DURHAM PUBLIC SCHOOLS

ROADMAP TO 100% RENEWABLE ELECTRICITY

North Carolina Clean Energy Technology Center
North Carolina State University
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NC CLEAN ENERGY TECHNOLOGY CENTER

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The **North Carolina Clean Energy Technology Center (NCCETC)** is a University of North Carolina System-chartered Public Service Center administered by the College of Engineering at North Carolina State University. Its mission is to advance a sustainable energy economy by educating, demonstrating, and providing support for clean energy technologies, practices, and policies. The Center provides service to the businesses and citizens of North Carolina and beyond relating to the development and adoption of clean energy technologies. Through its programs and activities, the Center envisions and seeks to promote the development and use of clean energy in ways that stimulate a sustainable economy while reducing dependence on foreign sources of energy and mitigating the environmental impacts of fossil fuel use. Since its founding as the North Carolina Solar Center in December 1987, the Center has worked closely with partners in government, industry, academia, and the non-profit community while evolving to include a greater geographic scope and array of clean energy technologies. The NCCETC would like to acknowledge and thank the following organizations. Without their contributions, this report would not have been possible.

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EXECUTIVE SUMMARY

The Durham Public School (DPS) district has been working to improve its schools' energy efficiency and have found real savings in doing so. However, even the district's most energy efficient school is still spending a significant amount of money on electricity, which is generally produced with non-renewable energy sources. In this study, we explore the technical and economic feasibility of DPS achieving 100% renewable electricity, as an increasing number of the world's cities, states, and corporations have committed to doing. Of the possible sources of renewable energy, solar energy is by far the most abundant and feasible for use by the DPS district. There are financially attractive options available today for the school district to acquire solar electricity with potential savings for the schools' budgets. In the long run, the price of adding solar photovoltaic (PV) systems will continue to decline, resulting in improved solar economics and increasing benefits of being powered by renewable electricity.

POSSIBLE PATHWAYS TO 100% RENEWABLE ELECTRICITY SCHOOLS

In this study, 100% renewable electricity is defined as annual renewable electricity generation equal to or greater than the annual total electricity usage. This does not require the school to go off-grid or install batteries to supply electricity. There are multiple pathways for DPS to achieve 100% renewable electricity for the district using grid-tied solar PV systems. The school system can consider pathways that include mostly school-by-school solar PV projects, focus more on the development of large portfolios/batches of rooftop projects, large-scale off-site solar or wind farms, or some combination of these options. The best option at a given time depends on current policies (e.g. interconnection standards, third party energy sales, net metering, virtual net metering, rate structures) and market conditions (e.g. interest rates, PV pricing, electric rates, avoided cost rates). While we can analyze the current policies and market conditions to recommend the best options for DPS today, it is difficult to predict how the landscape will change over time. Thus, this report gives a snapshot of current and future options with an estimation of their corresponding economic attractiveness. Estimations of the economics of renewable energy systems for DPS further out into the future are only made in broad brushstrokes, given the uncertainty of the fast moving world of energy policy and markets.

TECHNICAL ASSESSMENT: ON-SITE SOLAR CAN EQUAL 100% OF TOTAL ANNUAL ELECTRICITY USAGE

The DPS district has been making improvements to its school's energy efficiency. However, there is still incredible potential for district-wide energy efficiency savings, which were estimated for this report to be a 25% reduction from current usage. The resulting lower electricity requirements are referred to as post-Energy Efficiency, or post-EE. A detailed technical assessment of a significant sample of DPS schools found that the combined total annual production from standard-sized rooftop and parking lot PV systems (49-MW_{DC} of PV capacity) on all 49 schools is estimated to equal 142% of the post-EE total district annual electricity usage. If limited to only standard-sized rooftop PV systems (26-MW_{DC}), the annual on-site PV production is estimated to be about 78% of the district's post-EE annual electricity usage.

ECONOMIC ASSESSMENT: POLICIES AND MARKET FACTORS DETERMINE AFFORDABILITY

North Carolina is a national leader in PV installation. However due to the current mix of market and policy conditions, the vast majority of the PV panels installed in the state are in large ground-mounted systems, commonly referred to as solar farms. This sector divide is largely driven by the low retail electricity costs in the state that make it difficult to install financially-attractive residential or commercial rooftop systems as well as by the standard long-term power purchase agreements available to the much lower-cost solar farms. Therefore, the current and near-term economic realities and policies of the state are the main obstacles to realizing DPS's clean energy potential. In particular, the economic challenges in North Carolina can be boiled down to two major components: (1) developing projects or markets large enough to meet the necessary economies of scale, and (2) policies that limit ownership options and reduce income streams for solar PV installations (e.g. maintaining ownership of net-metered renewable energy certificates (RECs), restrictions on third party energy sales, absence of virtual net metering, and inability to carry forward annual net excess generation).

