SOLAR CANOPY POTENTIAL IN CONNECTICUT 2024

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The Potential of Solar Canopies in Connecticut: 2024 Update

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On October 5, 2024, Ridgefield High School celebrated the installation of a 990 kW series of solar canopies over the school parking lot.

Executive Summary

In 2021, People's Action for Clean Energy (PACE) published an analysis of the potential for solar on canopies in Connecticut (Rudge, 2021). It was clear from this analysis that canopies represent a significant resource for siting solar in the state. The study identified 8,461 potential sites, with the potential of deploying 7,021 megawatts (MW) of solar, capable of producing 9,226 gigawatt-hours (GWh) per year, or roughly 38% of the state's electricity usage. Since issuing this study, little progress has been made in realizing the potential of solar canopies. With the goal of increasing awareness of this resource, we have updated our prior analysis, incorporating the following key changes:

- Additional potential sites based on an updated dataset of impervious surfaces developed by the National Oceanic and Atmospheric Administration (NOAA) in 2021
- Evaluation of potential sites based on the proximity to substations
- Study of the coincidence of potential sites with existing commercial rooftop solar projects
- An assessment of the emissions mitigation potential of solar canopies
- A set of policy recommendations to advance solar canopy deployment, and suggested directions for future research in this area

The key findings of this report are:

- The study has identified 9,096 potential solar canopy sites on parking lots and similar impervious surfaces in Connecticut, with potential for 7,566 MW, producing 9,744 GWh, or 36%[1] of current electricity usage.
- Of these sites, 4,433 (49%) are within 2 miles of a power substation, and are therefore highly favorable for development. 3,695 (41%) are between 2 and 5 miles and 968 (11%) are more than five miles away.
    - 2,530 sites (28%) are adjacent to existing commercial solar arrays, making them also more favorable.
    - 1,624 (18%) are within the most favorable substation range and adjacent to existing solar. We identify these as key sites for development, which could amount to 2,306 MW producing 2,970 GWh annually.
- Importantly, sites not adjacent to substations or existing arrays offer unique potential to support the distribution grid, especially when paired with battery storage.

In light of these findings we present a range of policies and initiatives to realize the potential of solar canopies in Connecticut. These include:

- Develop a state solar canopy strategic plan
- Streamline and expedite upgrades and extensions to the distribution grid
- Increase incentives for solar canopies to reflect their true value

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[1] This percentage is lower than that in the 2021 study due to the inclusion of previously unavailable electricity usage data for CT municipal utilities in the denominator. On this basis, the prior percentage was 34.9%.

- Offer favorable treatment for solar canopies paired with battery storage, including those not sited near local electric loads
- Exempt solar canopies from local property taxation beyond the existing tax treatment of the property
- Implement additional initiatives to catalyze solar canopy deployment, especially in Environmental Justice (EJ) communities

New Potential Sites

Our previous analysis was conducted by identifying and analyzing parking lots based upon a geospatial dataset of impervious surfaces created by Connecticut Environmental Conditions Online(CT ECO) in 2012. This dataset was accessible and fairly up-to-date in 2021 when our original study was released but there has been significant development in Connecticut since that time. Consequently, this study provides an updated assessment of potential canopy sites based on analysis of the National Oceanic and Atmospheric Administration (NOAA) aerial imagery. This impervious surfaces database is similar to the one previously used, as the impervious surfaces can be identified clearly, but in the original CT ECO dataset the surfaces were already separated out and classified based on their usage. The CT ECO dataset provided vector shapes, while the NOAA database required that vector shapes be created from a raster file.

Using the new NOAA dataset, we were able to identify any new larger parking lots (greater than roughly 100 parking spaces as we used in our previous study). We overlaid our 2021 dataset over the NOAA dataset to identify any outstanding parking lots that were not covered by our data. Next, we examined the layer in ArcGIS to trace any easily identifiable large parking lots to convert the raster data into vector shapes. These new vector shapes were added into our previous dataset from 2021. Lastly, for each newly identified parking lot, we reproduced our calculations to determine the potential solar capacity and annual production for these potential sites.

Through this process we identified 680 new potential sites. These new sites could hold a capacity of 545 MW with an annual production of 702 GWh. This process identified on average 4 new sites per town. Combined with the old sites, our total number of sites has grown from 8,416 to 9,096. These 9,096 in total have a capacity of 7,566 MW and annual production of 9,744 GWh.

