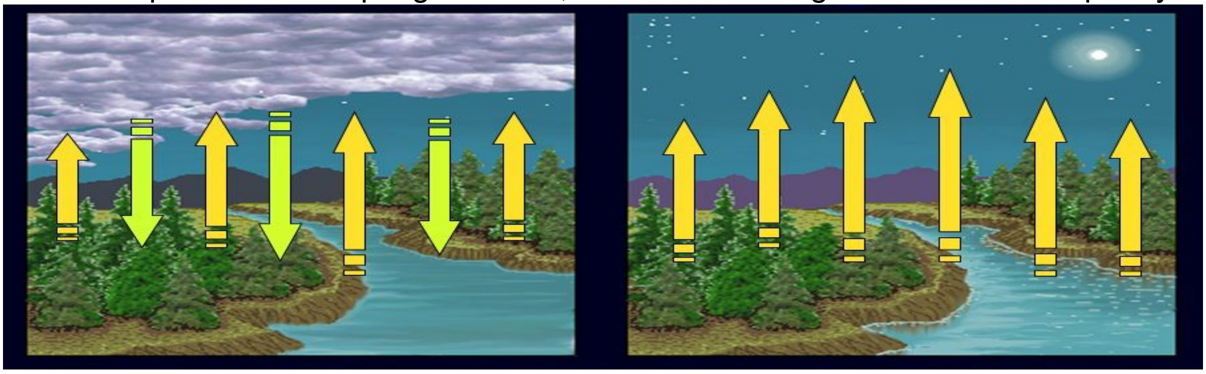
SPOTSYLVANIA SOLAR ENERGY CENTER

"Temporary temperature increase" concerns regarding Solar Fields: Clarification on causes, extent, and potential to mitigate

What causes the Solar Heat Island Effect?

Temperature increases are not caused by solar panels themselves being warm, but rather by (1) the solar panels trapping the sun's energy that accumulated throughout the day. A close analogy is how cloudy nights remain warmer than clear nights because clouds trap and reflect that day's energy back to the Earth's surface. The heat island effect is also the result of (2) less vegetation to cool the air through the natural process of transpiration than is found in nearby natural areas.

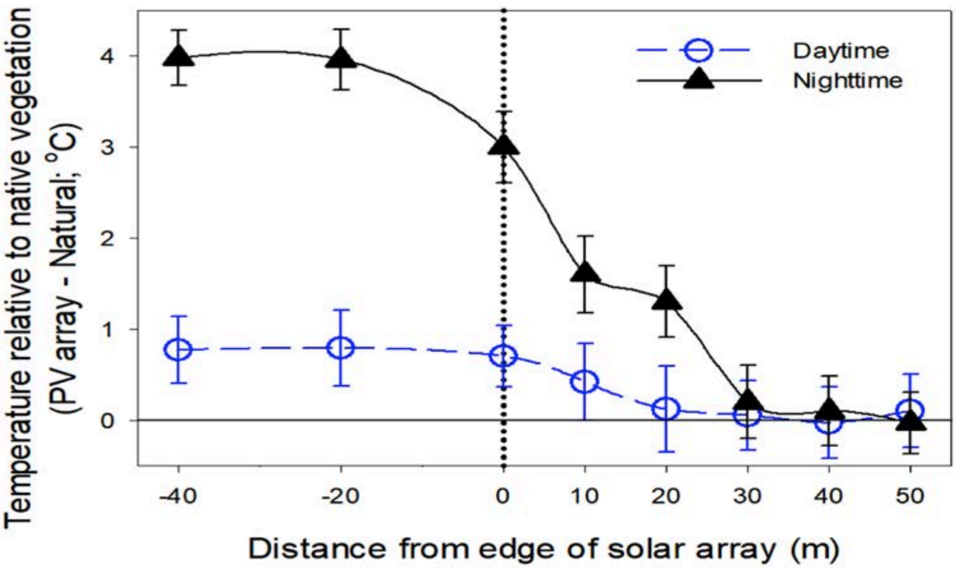
Clouds trap heat and keep nights warm, whereas clear nights cool off more quickly.



How far does the temperature increases reach?

Because the temperature increases are caused by trapped daytime energy being re-radiated back to the ground, if you move outside of the solar panel installation, the effect will dissipate. We measured air temperature within a solar array (40m and 20m [~130 and 65ft]), at the edge of the array (0m), and in 10m (~33ft) increments away from the edge of the array.

