LOCATION, LOCATION, LOCATION: COUNTY-LEVEL COSTS AND BENEFITS OF RESIDENTIAL SOLAR PHOTOVOLTAICS

Parth Vaishnav, Carnegie Mellon University, 412-268-9919, parthv@cmu.edu
Inês Azevedo, Carnegie Mellon University, 412-268-3754, iazevedo@cmu.edu
Jinhyok Heo, Cornell University, jinhyok.heo@cornell.edu
Nathaniel Horner, Carnegie Mellon University, nch@cmu.edu

Overview

Solar irradiance varies by location and time, as do the private benefits – in terms of offset electricity purchases – of rooftop solar photovoltaics (PV). The health and environmental benefits of displacing a unit of grid electricity production, which stem from reduced emissions of carbon dioxide, the oxides of nitrogen and sulfur, as well as fine particulates, also vary by time and location. This suggests that the minimum subsidy needed to entice homeowners to install solar PV also varies by location, as does the magnitude of the public benefit that the subsidy produces. Furthermore, because pollutants are transported over large distances, the benefits of displacing grid electricity production may be felt far away from where the offset electricity was produced, and where the solar panel is installed. For example, the benefits of installing solar panels on a farmhouse in the countryside might be concentrated in the center of a densely-populated city, because the small improvement in ambient air quality there affects a large number of people. This distribution may have environmental justice implications. We will produce a location-specific cost-benefit analysis that quantifies the county-level costs, benefits, and distribution of benefits for residential solar PV in the continental United States. We will analyse the implications of these results for targeted subsidies, and for environmental justice.

Methods

Siler-Evans et al. (2013) estimated the marginal benefits of wind and solar capacity across the United States. We have updated that analysis with more recent air quality models (Heo et al 2016a, 2016b; Muller 2014), and the most recent emissions data from the Continuous Emissions Monitoring System. While Siler-Evans et al. (2013) focused exclusively on the health and environmental benefits, we will also consider the location-specific cost of solar PV systems, drawing upon data from Barbose and Darghouth (2015). To quantify the owners' private benefit from a rooftop PV system, we will use various location-specific measures of the value if electricity, including the locational marginal price (LMP), as well as the the state- and county-average residential price of electricity (see, for example, Hagerman et al., 2016). We will also study the incentives currently available for rooftop solar (NC Clean Energy Technology Center, 2016), and compare them to our estimates of the minimum subsidy needed to incentivize home owners to adopt. Finally, we will extend Heo's earlier work on a reduced form integrated air quality model (Heo, 2015) to overlay estimates of the distribution of monetized benefits with census tract income data. We will compare this to the distribution of solar PV installations (and, by extension, the distribution of subsidies to promote solar PV). We will analyse the equity and environmental justice implications of these two distributions.

Results

Preliminary analysis of the costs and benefits of solar in two states, California and Pennsylvania, is shown in the figure below. For each county, costs include the annualized total unsubsidized (including soft) system costs ($5.9 per watt installed for PA from the Sunshine program (PA DEP, 2014) and $5.4 per watt installed for CA's Solar Initiative (CSI)). Benefits are value of electricity generated. In the figure we used the product of the electricity generated by a 1kW system by the state-average residential rate of electricity, $0.14/ kWh in PA and $0.18/kWh in CA. (EIA, 2016) and HECC benefits from reductions of emissions from fossil fuel generation. (Muller, 2011) The figure shows that even when accounting for the social benefits from reduced HECC, the cost of solar in PA outweighs the benefits (due to low electricity prices). In CA, because the solar resource is better and electricity more expensive, the costs and benefit are very similar.