Proximity to Substations

Within an electrical grid, substations serve multiple purposes and take different forms. Substations may primarily be used to facilitate step-up transmission, step-down transmission, regulate voltage, facilitate end-user distribution, make interconnections between separate systems managed by different utilities, or connect electric generation plants to larger systems (OSHA, 2023). When evaluating the value of decentralized forms of renewable energy generation, like solar canopies, researchers have demonstrated that proximity to substations can be beneficial in multiple ways. Production near local substations can enable more efficient distribution of electricity that results in fewer transmission losses and better management of excess production to meet peak loads at different times (Thapar, 2022). For example, a substation, similarly to battery storage and potentially in coordination with battery storage, can enable excess local production during the day to be distributed to other users at peak times once the sun sets.

Here, we conducted an analysis of the proximity between potential solar canopy sites and substations. Using existing data from the Massachusetts Office of Coastal Zone Management (2020) and the National Oceanic and Atmospheric Administration (2023), we plotted all major substations in the state of Connecticut. Using these point locations, we then classified our potential solar canopy sites based on their distance to the nearest substation.

The distances between sites and substations were calculated as the straight line between two locations (as-the-crow-flies). This was done primarily for simplicity of analysis due to grid infrastructure data being unavailable for analysis by the public. In Connecticut, utilities are not compelled to make their grid data easily accessible and usable for analysis which removes the possibility of analysis of grid interconnection on a state-level without access to proprietary data.

In our assessment we classified potential sites into three ranges based on their distance to any substation:

1. Substation less than 2 miles away (Most favorable)
2. Substation between 2 and 5 miles away (Moderately favorable)
3. Substation greater than 5 miles away (Somewhat favorable*)

These classifications draw on similar methods used in previous analyses by Synapse Energy when studying feasibility of different solar energy sites in Massachusetts (2023). Generally, group 1 is seen as most favorable for development, group 2 as moderately favorable, and group 3 as somewhat favorable. The prevailing assumption here is that potential sites that are closer to substations are more suitable sites for canopy development. This favorability is due to sites more proximate to substations being able to transmit energy more efficiently with less energy loss over long transmission distances. Therefore, if these sites are prioritized, distributed energy generation will be highly effective in supporting a larger grid network. Studies across different scales have used varying ranges to assess the relationship between substation proximity and favorability for solar development and varying degrees of complexity have been incorporated into different analyses to aim to account for data gaps and the nuances of interconnectivity in different areas (Katker et al., 2021; Kavuma et al., 2021).

*While this logic of assigning higher favorability to sites in close proximity to substations makes sense as one dimension of analysis, we also emphasize the unique value brought on by more remote sites away from substations. As explained in greater detail later in this report, distributed renewable energy generation and solar canopies in particular can provide immense value as resilience hubs. These hubs are valuable in both dense urban centers and more rural or suburban communities. When considering proximity to substations, sites that are further than 5 miles from a substation may actually indicate sites where there is greater demand for decentralized energy generation due to the massive transmission distances from existing power plants to end-users in rural communities.

Therefore, our database of sites with the additional detail of substation proximity enables planners, researchers, and other stakeholders to find both the most efficient locations for solar canopy development and the locations where there may be greater need to make up for deficiencies due to lack of transmission infrastructure.

Substation analysis results

All 9,096 sites were analyzed. Of all the potential solar canopy sites, 4433 (49%) are within 2 miles of a substation. 3,695 (41%) of sites are between 2 and 5 miles away from a substation. 968 (11%) of sites are further than 5 miles from a substation. This trend of the majority of sites being in close proximity or moderately close proximity to a substation makes sense in the context of our original findings. Substations generally are developed to meet demand, so the substations in Connecticut are nearby population centers, such as major cities. Our original study demonstrated that potential solar canopy sites follow this same pattern, as we focus on parking lots, which generally are located nearby population centers and urban geographies with a large amount of impervious surface.

The results of this analysis indicate that if sites within 2 miles of substations are prioritized for more efficient development of decentralized solar then 5,169 GWh could be produced annually, which accounts for about 21% of Connecticut's annual electricity consumption. Notably, while 49% of our potential solar canopy sites are within 2 miles of substations, these sites are, on average, larger than those further away. Therefore, the proportion of total capacity and annual production that these sites make up are slightly greater. These 4,433 sites account for 3,940 MW (52% of all potential solar canopy sites) and 5,169 GWh of production (53% of all potential sites).