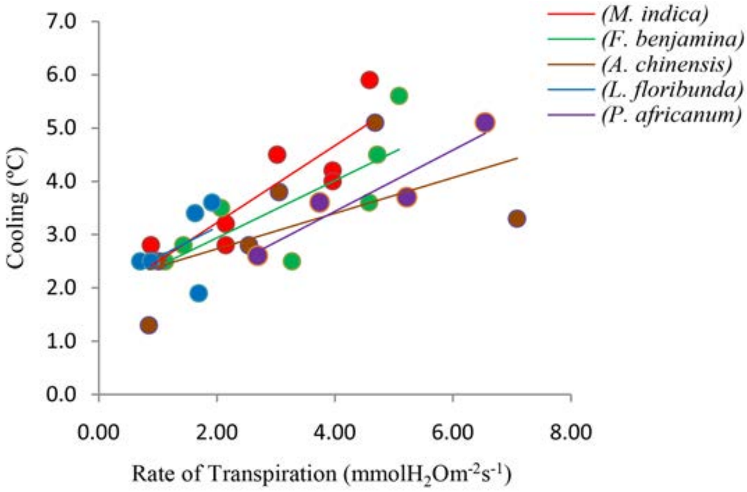
We found that by 30m (<100ft) away from the solar array edge, there was no detectable temperature increase.



How can you mitigate the temperature increases?

In all of the studies that have been published after extensive and rigorous peer review, the ***temperature increases dissipates without the presence of a vegetated barrier***. Any vegetation between the solar array and the surroundings will act to further mitigate any temperature increases, including the 100ft vegetative buffer around the entire site, as well as the preserved conservation areas weaving throughout the site. Plants lose water through the process called transpiration when they conduct photosynthesis, and this process actually creates a cooling effect. Individual trees can cool local air temperatures by as much as 6°C (~10°F), depending on the plant's transpiration rate.

Species	$\Delta \overline{T_a}$(°C)^z
U. parvifolia	2.52
P. indicus	2.24
S. sebiferum	1.81
F. microcarpa	1.79
F. elastica	1.74
P. chinensis	1.71
B. vulgaris	1.62
A. scholaris	1.53
L. formosana	1.43
B. ventricosa	0.92
B. javanica	0.77
C. fitula	0.64
Average	1.73



How likely are temperature increases within the solar field to negatively impact plant or animals outside of the solar array?

Our own research – along with that of the Department of Energy's National Renewable Energy lab – shows that we can actually restore prairie lands and grow food crops around and under solar panels. Beyond illustrating innovative applications in renewable energy systems, this co-location of pollinator habitat, grazing, and food production with PV arrays suggests that there are no ill effects of PV arrays on this vegetation or animals. Plants do not overheat or lose their potential to function by being in (extremely) close proximity to PV panels. A vegetative barrier around the solar array should dissipate any temporary temperature increases.

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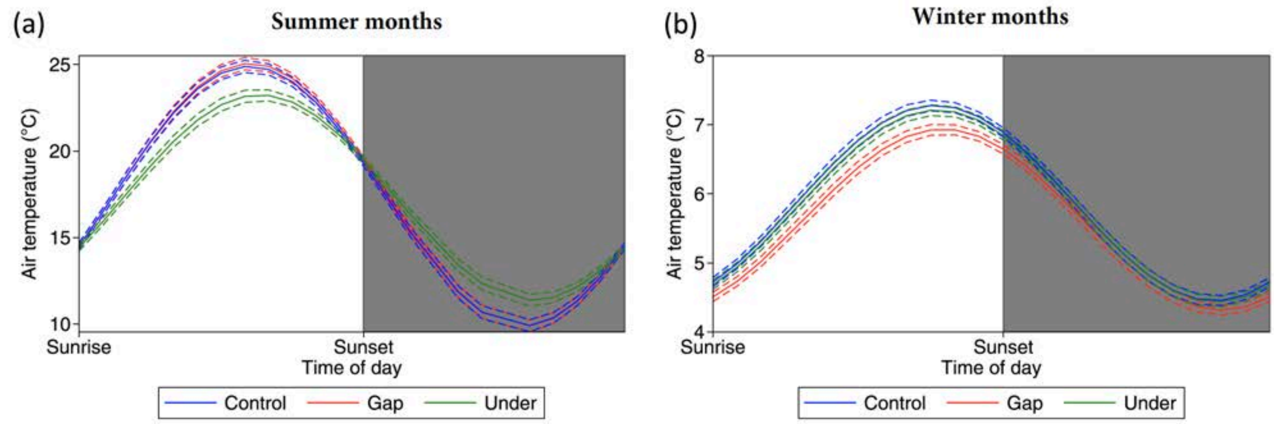
"Temporary temperature increase" associated with Solar Fields: Clarification on existence, mitigation tools, and impacts on setbacks

Is there any evidence for a temporary temperature increases reach in *vegetated* areas?

