Intro Slide – Alison Mickey: Good morning everyone. My name is Alison Mickey. I'll be moderating today's webinar which will cover new research into the rooftop solar technical potential for low-to-moderate income (LMI) households in the U.S. This research is part of the Department of Energy's Solar Energy Evolution and Diffusion Studies (SEEDS) program. It aims to develop data-driven, evidence-based strategies for scaling-up solar adoption among low and moderate communities across the U.S. The goal is to reach parity in solar penetration rates across socioeconomic dimensions. The research theme is interdisciplinary, drawing on experts from NREL, GRID Alternatives, Lawrence Berkeley National Lab, the University of Chicago, the University of Michigan Ann Arbor, and Advanced Grid Consulting.

The research has three parts. The first is to identify the solar technical potential among LMI households, which is the focus of our webinar today. The second is to determine the unique barriers that can influence LMI household solar decisions. And the third is to evaluate predictive models of decision making and then test real world methods of encouraging adoption among LMI households.

The project will draw on cutting edge research and analytic techniques from multiple disciplines to provide policymakers with evidence-based insights. Our presenters today are Ben Sigrin and Meghan Mooney. Ben is the principle investigator of this SEEDS project. Meghan is a geospatial data scientist at NREL. So without further ado, I will turn the webinar over to Ben and Meghan.

Ben Sigrin: Thank you Alison, and thank you to everyone who can take time out of your day to join us. My name is Ben Sigrin and today I'll be describing our recent publication to estimate the national technical potential of residential buildings, and for low-to-moderate income households specifically. Technical potential is a metric that quantifies the maximum generation available from a technology, and does not consider economic or market viability factors. More informally, it means "how much solar energy could we expect if we put solar panels on every residential building?"

Slide 2: Ben: Before continuing with the presentation, let me tell you more about our project and why we're doing this work. Our project is funded by the U.S. Department of Energy, Solar Energy Technologies Office under a three-year grant. Our broad goal is to develop data-driven, evidence-based strategies for scaling-up solar adoption among low and moderate communities across the U.S. To do that we will identify the solar technical potential among LMI households, which is the work presented today, as well as use surveys to determine the unique barriers and factors that can influence their solar decisions, evaluate predictive models of LMI decision-making, and experimentally test real world methods for motivating adoption among LMI households.

Slide 3: Ben: Though increasing solar access for all households has seen some traction in recent years, it is worth asking why? Why does rooftop solar potential for LMI households matter? First, in this study we define low and moderate income households, or LMI households, as those earning less than 80% of area median income, which is the same definition as the Housing and Urban Development Department. By this definition low and moderate income households represent a very large constituency within the U.S.—43%, or nearly half of the population. Moreover, low-income households spend a disproportionate fraction of their income on energy, so bill savings from solar would be more impactful than for their higher-income counterparts.

From an equity perspective, residential solar has disproportionately been adopted by high-income households, often benefiting from public-funded incentives. Thus there is a growing backlash against solar policies that appear to favor the more affluent. Without recourse, rooftop solar risks a reputational backlash—in time, it could be perceived as solely the purview of the wealthy, and its deployment not seen as a public benefit.

Finally, there is growing interest in policy interventions that can create more equitable rooftop solar access. However, poor understanding of how much rooftop solar LMI communities can accommodate may lead to ineffective policies. Our ultimate goal in this research is not to advocate for any one policy, but to provide objective data for regulators and others to make informed decisions that are best for their own communities.

Slide 4: Ben: This study seeks to address three research questions:

First, what is the quantity and spatial distribution of residential rooftop solar technical potential, stratified by income, building type, and tenure? At a gross level, these data allow improved estimates of the possible opportunity for deployment, as well as the magnitude of various policy interventions.

Second, among low and moderate-income households, what is the feasibility of achieving parity in solar access across income groups? Specifically, we investigate the feasibility of offsetting at least 33% of LMI electrical consumption with solar generation in each U.S. county. In counties where that fraction is infeasible, we consider novel deployment models, such as community solar, virtual net metering, and other shared solar models.

Finally, LMI households interact with a vast web of nonprofit entities, such as churches and schools. What is the quantity of technical potential for these classes of buildings, and to what extent might these buildings “oversize” systems on their roofs to share export generation with their communities to LMI households?

Next, I’ll let my colleague Meghan Mooney talk more about the methods in this study.