A Strong Economic Case for Solar in DPS Exists Today and in The Coming Years

Last year, DPS spent over $5.7 million on over 65,000,000 kilowatt hours (kWh) of electricity. Provided no large unexpected changes in policy, technology, or markets over time, DPS can add PV systems, and perhaps wind as well, to meet its annual electricity needs at a lower cost than continuing with business as usual (purchasing all of its electricity at retail rates). In addition to saving money, another benefit of solar investment is a predictable and stable cost of electricity for the long life of the PV system. Comparative economic modeling of the school district's electricity costs for the next 25 years allows for a side-by-side look at many solar project options and market and policy scenarios. Specifically, our analysis provides a comprehensive overview of the project types and policy and market conditions available today and in the next 5 to 10 years. Today, the most financially attractive options require a third party owner in order to monetize the available tax benefits, namely the federal investment tax credit (ITC) and five-year accelerated depreciation, which are not usable by DPS directly because of its nonprofit status.

Current and Future Financially-Attractive Solar Options

Under current policies in North Carolina, the most attractive path to maximize financial returns on a solar investment is a partnership-flip ownership model for a solar farm whereby the school obtains ownership of the PV system after seven years of joint ownership with third-party investors**.** This structure is already in use by over 100 operating solar farms in North Carolina. Such an arrangement can provide DPS with electricity cost savings over the 25-year life of the PV system, saving the school district as much as $370,000 for every one MW_{DC} of PV installed, or an average of about $259,000 for each school that achieves 100% renewable electricity. This is a 9% electricity cost savings over the do nothing scenario of continuing to purchase electricity from the utility.

DPS also has the option of a similar arrangement for on-site rooftop solar installations that consists of a portfolio of large rooftop systems built under a single contract, but is more expensive than one or more large ground-mounted systems. This district-level portfolio approach to projects creates an economy of scale that would reduce the installed cost of on-site PV systems. Using a partnership-flip ownership model for a portfolio of large rooftop systems can save DPS as much as $160,000 for every one MW_{DC} of PV installed, or an average of about $112,000 for each school that achieves 100% renewable electricity. This is a 4% savings over the do nothing scenario of continuing to purchase electricity from the utility.

Potentially more attractive than either of these options, although currently prohibited in North Carolina, is a power purchase agreement (PPA) with a third-party owned PV system, also known as third party energy sales. In this arrangement, the school purchases solar electricity from the third-party owner of the PV system and then net meters that electricity, which means the school is able to use the solar electricity directly and "sell" any excess energy to the utility for credit on its electricity bill. When coupled with solar-friendly updates to North Carolina net metering policy, such a setup has the potential to save DPS $480,000 for every one MW_{DC} of PV installed, or an average of about $336,000 for each school that achieves 100% renewable electricity. This is an 11% savings over the do nothing scenario of continuing to purchase electricity from the utility. In the 25 states where this option is legal, it is the most common arrangement used for on-site PV, largely because of its simplicity.

Continued Drop in Solar Prices Will Lead to More Savings

It is expected that the cost of solar PV will continue to decline, while electric utility rates are expected to climb. Currently, the turnkey cost of large simple rooftop PV systems is about $2.00/watt while a ground-mount solar farm is about $1.50/watt. A portfolio of large rooftop systems built under a single contract is estimated to result in a 6% cost reduction (derived from economies of scale) to approximately $1.88/watt. If the cost of PV continues to decline as aggressively as it has in the last two years, North Carolina could see consistent $1.50/watt pricing for commercial rooftop systems and $2.50/watt for parking lot shade structures within the next five years. At a price of $1.50/watt, which could be achieved for a 75% roof and 25% parking lot system in more than five years, there are several additional on-site project options that have the potential to save DPS money on its electricity bills while supplying DPS with clean renewable energy.

In summary, the current money-saving solar option for DPS is limited to large partnership-flip projects that require third-party tax equity investors and low-cost bond financing. While difficult to set up due to the complexity and the accompanying legal, accounting, and administrative costs for the school, these systems provide a proven path to cost-effective renewable electricity. Over time, solar PV price reductions will make it more feasible for solar systems to be installed on school roofs and over parking lots. It is also possible that in the future, simpler ownership structures, such as a third-party-owned system that does not require a joint partnership, will be available for North Carolina school districts, further enhancing the attractiveness of investing in renewable electricity.