This analysis of substation proximity is supplemented by further analysis in the next section which examines sites adjacent to existing rooftop solar projects. A final analysis is completed in that section combining sites adjacent to existing solar with the substation proximity analysis to indicate sites with compounding favorability across these two parameters.

Table 1: Substation Proximity Analysis

Distance from Substation	Number of Sites	Percent of Total Sites	Total Capacity (MW)	Total Production (GWh)
Under 2 Miles	4,433	49%	3,940	5,169
2-5 Miles	3,695	41%	2,997	3,932
Subtotal Under 5 Miles	8,128	89%	6,937	9,101
Over 5 Miles	968	11%	630	827
Total	9,096	100%	7,567	9,928

Figure 1: Substations and major gridlines in Connecticut

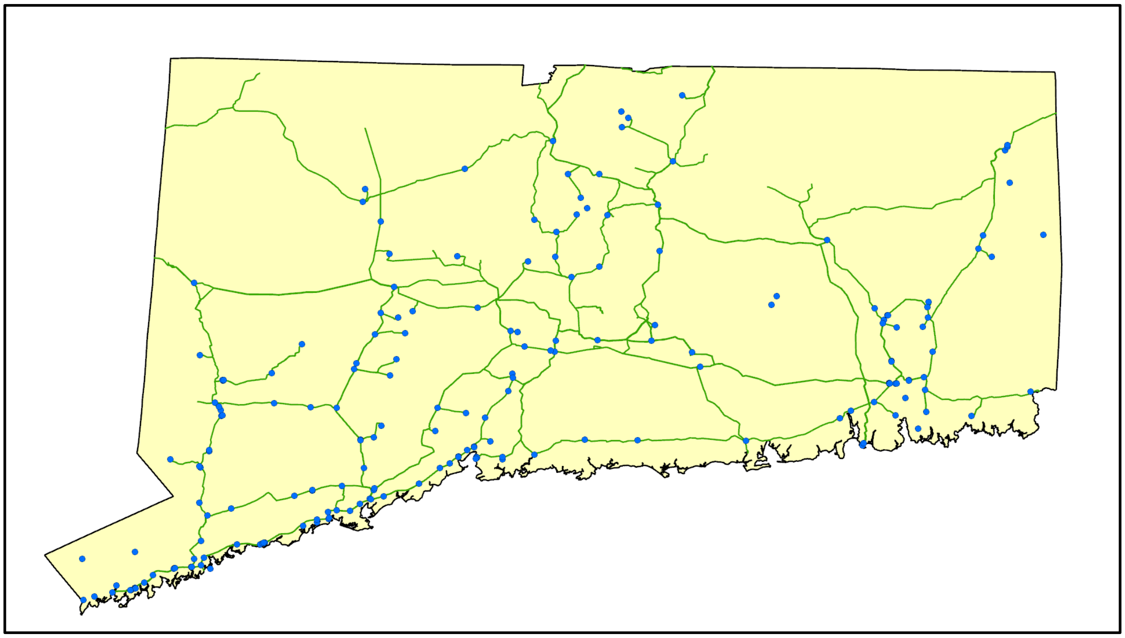


Figure 2: Substations and ranges. Lighter inner circles indicate 2 mile buffer from each substation outward and darker outer circles indicate 5 mile buffer. Darkest blue areas are overlapping ranges.