Slide 5: Meghan:

To answer these questions outlined by Ben, we used data derived from light detection and ranging, also known as “LiDAR”, which is a remote-sensing method that collects 3D data of the Earth’s surface by sending out pulse laser beams from an airplane and measuring the return. These data come from the Department of Homeland Security and cover 128 metro regions (or approximately 23% of the US building stock and 32% of the U.S. Census Tracts) at a 1-meter resolution.

Using LiDAR scans, as opposed to aerial imagery, allows us to infer the building footprint and the unshaded roof area, azimuth, and tilt for each distinct roof plane, although roof age or other structural concerns are not considered. These data are then intersected with U.S. Census Bureau socio-demographic and building stock data at the tract-level to better understand the total usable rooftop area for LMI households. Statistical techniques also are used to estimate rooftop potential in areas not covered by the LiDAR scans. This imputation process involves a series of models to estimate number of buildings from household counts, number of suitable buildings, and the size and orientation of the developable planes.

The level of spatial resolution in this study is quite high, with results presented at the Census tract level. This allows us to make detailed calculations for cities and neighborhoods. We also looked at three representative regions (San Bernardino-Riverside, Chicago, and Washington D.C.) in more depth.

Finally, all data used in this study is publicly available for download, both as a data product and through an interactive web application. We encourage other researchers to use this data as a starting point for your own research.

Slide 6: Meghan: The time constraint, and desire to appeal to a general audience, prevents us from providing an in-depth walkthrough of our full methodology. If you're interested I really encourage you to read our report to learn more about what we did and why.

But, at a high level our methods follows four steps:

1) We use the LiDAR data to observe attributes of rooftop in the 128 metro areas to classify each building's roof, like the area.
2) For areas outside the LiDAR data coverage we trained a statistical model to impute the rooftop characteristics, such as the fraction of solar-suitable buildings in the tract. This statistical model was trained on 75% of the tracts with LiDAR coverage and validated by applying it to the remaining 25% out-of-sample tracts.
3) We intersect the LiDAR data with Census demographics tables of household counts by income, tenure, and building type. It's important to note that the LiDAR data does not allow to directly observe the tenant's attributes, that is, we don't know for certain if a building's occupant is low-income. Instead, we use disaggregation methods, which are accurate and unbiased over thousands of buildings.
4) Finally, we simulate the solar generation for each roof using NREL PVWATTS and aggregate statistics at the tract and county level.

Slide 7: Meghan: In this study we used data to estimate the amount of rooftop solar technical potential. What do we mean by the amount of "solar suitable" buildings? In truth, there isn't a single definition of when a roof is suitable or not, though there are some common-sense guidelines that are followed by today's industry.

In this study we defined suitability with 4 characteristics: the roof needed to be mostly unshaded, it needed to have planes that were West, South, or East-facing, it needs to not have excessive tilt, and there needed to be at least 10 square meters of deployable area. We also assume a panel power density of 160 Watts per square meter. These parameters are the same as those used in previous NREL studies.

Slide 8: Meghan: We find that over all tracts and all residential buildings in the United States, the estimated residential rooftop solar technical potential is nearly 1,000 terawatt-hours of generation, or about 75% of residential electrical consumption. Significant solar potential is found in every income group, with the greatest overall potential in the non-LMI income group, and with 416 TWh for low-to-moderate households over 25.5 million solar-suitable buildings. This is equivalent to about 330 GW of capacity. The LMI potential is approximately 42% of the total U.S. residential potential, which is substantial.

We also find that the average household potential was 8,553 kWh per year.

Slide 9: Meghan: We find that the quantity of residential technical potential is highly concentrated amid urban and other densely-populated areas with more building stock. Many of the areas with high levels of potential already have significant levels of residential solar deployment, for instance--Arizona, California, Maryland, Massachusetts, New Jersey). Although we also find that there also several states with high solar potential with currently-low levels of solar deployment such as Illinois, Ohio, Florida, Pennsylvania, and Texas—indicating the opportunity for future growth.

