada Public Utilities Commission

Siting of a utility facility, including renewable energy infrastructure, in Nevada must be done in compliance with the Utility Environmental Protection Act ("UEPA") and with approval of the Nevada Public Utilities Commission ("NPUC").[12] A utility facility is defined as: (1) electric generating plants and their associated facilities; and (2) electric transmission lines and substations that operate at 200 kV or more are not required by local ordinance to be underground and are constructed outside an incorporated city.[13] Electric generating plants using renewable energy and having a nameplate capacity of 70 MW or less are excluded from the NPUC's jurisdiction.[14]

If the generating facility or transmission line is within the NPUC's jurisdiction, the owner must obtain a UEPA permit before commencing construction.[15] The NPUC considers the following when determining whether to approve an application for a UEPA permit:

- Nature of the probable effect on the environment
- Extent the facility is needed to ensure reliable service to Nevada customers
- Whether the need balances any adverse environmental effect
- Whether the facility represents the minimum adverse environmental effect, considering available technology and the nature and economics of the alternatives
- Whether the facility location conforms to state and local laws and regulations
- Whether the applicant has or is in the process of obtaining all other required permits, licenses and approvals required by federal, state, and locals laws and regulations
- Whether the facility will serve the public interest.[16]

The UEPA application must also be submitted to the Nevada Division of Environmental Protection.[17] If the proposed location is on federal lands, the applicant will also have to comply with federal environmental laws and regulations, including NEPA. The environmental studies done in accordance with NEPA must be submitted to the NPUC.[18]

As in Arizona, any facility approved by NPUC will also have to comply with local ordinances. These may include, but are not limited to, zoning criteria, building permits, electrical permits, and requirements that distribution lines be placed underground.

III. Siting Considerations: Federal, State, or Private Lands

Superior energy production potential, close access to transmission, and sufficient water (if needed) are prerequisites for identifying possible sites for renewable energy projects. Land ownership will determine the process, time, and expense associated with obtaining the authorizations required to build and operate the project.

A. Federal lands

Siting renewable energy projects on federal lands has benefits and drawbacks. On the positive side of the ledger, land acquisition costs historically have been less than the costs of acquiring state trust land or private land. Additionally, so long as the project is on land designated for utility development by the applicable federal land manager, the likelihood of eventual approval is quite good. However, on the other side of the spectrum, some federal lands are designated as national monuments or natural preserves. Such lands usually are considered not compatible with major transmission projects. Lands that are identified as neither a utility corridor nor as a national monument are "gray areas" that may be designated as "open space."

Another concern with the use of federal lands is the long licensing timeframe, given the time associated with the NEPA process. In addition to the time-intensive procedural requirements of NEPA, another concern with siting projects on federal land is the sheer number of proposals that have already been submitted. In effect, the federal government is dealing with a land rush. To address this problem systematically, rather than on a project-by-project basis, BLM and DOE are in the process of developing a programmatic environmental impact statement ("PEIS") for utility-scale solar energy developments on federal lands.[19] While this approach is understandable, it will inevitably increase the time necessary to obtain approval on federal lands. The public comment period in this proceeding was recently extended until September 14, 2009[20] and the release date of the draft PEIS is still "to be determined."[21] The completion of the final PEIS and the Record of Decision in this proceeding are also "to be determined".[22]

In addition to timing, the use of federal lands often brings objections from conservationists and outdoor enthusiasts. Environmental groups often prefer the use of previously disturbed private land than federal land. In that vein, Senator Dianne Feinstein announced recently that she planned to introduce legislation to prohibit the development of renewable energy projects on hundreds of thousands of acres in the Mohave Desert.[23]

Yet another concern with siting projects on federal land is the potential for conflicting approvals from state and federal agencies. On federal lands, a project proponent must obtain authorization from both the federal land manager and the state utility commission. If the federal land manager and the state utility commission have different opinions on where the project should be located, the project is stuck in limbo. This is not just a speculative concern. In one Arizona line siting case, the Arizona Corporation Commission approved a route through U.S. Forest Service land.[24] The U.S. Forest Service refused to grant the same right-of-way that the Commission deemed necessary to provide reliable service to the Nogales area.[25]

B. State Trust Lands

State trust lands can be an attractive choice for siting projects. The approval process can be run concurrently with other siting requirements, and state trustees are generally willing sellers or lessors, so long as it can be shown that the benefits to the trust outweigh any harm to other trust lands located adjacent to or near the proposed facility. Impact to trust lands can be reduced by siting infrastructure along section lines and other linear features.

One potential concern with siting on state trust lands is the fact that approvals from both the state land department and the state utility commission are required. In the event that the two state agencies do not agree on the same site, the project cannot be built. Historically, the risk of conflicting approvals between two state agencies is less than the risk of disparate federal and state ones. As more and more facilities are proposed, however, the risk of conflict inevitably rises.