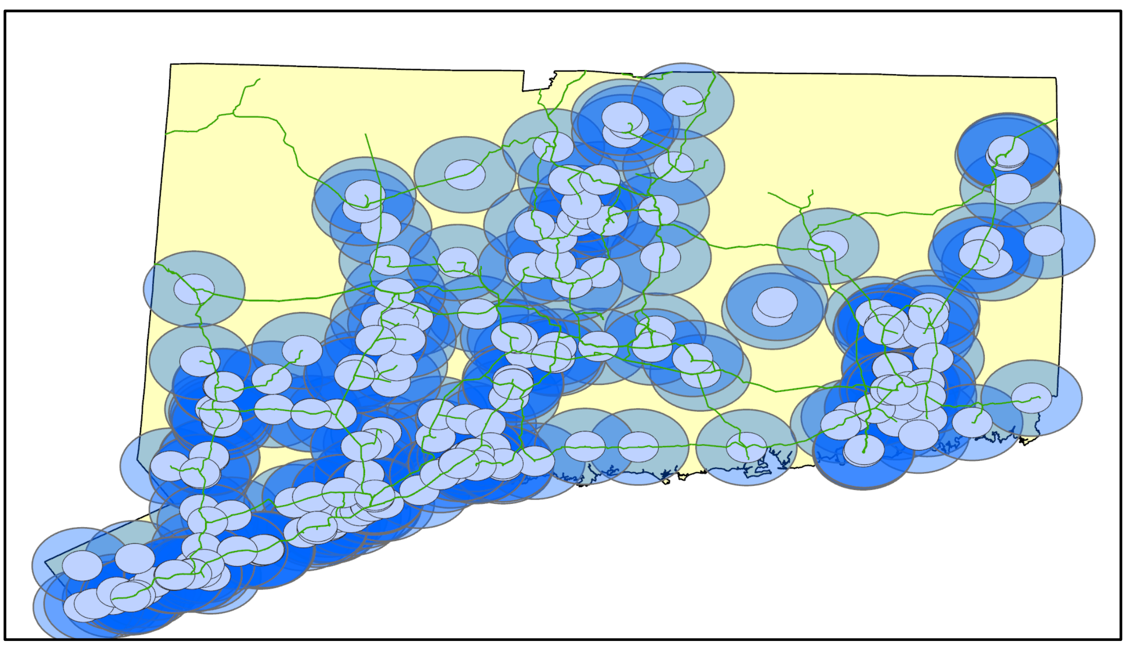
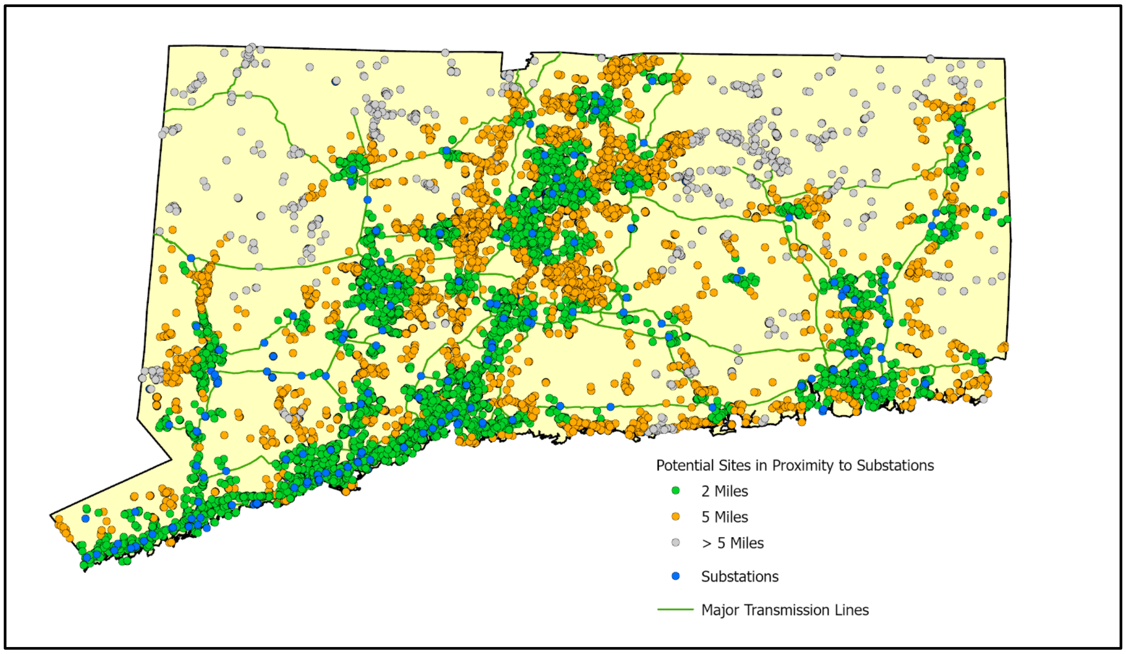


Figure 3: Substations and classified sites. Green sites are group 1 potential solar canopy sites, orange are group 2, and gray are group 3.