Slide 10: Meghan: Whereas the previous figure highlights areas of the county with the most overall residential potential, this figure instead shows which areas of the country have the highest fractions of LMI solar potential. We find that in 14% of counties LMI technical potential comprises at least half of the county's solar potential. Spatial trends in the fraction of LMI potential are substantially different than those of the absolute amount. At a high-level, patterns of LMI potential mirror overall income trends in the United States. LMI potential percentages are greatest in lower-income counties and are also distinctly higher in rural or semi-rural counties. Areas with disproportionately greater fractions of LMI potential are seen in the Southeast (i.e., Alabama, Arkansas, Kentucky, Louisiana, Mississippi, West Virginia) and portions of Midwest and Mountain West. One clear takeaway is that there are significant LMI opportunities in every state.

Slide 11: Meghan: Finally, previous maps were shown at the county-level, even though the underlying data is tract-level. Tract-level maps, however, are well-suited to demonstrate community-level patterns within a city. As a demonstration we mapped solar technical potential for LMI households at the tract level for four cities—Chicago, Illinois; San Bernardino/Riverside, California; and Washington, D.C. (Figure 4), normalized by the tract's total residential generation potential.

Unsurprisingly, we found that the modeled LMI generation is strongly correlated with lower-income neighborhoods in each city. For instance, we can see clear patterns in Chicago's historic South Side neighborhood. Moreover, the results demonstrate that a substantial portion of each city's solar technical potential is in LMI neighborhoods. Therefore, decreased deployment of solar in lower-income neighborhoods would substantially limit the overall deployment potential in these cities.

Next, I'll let Ben tell you more about the breakdown of solar potential on different building types.

Slide 12: Ben: The current U.S. residential rooftop PV market largely is concentrated among high-income households and for single-family owner-occupied homes. Next, we discuss the deployment opportunity on other types of buildings—renter-occupied and multi-family. Though these types of buildings have been previously underrepresented, our results indicate that nearly 60% of the LMI potential exists on renter-occupied or multi-family dwellings. Put another way, we are leaving a lot of opportunity on the table by not addressing the barriers to deployment on these types of buildings.

Slide 13: Ben: We estimate that a majority of the residential potential, or 68%, is situated on single-family buildings, as compared to multi-family buildings. Single-family technical potential exceeded multi-family potential for each income group. Within LMI households, however, the distribution is more uniform, with multi-family buildings comprising 40% of the LMI-specific potential.

Similar trends are seen for the segmentation of potential between owner-occupied and renter-occupied buildings as there is a strong correlation between occupancy in multi-family buildings and rental status. We estimate that 66% of the residential potential is situated on owner-occupied buildings, as compared to 34% for renter-occupied buildings. For LMI households, potential on renter-occupied buildings slightly exceeds that of LMI owner-occupied buildings.

Slide 14: Ben: Taken together, this figure shows the intersection of potential by both tenure and building type for LMI households. The largest modality of potential is for single-family owner-occupied buildings, or 177 TWh, followed closely by multi-family renter-occupied buildings, which have 140 TWh of potential. Though deployment of rooftop solar historically has been concentrated on single-family, owner-occupied buildings, these results indicate that nearly 60% of potential for LMI buildings exists on these other underrecognized tenure-type combinations.

Slide 15: Ben: The U.S. Department of Energy's Solar Energy Technologies Office recently announced updated cost targets of $0.05/kWh for residential-scale solar systems by 2030. Using these costs, NREL estimated that achieving these costs could result in 971 GW of PV capacity in 2050, or 33% of national generation. Inspired by this goal we investigate the feasibility of having rooftop solar offset at least 33% of LMI household electrical consumption in each U.S. county.

Note that the data does not enable assessment of the feasible offset fraction *at the household level*, and instead should be interpreted in aggregate over the county. The analysis also only considers consumption offsets over an annual basis and does not consider hourly mismatches in generation and consumption—which could be substantial without energy storage or other load-shifting methods.

We find that on a national basis it is technically feasible to offset 33% of LMI household electrical consumption with only single-family owner-occupied (SFOO) buildings, although to do so requires buildout on essentially all SFOO buildings— which we ultimately consider impractical.

Slide 16: Ben: In contrast, there is more than sufficient roof space to meet the 33% offset target when including renter-occupied and multi-family buildings. Specifically, we find that LMI households could offset 80 to 90% of the electrical consumption with rooftop solar generation. These targets are actually more feasible for LMI households than non-LMI ones due to lower per-capita levels of consumption.

The main takeaway is that most LMI electrical consumption can be met with rooftop solar, but it’s unlikely it could offset 100% of electricity consumed and would require deployment on non-traditional building types.