Most of our discussions around the Spotsylvania site have revolved around the temporary temperature increases and associated reach of that increase within unvegetated PV arrays[1,2]. However, re-vegetated PV solar arrays are fundamentally different than those with bare soil because they include the transpirational cooling of understory grasses. ***Field measurements within re-vegetated PV arrays (directly 'Under' panels and in the 'Gap' area between PV arrays) and in a field away from the PV arrays (Control) have shown that air within a PV arrays are actually slightly lower in the summer and nearly equal in the winter*.**



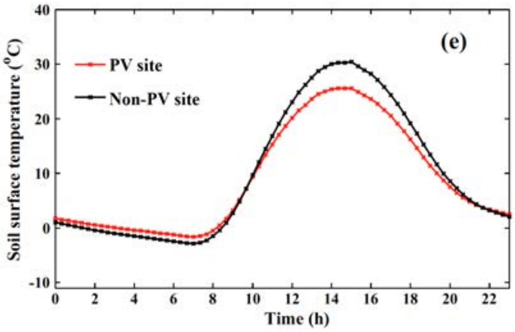
Elevation (m)		0.5	1.2	2.0	2.7
Temperature (°C)	Mean/Std (solar panel area)	18.34/7.87	18.03/8.06	18.30/7.39	18.37/7.65
	Mean/Std (control area)	18.27/7.85	18.32/8.31	18.36/7.47	18.11/7.64

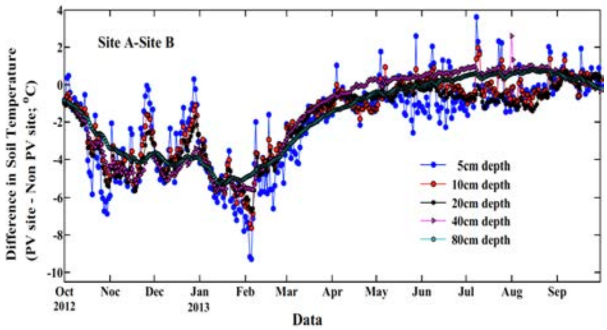
The absence of any temporary temperature increases in re-vegetated PV sites has been shown in both the UK (Lancaster[3]; Top graphs and left image) and the US (Oregon[4]; Right image and data table). Because no study has even shown a temporary temperature increases in a re-vegetated PV array, setbacks are purely for visible screening.

How does a PV array impact soil temperature?

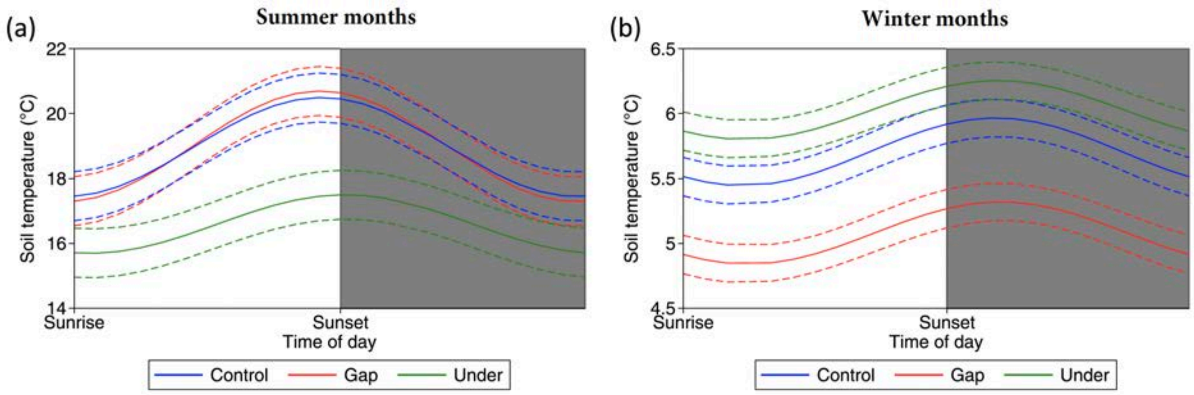
Soil temperature is an important characteristic in determining ecosystem health. As such researchers have studied the potential for warming of soils under PV arrays across sites that differ in their environmental conditions and degree of revegetation after the PV installation. ***Neither sites from unvegetated PV arrays[5] (upper graphs below) nor re-vegetated PV arrays[3] (lower graph panels) have shown any evidence of temporary temperature increases within the soils associated with PV arrays*.**

Soil Temperature patterns in <u>unvegetated</u> areas:





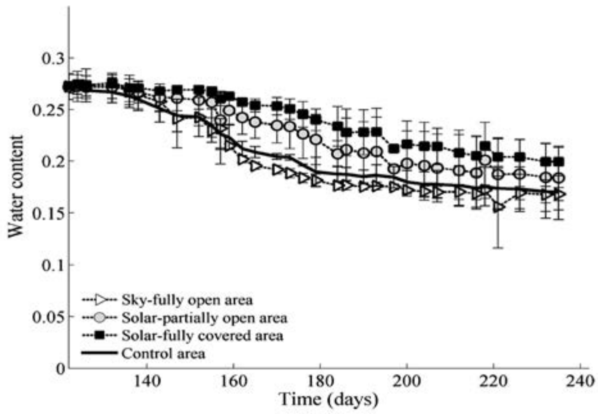
Soil Temperature patterns in <u>re-vegetated</u> areas:

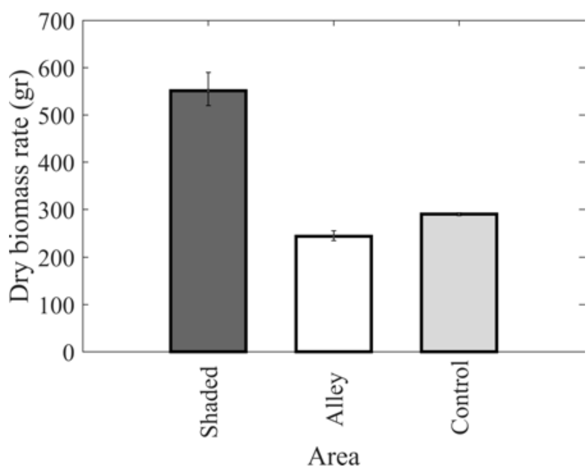


How does a PV array impact soil moisture?

The presence of moisture in the soil allows for both regrowth of vegetation and recharge of important streams and watersheds. Because of this concern researchers have studied the potential for reductions in soil moisture under PV arrays across sites that differ in their environmental conditions and degree of revegetation after the PV installation. ***Neither re-vegetated PV arrays in both wetter areas of the US[3] like Spotsylvania (graph below) and drier areas in the US have shown any evidence of reduction in moisture within the soils associated with PV arrays*.**

Research in both wetter and drier regions have shown that moisture remains within re-vegetated PV arrays slightly longer (left panel), promoting increased vegetative growth and biomass[4,6] (right panel).





Will a vegetative barrier influence local temperature?

Importantly, all studies on unvegetated PV arrays have shown that temporary temperature increases dissipates without the presence of a vegetated barrier, and re-vegetated PV arrays have shown no evidence of temporary temperature increase that warrants mitigation. Any vegetation between the solar array and the surroundings will act primarily as a vegetative screen. That said, a vegetative buffer around the site, as well as the preserved conservation areas weaving throughout the site can help add cooling. Plants lose water through the process called transpiration when they conduct photosynthesis, and this process actually creates a cooling effect. Individual trees can cool local air temperatures by as much as 6^{o}C (~10^{o}F), depending on the plant's transpiration rate. A standard visual vegetative buffers average 50 ft should suffice.

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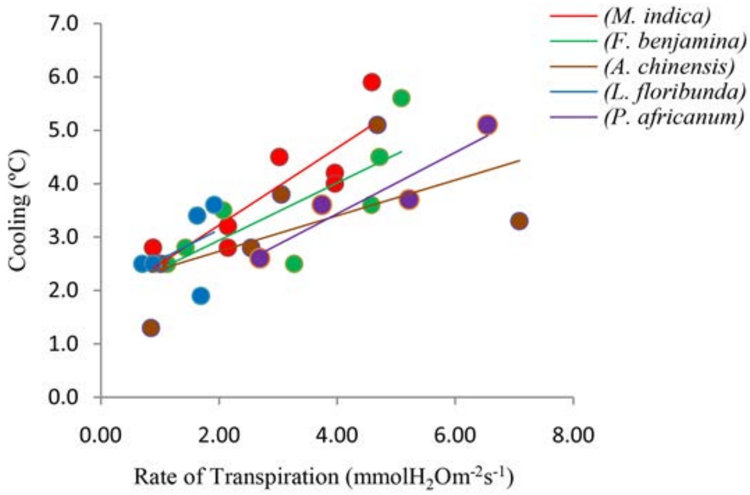

How likely are temperature increases within the solar field to negatively impact plants, animals, or the larger watershed outside the solar array?

Our own research – along with that of the Department of Energy's National Renewable Energy lab – shows that we can actually restore prairie lands and grow food crops around and under solar panels. Beyond illustrating innovative applications in renewable energy systems, this co-location of pollinator habitat, grazing, and food production with PV arrays suggests that there are no ill effects of PV arrays on this vegetation or animals. Plants do not overheat or lose their potential to function by being in (extremely) close proximity to PV panels. A vegetative barrier around the solar array should dissipate any temporary temperature increases.

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References sited:

1 Barron-Gafford, G. A. *et al.* The Solar Heat Island Effect: Larger solar power plants increase local temperatures. *Nature Scientific Reports* **6: 35070**, DOI: 10.1038/srep35070 (2016).
2 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).
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6 Barron-Gafford, G. *et al.* Agrivoltaics: A novel approach to colocatingfood and solar renewable energy to maximize food production, water savings, and energy generation. *Nature Sustainability* (*In review*).