Coincidence with Existing Commercial Rooftop Solar Projects

The second new analysis developed for this study examines the geographic overlap between potential solar canopy sites and existing commercial solar installations. The purpose of this analysis is to identify solar canopy sites that are located on properties which have already indicated interest in developing solar, and therefore may represent strong candidates for solar canopy project development. This analysis provides data to support a “snowball” solar energy development strategy whereby regional hotspots are supported (Curtius et al., 2018). Organic growth that happens due to proximity and connection to earlier adopters of renewable technology is an important factor to consider. By understanding the connections between existing projects and potential solar canopy sites, we have identified potential hotspots to further support and target for new development.

The Renewable Portfolio Standard (RPS) data set published by the Public Utilities Regulatory Authority (PURA) was used to determine the location of existing commercial solar projects across the state. Using this information, we then plotted all potential solar canopy sites that matched the location of one of these RPS sites to evaluate the number and location of potential sites that coincide with existing projects. We present this analysis for class I energy systems alone as that category includes all solar projects. Class II and class III move beyond what most would consider “renewable” energy sources into technologies that are not fossil fuel but still have significant environmental issues, such as trash-to-energy systems and efficient heating and power systems (PURA, 2023).

Based on our findings, there are 2,519 (28%) potential solar canopy sites in areas adjacent to existing class I commercial solar installations. These sites account for 3,398 MW and can produce 4,376 annually. The appendix of this report provides a list of the locations of all sites that coincide with existing commercial solar installations and provides additional information on each of these sites' proximity to substations.

When combining the results of these two analyses key insights can be gained. Of particular importance, we have identified 1,624 (18%) sites that meet the favorability criteria of both analyses. These sites are within 2 miles of a substation (group 1) and are adjacent to existing solar projects. These sites alone represent a priority set of potential solar canopy sites that could amount to 2,306 MW with a capacity of 2,970 GWh of annual production. However, this must be integrated with more detailed information on the current load and remaining capacity of each substation to determine whether additional load can be supported by a substation. This information on current load and remaining capacity would not necessarily be a hindrance to development but could also indicate areas that require expanded capacity of substations. Additionally, when considering resilience hubs there are 99 (1%) sites that are both 5 miles away from any substations and also adjacent to existing projects. These sites in locations with minimal grid infrastructure would total 80 MW of capacity and produce 103 GWh annually.

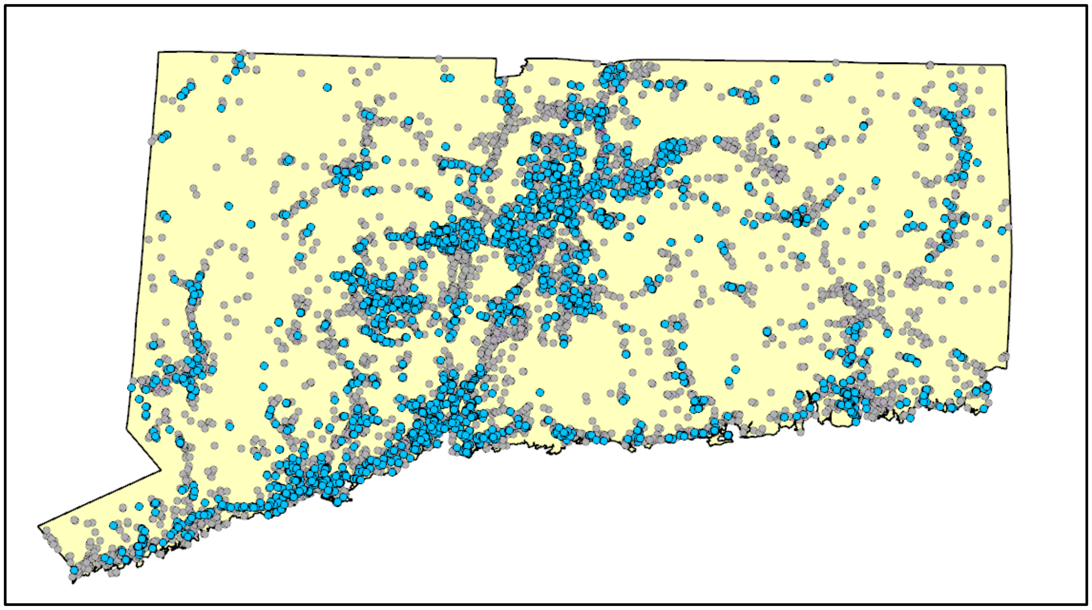
Table 2: Coincidence of potential canopy sites with existing commercial solar installations

