Avoided Carbon Emissions from Solar Panel Systems and Sequestered Carbon Emissions from Tree Growth

Introduction

ODOT is in the process of evaluating several right-of-way sites for ground-mounted solar generation to reduce its carbon emissions and to purchase green power at or below grid rates.

Siting Solar Panel Systems for Maximum Performance

ODOT wants to ensure that solar panel systems sited in the right-of-way are designed for maximum electricity generation and minimal environmental impact. In order to achieve maximum electricity generation, the solar energy potential for a specific site is determined by calculating the scale of the solar resource and the likely efficiency of the solar panels used to convert sunlight into electricity.

Solar resource is sunlight that enters the earth's atmosphere and reaches the ground directly rather than being reflected, absorbed or scattered. The solar resource is dependent on the latitude, season, time of day, tilt and orientation of the solar panels, air quality, atmospheric conditions such as cloud cover and sky view obstructions such as buildings and trees.

There are many methods for collecting solar resource data. The most common method in Oregon is to complete a Solar Site Assessment form available through the Oregon Department of Energy. To start, a sun path chart developed by the University of Oregon Solar Radiation Monitoring Laboratory is used to estimate solar panel system performance based on the site's proximity to Oregon regions where daily and monthly solar resource data has been collected. Then the combination of panel tilt and orientation angles in degrees can be determined in order to maximize the solar potential of the solar panel system. A tilt and orientation factor (TOF) of 100% represents no loss in solar potential and a 70% TOF indicates a loss of 30% in solar potential. The final step is to account for sky view obstructions, such as buildings and trees, which will have a shading effect on the system and a resulting loss of solar potential.

Shading of solar panels due to a building, utility pole, cloud or tree, can have a negative impact on the performance of the solar panel system. Even the partial shading of one or two cells from a solar panel can reduce the solar electricity output dramatically. If the shading persists for a long period, it may even damage the system by creating hot-spot heating. Additional maintenance of trees adjacent to the solar panel system is usually required to prevent damage done to the arrays due to fallen branches and duff, which could also increase the shading effect and reduce the solar electricity output of the system.

Total solar resource fraction (TSRF) is the measure of the effect of shading on a solar panel system's solar electricity generation potential. The closer the TSRF value is to 1, the more efficient the array will be at producing solar electricity. Oregon Administrative Rule #330-135-0030, "1.5 Percent for Solar Energy in Public Building Construction Contracts," mandates a TSRF value of 0.75 or higher; this is also a technical requirement to qualify for the Business Energy Tax Credit (BETC).

Solar Electricity Generation and Avoided Carbon Emissions

Solar electricity generation produces zero carbon emissions. When solar electricity (or renewable energy) is produced in Oregon, it displaces electricity in the Pacific Northwest Regional Energy Grid that would have been produced at power plants from a mix of hydropower[1] and renewable sources (55%), coal (34%) and natural gas (11%). Hydropower, like solar generation, releases zero carbon emissions. However, electricity produced from coal and natural gas produces 2.10 and 1.32 pounds of carbon emissions per kilowatt-hour respectively.

[1] The consideration of hydropower as a renewable energy source is controversial. Some environmentalists believe that only run-of-the-river hydropower projects are renewable energy sources. These projects generate electricity from the natural flow and elevation drop of a river and can involve small dams, but they are constructed in a way that does not flood massive amounts of land or interfere greatly with aquatic life.

Trees and Carbon Emissions Sequestration

According to the Environmental Protection Agency, terrestrial carbon sequestration is the process by which trees, plants and crops absorb carbon dioxide through photosynthesis. This absorbed carbon dioxide is sequestered or stored as carbon in biomass such as tree trunks, branches, foliage and roots, and in soil. The term "carbon sinks" is used to refer to forests, croplands and grazing lands, and their ability to sequester more carbon or carbon emissions than they release. In a 2004 study of California forest carbon sinks, an acre of Douglas firs (a tree commonly found in Oregon) was estimated to sequester or reduce carbon emissions by approximately 2 metric tons of CO_2e (carbon dioxide equivalent) per year, and a single Douglas fir was estimated to sequester 0.01 metric tons of CO_2e per year.

Tree Versus Solar Panel Scenario

Many right-of-way sites that are being considered for solar development projects contain trees, with Douglas firs being the most common in Oregon. The shading effects of trees on solar panels can drastically reduce the TSRF and solar potential of a system depending on the number of trees, path of the sun and the amount and time period of the shading. Should the tree or trees be removed to maximize the solar potential of the solar panel system? This is a complex issue because trees provide many benefits, including habitat for wildlife, aesthetics and terrestrial carbon sequestration. Of these benefits, the carbon sequestration can be quantified. The following scenario is provided to highlight the complexity of the tree versus solar panel issue:

> *A ground-mounted solar panel system is sited in an ODOT right-of-way to produce solar electricity output of 100,000 kilowatt-hours (kWh) annually. Each year, the production of 100,000 kWh of solar electricity will reduce carbon emissions by 38.9 metric tons of CO_2e compared to the Pacific Northwest Regional Energy Grid. If shade from a tree or trees reduce the solar potential for the site by 1%, the TSRF value of the solar array is reduced to 0.99 and the solar electricity output is reduced to 99,000 kWh. This decrease in solar panel productivity will result in the need for additional Pacific Northwest Regional grid power to be produced, which in turn results in more carbon emissions.*

Will this increase in carbon emissions due to tree shading be offset by the amount of carbon emissions that a tree sequesters?

> *In this scenario, if the 1% reduction due to shade is the result of one tree, the answer is no. If the same amount of shade were produced from 39 trees, the choice between the carbon sequestration of the trees versus the efficiency of the solar panel system would be a tie, based on carbon emissions alone. This is because the annual generation of 100,000 kWh of solar electricity will reduce carbon emissions by 38.9 metric tons of CO_2e. Therefore, a reduction in solar panel efficiency by 1% (TSRF = 0.99) due to tree shading results in an increase in carbon emissions by 0.39 metric tons of CO_2e per year due to that same electricity needing to be produced from the energy grid mix rather than from solar.*

While 39 trees annually sequester the equivalent avoided carbon emissions from 1,000 kWh of solar electricity production (the amount of lost solar electricity due to shading in this scenario) from the Pacific Northwest grid mix, the tree versus solar tradeoffs cannot be made on this dichotomy alone. Trees vary in shape and size, and their shade impact on the solar panel system will vary depending on their proximity to it, the density of foliage and the time of year. Therefore, when considering the trade offs between sequestered carbon from onsite trees versus the loss of solar electricity production from shading, each site must be evaluated on a case-by-case basis.