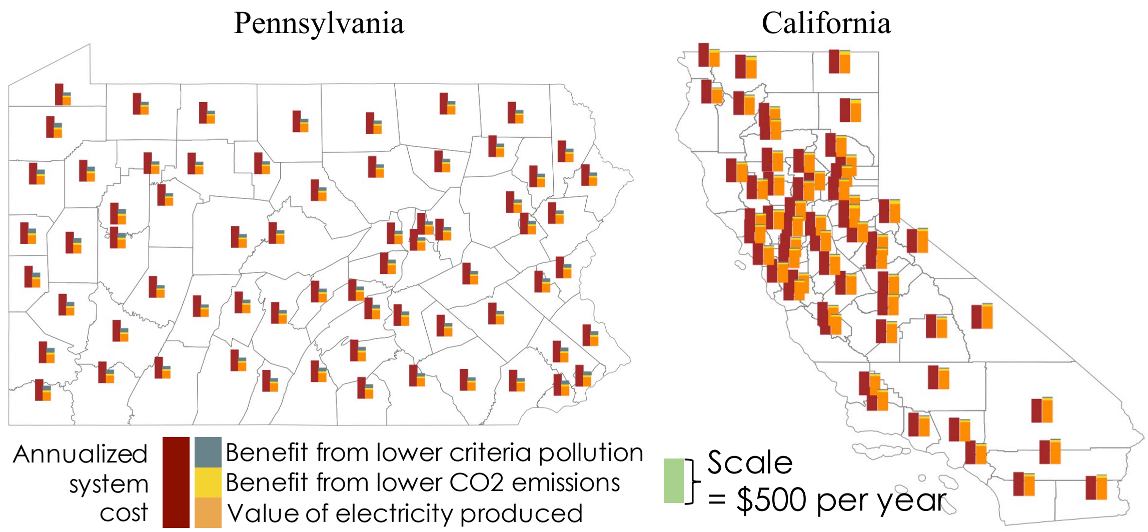

Figure 1: The figure shows the benefits and costs associated with installing 1kW of PV at different locations in PA and in CA. Left bars represent costs and right bars benefits. Costs are the system installation costs. Benefits include value of electricity generated and reduced pollutant emissions.

We will produce similar results for every county in the US, informed by higher-resolution data on solar PV system costs and benefits. We will also study the environmental justice implications of these results.

Conclusions

Economic incentives for renewable energy production are often determined at the state or even federal level, even when the production of that energy is widely distributed, and its benefits vary based on where it is produced. Our analysis will show that it is possible to target subsidies more precisely, and therefore reduce leakage. Since the beneficiaries of subsidies for residential solar PV installations are usually comparatively well-off, it could be hypothesized that these subsidies are regressive. We will critically examine this hypothesis by evaluating the distribution of the health and environmental benefits of solar PV.

References

Barbose, G., Darghouth, N., 2015. Tracking the Sun VIII: The Installed Price of Residential and Non-Residential Photovoltaic Systems in the United States. Lawrence Berkley National Lab.

EIA, 2016. State Electricity Profiles.

Hagerman, S., Jaramillo, P., Morgan, M.G., 2016. Is rooftop solar PV at socket parity without subsidies? Energy Policy 89, 84–94. doi:10.1016/j.enpol.2015.11.017

Heo, J., Adams, P.J., Gao, H.O., 2016a. Public Health Costs of Primary $PM_{2.5}$ and Inorganic $PM_{2.5}$ Precursor Emissions in the United States. Environ. Sci. Technol. doi:10.1021/acs.est.5b06125

Heo, J., Adams, P.J., Gao, H.O., 2016b. Reduced-form modeling of public health impacts of inorganic $PM_{2.5}$ and precursor emissions. Atmospheric Environment 137, 80–89. doi:10.1016/j.atmosenv.2016.04.026

Muller, N.Z., 2011. Linking Policy to Statistical Uncertainty in Air Pollution Damages. BE J. Econ. Anal. Policy 11, 1–29.

Muller, N.Z., 2014. Boosting GDP growth by accounting for the environment. Science 345, 873–874. doi:10.1126/science.1253506

NC Clean Energy Technology Center, 2016. Database of State Incentives for Renewables & Efficiency.

PA DEP, 2014. Final PA Sunshine PV Report as of 4_30_14 Data.

Siler-Evans, K., Azevedo, I.L., Morgan, M.G., Apt, J., 2013. Regional variations in the health, environmental, and climate benefits of wind and solar generation. Proc. Natl. Acad. Sci. 110, 11768–11773. doi:10.1073/pnas.1221978110