Adjacent to Class I Renewables?	Number of Sites	Percent of Total Sites	Total Capacity (MW)	Total Production (GWh)
Yes	2,519	28%	3,398	4,376
No	6,577	72%	4,169	5,552
Total	9,096	100%	7,567	9,928

Table 3: Overlapping Analysis of Substation proximity and coincidence with existing solar

Distance from Substation and Existing Solar	Number of Sites	Percent of Total Sites	Total Capacity (MW)	Total Production (GWh)
Under 2 Miles	1,624	18%	2,306	2,970
2-5 Miles	807	9%	1,021	1,315
Subtotal Under 5 Miles	2,431	27%	3,327	4,285
Over 5 Miles	99	1%	80	103
Total	2,530	28%	3,407	4,388

Figure 4: Potential solar canopy sites adjacent to existing commercial solar projects. Blue points indicate sites meeting this criteria. Grey points are all other potential sites.



Emissions Mitigation

Our previous analysis emphasized the potential capacity and annual production of electricity that would result from solar canopies sited on parking lots across Connecticut. In addition to the energy produced by these sites, it is also important to account for the level of greenhouse gas emissions that would be mitigated if these arrays were to replace fossil fuel systems. Here, we base our analysis on the EPA's Greenhouse Gas Equivalencies Calculator incorporating AVoided Emissions and geneRation Tool (AVERT) (2024). This tool relies on the "national weighted average CO2 marginal emission rate to convert reductions of kilowatt-hours into avoided units of carbon dioxide emissions" meaning that our analysis here does not account for the specifics of Connecticut's current fossil fuel use. Connecticut's current electricity consumption sources rely significantly on natural gas, so there is still a need to greatly reduce emissions by switching to renewables like solar and wind, particularly given the significant volume of methane leakage through aging pipeline infrastructure. Overall, the total potential solar canopy production of 9,744 GWh from 9,096 sites would mitigate roughly 6.82 million metric tons of carbon dioxide, which is equivalent to the annual electricity use of roughly 8,880 homes. The sites we indicated as most favorable by our two new analyses account for 2,970 GWh, which is equivalent to 2.07 million metric tons of carbon dioxide equivalent to the annual electricity use of roughly 8,240 homes. The additional calculations for different categories are indicated below in table 4.

Table 4: Emissions mitigation for different sets of potential solar canopy sites

Site Selection	Total Production (GWh)	Mitigated CO2 Emissions (thousand metric tons)
Under 2 Miles Substation	5,169	3,618
2-5 Miles Substation	3,932	2,753
Subtotal Under 5 Miles Substation	9,101	6,371
Over 5 Miles Substation	827	579
Total	9,928	6,950
Existing Solar Overlap	4,376	3,057
Under 2 Miles Subst. & Existing Solar	2,970	2,070
2-5 Miles Subst. & Existing Solar	1,315	918
Subtotal Under 5 Miles Subst. & Existing Solar	4,285	2,988
Over 5 Miles Subst. & Existing Solar	103	71
Total	4,388	3,059

Benefits of Solar Canopies

Based on the foregoing analysis, it is clear that solar canopies have the potential to provide a significant share of Connecticut's energy needs. Realizing this potential will bring a range of benefits to the state, including:

- By using land that has already been developed, canopies reduce the pressure on farmland and forests, thereby preserving natural resources and improving health and well-being.
- For the same reason, canopy projects face less public resistance and can be approved and developed more quickly than those on land.
- Because canopies are typically located near businesses and other activities using electricity, they greatly reduce the need for additional transmission and distribution (T&D). While all solar projects tend to obviate additional T&D, this effect is greater for canopies due to their direct proximity to electric loads.
- Many canopies can be sited in Environmental Justice (EJ) communities, thereby benefiting residents directly. Currently, many federal and state incentives are available for EJ communities, making these projects more economically viable.
- When paired with battery storage, the value of distributed solar increases significantly (CT DEEP & PURA, 2020). Solar canopies paired with storage can increase the stability and resilience of the distribution grid.

i. Such installations are excellent candidates for resilience hubs, capable of providing essential services during grid outages.

ii. Solar canopies with storage can support the distribution grid, even when located away from electric loads.