Recommended Next Steps towards a 100% Renewable Electricity Future

While it is difficult to predict a timeline for when and how policy and markets might change to create new economic environments, it is clear that in order for DPS to most efficiently achieve a long-term goal of 100% solar, DPS must continue to build solar knowledge and experience over time to take advantage of renewable energy development opportunities when the conditions are best. The climb up this learning curve is best started now, making DPS more able to follow policy and market changes and recognize when trigger points are reached for updating the DPS solar development strategies. For example, DPS staff should be able to interpret the economic impacts of policy changes, such as those involving third party sales and net metering. Also, it is entirely feasible to have a long-term plan to study and forecast the impact of the current solar policies, utility rates, and PV prices at the end of each fiscal year and convert them to metrics for economic analysis.

Thus, it is recommended that DPS start working to develop a pilot solar farm or significant on-site PV systems on the best schools for solar. The DPS district has many metal roofs, which have a very long life, that are ready for solar PV installation today. Many of the district's non-metal roofs are in need of replacement within the next 5 to 10 years, thus offering many additional good candidates for rooftop solar PV. To start the development process, DPS should conduct a more detailed analysis of the economics of solar PV, including an evaluation of the possibility to issue new bonds under the Clean Renewable Energy Bonds (CREBs) program, and could release a Request for Proposals (RFP) to solicit bids to determine available pricing and partners.

Finally, it will be important for DPS to examine all the differentials between the 'do nothing' option and various renewable energy options, including the additional non-monetary benefits of moving to 100% renewable electricity. While it is very difficult to quantify the financial value of such externalities, nearly everyone can agree that there are significant benefits of renewable energy. Those additional values include: clean air and water, reduced fossil fuel consumption, learning opportunities for children (science, technology, engineering, and mathematics), and many others. By developing a long-term plan to be powered by 100% clean, renewable electricity, DPS will bring these countless benefits to its students, staff, and the surrounding community.

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GLOSSARY

Commercial-Scale Photovoltaics: Includes commercial, institutional, and non-residential PV installations. This refers to moderate sized PV systems, generally 50 kW to 1,000 + kW, most often installed on flat rooftops.

Demand-Time of Use Rate, or TOU-Demand: A type of electric utility rate schedule that includes a monthly charge for the peak power demand during the month as well as charges for energy that vary based on the time of use (TOU) of the electricity, i.e. on-peak and off-peak.

Demand Charge: A billing mechanism used to recover the cost of providing transmission and distribution service. The charge is based on the highest power demand during any 15 to 30 minute interval measured in a billing period. Demand charges may be a fixed charge per kilowatt, or divided into rate brackets: the highest charge on the first bracket, and lesser charges on the following brackets.

Direct Ownership: A renewable energy facility ownership structure where the end user of the electricity is the owner of the renewable energy system (see section 4 for more information).

Energy Use Intensity (EUI): Expressed as energy per square foot per year. EUI is calculated by dividing the total energy consumed by the building in one year (measured in kBtu or gigajoules) by the total gross floor area of the building.

Investment Tax Credit (ITC): A dollar for dollar reduction in the tax liability of the person or entity that made a qualifying investment under the tax law. Investment tax credits are structured to encourage economic activity in various locales, sectors, or industries.

kBtu/ft2/year: This is the unit of site energy intensity and source energy intensity. kBtu is an amount of energy, "/ft2" means per square foot of building area, and "/year" means per year.

Kilowatt Hour (KWh): A measure of electricity defined as a unit of work or energy, measured as 1 kilowatt (1,000 watts) of power expended for one hour, and the common billing unit for electrical energy.

Levelized Cost of Electricity (LCOE): Typically defined as the ratio of an electricity-generation system's costs—installed cost plus lifetime operation and maintenance (O&M) costs—to the electricity generated by the system over its operational lifetime, given in units of cents/kilowatt-hour. In our analysis, we have expanded this definition slightly to cover all of the school district's electricity sources, including its purchase of grid electricity.

Modified Accelerated Cost Recovery System (MACRS): The Modified Accelerated Cost Recovery System is the current tax depreciation system in the United States. Under this system, the capitalized cost basis of tangible property is recovered over a specified life by annual deductions for depreciation. Renewable energy equipment is able to use the 5-Year MACRS schedule.