Slide 17: Ben: Not all counties can offset 33% of their LMI electrical consumption with in-county rooftop solar. When considering only single-family owner-occupied buildings, 40% of U.S. counties have insufficient rooftop solar potential to offset 33% of LMI electrical consumption, which is shown on the left figure. However when including the remaining residential building stock this figure decreases to 1%, as shown on the right figure.

The largest remaining shortfalls are for mobile homes, whose roofs are typically not suitable for solar.

You can see there are strong spatial trends in the potential for solar to offset LMI consumption. These patterns most-strongly reflected regional variation in per-capita electricity consumed, primarily due to which fuels are used for building heating and cooling loads. For instance, electricity consumption is higher in the Southeast, which makes it harder to offset 33% of the consumption. Other trends include solar irradiance, building-stock composition, and the prevalence of solar-suitable rooftops.

Slide 18: Ben: Low- and moderate-income households interact with a vast web of non-profit entities, and it is plausible that these buildings could “oversize” photovoltaic (PV) systems on their buildings to share solar generation with their communities. We estimate the generation potential within the cities of Chicago, Illinois; San Bernardino/Riverside, California; and Washington, D.C., for five building types: public sites, public housing, K–12 public schools, homeless shelters, and places of worship.

Based on the building’s size and average electrical consumption per square foot for comparable buildings, each building’s electrical consumption was estimated, and thus the feasibility of oversizing systems to export excess generation to nearby LMI households.

Based on these assumptions, there is enough gross generation potential on the select building types to meet 9%-29% of LMI consumption in respective cities. However, when accounting for the building’s energy consumption, this fraction decreased to 1.3 – 8.7% of LMI consumption.

Schools, followed by places of worship had the greatest opportunity to export generation to the community of the five building classes considered. Schools typically have large flat roofs and decrease consumption in the summer, when solar irradiance is highest. Places of worship are favorable because they have low levels of electricity consumption year-round and moderately favorable roof characteristics. Unfortunately, public housing, public sites, and homeless shelters likely have insufficient rooftop space to offset 100% of their own on-site consumption. These results indicate that there is a modest, though not overwhelming, opportunity for buildings that serve LMI populations to oversize a PV system—and that projects are best evaluated on a case-by-case basis.

Slide 19: Ben: Wrapping up, we find that there is a substantial technology opportunity for rooftop solar on LMI buildings, on the order of 300+ GW. Though there are clear market and economic barriers, ignoring this segment could significantly limit the U.S. rooftop solar market.

Reaching this potential, however, requires deployment models other than those commonly found today, particularly, models that can address coordination issues inherent to rental-occupied and multi-family buildings. Such models must ensure that rental-property owners are incentivized to install solar on their buildings—for example, by bundling utility expenses with rent payments as a means of passing solar costs and savings through to the renter. These models also would need to address the diverging requirements and energy burdens of owners and tenants. For example, California recently developed an incentive program dedicated to affordable multi-family housing, with requirements that at least half of energy generated onsite be used to serve tenants loads (CPUC 2017b). In Colorado, the Denver Housing Authority's 2 MW low-income community solar garden has demonstrated a scalable model for offsite generation through utility partnerships. Virtual net metering also can be effective in enabling building owners to provide surplus generation directly to their occupants.

To further unlock the low-income solar market also requires addressing other barriers endemic to low-income households, such as, poor access to credit, low capital availability, housing uncertainty, and many more.

Slide 20: Ben: This report ultimately seeks to provide objective data for regulators, policymakers, nonprofits, and project developers to make informed decisions that are best for their own communities. To this effect, all data used in this study are provided freely via NREL's website in two formats.

The first format is the Rooftop Energy Potential of Low Income Communities in America, or "REPLICA" data set which contains the technical potential data used in this report, accompanied by several additional techno-economic variables (e.g. electricity expenditures ($/month), demographics, utility electric rates) which are all available for download as flat files. We think this data set alone will help policy-makers, researchers, and other stakeholders to have vastly more precise knowledge of the U.S. residential potential.

The second format—an interactive web application using NREL's OpenCarto platform—was developed to enable user to browse, visualize, and export results.

Slide 21: Meghan: Thank you so much for attending our webinar. You can learn more about the report, data set, and web app with the following links.