C. Private Lands

Siting projects on private land can be ideal from a timing and risk standpoint, so long as willing sellers exist for both the plant site and the transmission line. If willing sellers have not been identified beforehand, a developer must determine whether he can acquire the lands through eminent domain, if necessary.

As part of their review, state utility commissions will assess the impacts of the project on the land proposed for the project as well as nearby properties. There are usually three major issues in evaluating the impact of a project on private land.

- First, is the land currently in use? Is the private land developed with dwellings or commercial buildings that might be "taken" by placement of the project? State siting authorities will try to avoid such a route.
- Second, is the private land undeveloped but the subject of pending or approved plans, such as planned area developments and approved plats? Again, siting authorities will give weight to those future plans as required by the state law, but must balance the project's impact on such future plans against the need for the project.

- Third, if the private land is not developed nor the subject of any future plans, the private landowners may be concerned that the transmission line will negatively affect the future value of the land.

IV. Conclusion

While the development of renewable energy projects has the potential to provide numerous benefits to the region and the country, navigating the minefield of licensing requirements without delays or setbacks is critical to move projects from the drawing board to reality. Careful consideration of these issues early in the process will help ensure the licensing process is as straightforward and timely as possible.

Mr. Albert Acken is a partner in the Environmental, Natural Resources and Utilities Practice Group at Lewis and Roca LLP. He can be reached at AAcken@LRLaw.com. Mr. Thomas Campbell is also a partner at Lewis and Roca LLP, and his practice is concentrated in the areas of regulatory and administrative law, particularly energy, telecommunications, water and utility regulation. He can be reached at TCampbell@LRLaw.com.

---

[1] American Clean Energy and Security Act of 2009, H.R. 2454, 111th Cong. § 703 (as passed by House, June 26, 2009).

[2] American Recovery and Reinvestment Act of 2009, Pub. L. No. 111-5, 123 Stat. 115 (2009).

[3] 42 U.S.C. § 4332.

[4] *See, e.g.*, A.R.S. § 37-461 (Grants of rights-of-way and sites for public uses).

[5] Energy Policy Act of 2005, Pub. L. No. 109-58, 119 Stat. 594 (2005) (codified at 16 U.S.C. 824p).

[6] Filing Applications for Permits to Site Interstate Electric Transmission Facilities, 71 Fed. Reg. 69,440, ¶ 26 (Dec. 1, 2006).

[7] *Piedmont Environmental Council v. FERC*, 558 F.3d 304 (4th Cir. 2009).

[8] Under A.R.S. § 40-360, a "plant" is defined to be a thermal electric, nuclear or hydroelectric generating unit. As a result, certain solar technology such as concentrating solar power ("CSP") that make use of the sun's heat are considered thermal projects and are subject to the CEC process. Other solar projects, such as certain types of photovoltaic projects that use the light from the sun rather than the heat, are not subject to the CEC process. Wind generated facilities, because they are not thermal, do not need a CEC. However, facilities that do not need a CEC for the plan may still need a CEC for the transmission lines necessary to connect the facility to the transmission grid."

[9] A.R.S. § 40-360.03.

[10] A.R.S. § 40-360.05(A) (parties to a proceeding); and A.R.S. § 40-360.04(C) (receipt of evidence).

[11] A.R.S. § 40-360.07.

[12] N.R.S. 704.865.

[13] N.R.S. 704.860.

[14] N.R.S. 704.860(1).

[15] N.R.S. 704.865.

[16] N.R.S. 704.890(1).

[17] N.R.S. 704.870(3); and 704.875.

[18] N.R.S. 704.870(1)(b).

[19] Notice of Intent to Prepare a Programmatic Environmental Impact Statement to Evaluate Solar Energy Development, Develop and Implement Agency-Specific Programs, Conduct Public Scoping Meetings, Amend Relevant Agency Land Use Plans, and Provide Notice of Proposed Planning Criteria, 73 Fed. Reg. 30,908 (May 29, 2008).

[20] Notice of Extension of Public Comment Period for Programmatic Environmental Impact Statement To Develop and Implement Agency-Specific Programs for Solar Energy Development, 74 Fed. Reg. 37,051 (July 27, 2009).

[21] Solar Energy Development Programmatic EIS Information Center, *Solar Energy Development Programmatic EIS Schedule*, http://solareis.anl.gov/eis/schedule/index.cfm (last visited July 29, 2009).

[22] *Id.*

[23] *See, e.g.*, Richard Simon, *Feinstein wants desert swaths off-limits to solar, wind*, L.A. Times, March 25, 2009, http://articles.latimes.com/2009/mar/25/nation/na-desert25.

[24] Arizona Corporation Commission, Line Siting Case 111, Docket No. L-00000C-01-0111-00000.

[25] *Id.*