- Canopies protect activity below (e.g., parking) from the elements and reduce urban heat island effect.

Proposed Solar Canopy Deployment Strategies

In order to advance the deployment of solar canopies, we recommend the following policies and initiatives:

- **Develop a solar canopy strategic plan**
  Recent, failed state legislation called upon DEEP to develop a plan to "identify opportunities and potential sites for solar canopies in the state" and "prioritize the development of solar canopies in environmental justice communities." This plan was to "include recommendations for policies, programs or regulations to promote the construction of solar canopies in the state, consistent with the … Integrated Resources Plan…and Comprehensive Energy Strategy…" (CT House of Representatives, 2024).

  Despite the failure of this legislation to pass in the General Assembly, we request that DEEP follow through on developing this strategic plan. Such a plan could provide clear guidance on ways for Connecticut to realize the potential of this resource.

- **Streamline and expedite upgrades and extensions to the distribution grid**
  Many of the potential solar canopies identified in our study could not be built today due to insufficient capacity in the distribution grid. Connecticut must make rapid and significant upgrades to substations and circuits across the state. If planned properly, these investments will yield returns in the lower energy costs and economic activity generated by the interconnection of solar projects, both canopies and others.

  Connecticut must engage in an ambitious, transparent and collaborative initiative to plan and implement necessary grid upgrades. This initiative should include:
  - Improved grid hosting capacity maps, capable of interactive analysis using GIS tools and including greater details on interconnection queues
  - The launch of additional Affected System Operator (ASO) and Cluster Interconnection studies to prioritize substation upgrades
  - Support for "flexible" solar interconnections, allowing for occasional curtailment, thereby reducing the need for grid upgrades (Driscoll, 2024)
  - Support for "non-wires alternatives", including solar canopy "resilience hubs" (i.e., solar paired with storage, EV charging) in areas with limited grid capacity

- Increased incentives for solar canopies to reflect their value

As enumerated in the previous section, solar canopies offer a unique value proposition due to their construction features and location. Because they are typically more expensive to deploy than rooftop solar, it is important to recognize these additional benefits in the design of solar programs and incentives. Current incentives for solar canopies are insufficient and do not reflect the true value they generate. We recommend the following incentives and policies:

i. Allow the amount of energy generated by both rooftop and canopy solar to exceed local usage. (Currently, only rooftop is permitted.)
ii. Create a separate category for canopies within the small Non-Residential Renewable Energy Solutions (NRES) Program, with separate limit (e.g., 25 MW) and an "adder" (e.g., $0.05 per kWh) to the compensated rate.
iii. Increase the bid preferences to 50% in the NRES medium and large categories and Shared Clean Energy Facilities (SCEF) program.
iv. Require that all SCEF solar canopy projects above a certain size (e.g., 500 kW) be paired with battery storage, with concomitant increase in bid preference to reflect the fact that such projects support and stabilize the grid.

- **Exempt solar canopies from local property taxation beyond the existing tax treatment**
  By definition, solar canopies preserve the existing activity underneath, including parking, storage or other uses. As such, the property is already subject to taxation. Installation of a canopy should have no impact on the existing tax treatment.

- **Other initiatives**

i. Issue a Request for Proposals (RFP) for one or more "mega-canopy" projects (e.g., at airports, seaports). Consider, for example, the 12-MW solar canopy-plus-storage being built at JFK Airport (NY Governor 2024).
ii. Launch a project to build 20 solar canopies in EJ communities by 2026. Such a project should:
    1. Be a collaboration of policymakers, municipal officials, utilities and industry
    2. Streamline permitting, interconnection and financing
    3. Maximize available state and federal incentives
    4. Involve direct benefits to the community
iii. Identify state properties suitable for lease to private parties for the construction of solar canopies.
iv. Provide grants to communities to identify feasible sites for solar canopies.

Future Directions for an Updated impervious Surface and Parking Lot Database

- Re-creating previous methods with new data

To further develop this database of potential solar canopy sites across Connecticut, a more comprehensive and resource-intensive process would need to be completed. One of the foundations of PACE's 2021 analysis was the previously made vector-based dataset of all impervious surfaces across the state (CT ECO, 2012). This database, hosted by CT ECO, provides accessible spatial data on different impervious surface areas segmented into distinct shapes and categories. This original process was completed by using raster analysis techniques evaluating aerial images of Connecticut and distinguishing areas with different saturation characteristics to identify impervious surfaces. Following this process, a "heads-up" vectorization process was used to convert raster data to vector data where different objects are separated out and described with their attributes. Vectorization processes like this can include some level of automation but generally require a significant amount of manual tracing and quality control from individuals over a large amount of time.

Re-creating this process would be a significant endeavor beyond the scope of PACE alone and would provide very useful information to reflect the infrastructure development that has occurred over the past decade. This information becomes increasingly relevant as more impervious surfaces are developed and other areas like covered parking garages can be included to understand potential for solar canopy siting. CT ECO regularly produces new high-resolution aerial imagery raster files of the entire state every few years, and their most up-to-date version will be released in 2024 to reflect imagery taken in 2023. Basing a new vectorization of impervious on this new imagery will provide an update to a dataset that is now more than a decade old.

In addition to a new vectorization, additional parameters could be added to the potential solar canopy analysis itself. Notably, key factors that have been used in other analyses that would be valuable are (1) slope of site locations, (2) zoning map overlays, and (3) further detail into grid interconnection. Incorporating data of slope would provide greater detail into the relationship between capacity and annual production at different locations on a site-specific or hyperlocal level, and would help to identify sites where development would be very difficult due to topographic challenges. Including zoning maps would be valuable and involve weaving together a patchwork of data from different towns across the state. By incorporating these maps assessments could be made into feasibility, sectors to target, and possible priorities for rezoning. Finally, as stated earlier it is challenging to provide further detail concerning grid interconnections in Connecticut specifically because of the lack of data accessibility provided by utilities. If the state is able to follow models for utility data transparency and usability like that implemented in New York then researchers for any topic related to energy modeling would greatly benefit.

- Machine learning model

A final promising method to automate and provide more detail on potential solar canopy sites is to leverage machine learning models. A recently published model created by ESRI specifically targets parking lots (2023). By using this model and others like it, researchers studying solar canopy siting could automate the process of analyzing raster imagery and provide highly detailed boundaries and characteristics for parking lots. The notable limitation with this process as it stands is that machine learning models require a significant level of processing power and cannot operate on the scale of an entire state, at least in a manner more efficient than current methods that incorporate a combination of automated and manual work.

- Substation load analysis

  As mentioned previously, there are some issues with using the proximity that potential sites have to substations as a metric of favorability. While the results we provide through that analysis are still highly valuable, an additional detailed assessment accounting for existing load and capacity of individual substations would be highly beneficial for statewide planning of renewable energy development. This likely will be possible as utilities in Connecticut continue to update their hosting capacity maps. However, while these maps are currently useful to local developers aiming to assess one project at a time, a more accessible dataset that is usable for large-scale analysis is needed to produce a statewide analysis of solar canopy potential siting in relation to substation capacity. This future research direction would be bolstered by our previously described proposal for a mandate that utility data be more accessible, transparent, and usable for analysis.

Conclusions

Solar canopies have the potential to supply a significant portion of Connecticut's electricity needs. PACE has identified over 9,000 potential canopy sites in the state, capable of deploying over 7,000 MW, supplying 36% of our current electricity usage. Nearly half of these are located within two miles of a substation, and 28% are adjacent to existing commercial solar. Eighteen percent are both.

Yet, only a small fraction of these potential canopies has been built, or could be built due to prevailing solar policies and to the current condition of our electric grid. Realizing the potential of solar canopies in Connecticut will require concerted effort by state policymakers to ensure they are valued property in solar incentives. Moreover, the rapid buildout and upgrade to our distribution grid is essential not only to solar canopies but also more broadly to solar deployment and the electrification of transportation and heating.

By building solar canopies, we will not only meet our energy needs, but also preserve our farmland and forests, reduce emissions and promote Environmental Justice communities. By improving existing solar programs and incentives, and conducting a range of initiatives, Connecticut has an opportunity to become a national leader in the deployment of solar canopies.

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