Net-Positive Energy: A term used to describe a building that produces more energy than it uses over the course of a given time period, generally annually.

Net Metering: A billing mechanism under which electricity generated by a customer's on-site generating facility and delivered to the local distribution facilities may be used to offset electricity provided by the utility to the customer during the applicable billing period (see section 4 for more).

Net Solar Value: The financial value of a net-metered PV system, determined by subtracting the utility bill with solar from the utility bill without solar and dividing by the number of kWh produced by the PV system during this period, generally a one-month billing cycle in units of $/kWh.

Net Zero Energy: A term used to describe a building or other energy user that produces as much energy as it uses during the course of a given time period, generally annually.

Post-Energy Efficiency Improvements (Post-EE): The annual electricity usage of a school after additional energy efficiency improvements have been completed.

Solar Power Purchase Agreement (PPA): A financial arrangement in which a third-party developer owns, operates, and maintains the photovoltaic (PV) system, and a host customer agrees to site the system on its roof or elsewhere on its property and purchases the system's electric output from the solar services provider for a predetermined period.

PV Capacity, DC and AC: The maximum nameplate operating power of a solar PV system, expressed in kilowatt or megawatt. Defined either by the maximum direct current (DC) production capacity of the system's solar modules, or the alternating current (AC) production capacity of the inverter. In today's PV systems, the DC capacity is typically 10% to 50% larger than the AC capacity.

Renewable Energy Certificates (RECs): Also referred to as Renewable Energy Credits, represent the property rights to the environmental, social, and other non-power qualities of renewable electricity generation. A REC, and its associated attributes and benefits, can be sold separately from the underlying physical electricity associated with a renewable-based generation source.

Sell-All: A billing/interconnection arrangement to sell-all of the production of a renewable energy facility to another entity, generally the local electric utility (see section 4 for more).

Site Energy Intensity: A measure of the energy efficiency of a building, defined in terms of annual energy used at the site (usually in kBtu) per area of conditioned building floor space (usually in ft^2).

Source Energy Intensity: A measure of the energy efficiency of a building, defined in terms of annual energy required at the source of energy (e.g. energy in the coal or gas used to generate the electricity used in the building) to provide the building with its energy needs. Usually in terms of kBtu per area of conditioned building floor space (usually in ft^2).

Solar Renewable Energy Certificate (SREC): A REC produced by solar energy.

Standby Charges: Charges levied by utilities on a distributed generation system, such as an on-site combined heat and power (CHP) system or solar PV, to cover a utility's costs to be prepared to provide power in the event that the distributed generation system experiences a scheduled or emergency outage and then must rely on power purchased from the grid.

Third-Party Owned: An ownership structure where an entity other than the energy end user or the local electric utility owns the renewable energy system. There are several common forms of third party ownership (see section 4 for more).

Time of Use Rate (TOU): The rate charged by an electric utility for service to various classes of customers during different times of the day.

Watt, kW, and MW: The International System of Units (SI) unit for power, which is a rate of energy transfer/conversion. The unit is defined as joule per second and can be used to express the rate of energy conversion or transfer with respect to time. One watt is small in today's modern world, so kilowatts (1 kW = 1,000 W) or megawatts (1 MW = 1,000,000 W) are often used.

Watts/ft^2: The units used to describe the power density of a solar PV panel or array. The watts refer to the peak power generation from the module or array at standard testing conditions (STC), which represents near ideal solar generation conditions.

Virtual Net Metering: A net metering arrangement that allows excess net metering credits produced by a solar system to be allocated to multiple on- or off-site electricity accounts.

Utility-Scale PV: Large scale solar PV, larger than residential, commercial, and industrial PV. Generally a ground-mounted system. There is no single definition for the minimum PV AC capacity of a utility-scale system, but 1-MW, 2-MW, and 5-MW are the most common starting thresholds.

1. INTRODUCTION

Education is one of the most important investments our society can make in its future. An integral part of such investment is the infrastructure and the buildings where education takes place and the energy that it takes to operate them. That energy can come from either renewable or nonrenewable sources and can be a significant expense. Durham Public Schools (DPS) spent over $5.7 million on about 65,000,000 kWh of electricity last year. This represents almost 1.5% of the total DPS budget, or about $125 per student per year.

Investing in renewable energy systems on schools can bring many positive outcomes for schools, including[1]:

- **School and Student Reinvestment:** Energy costs are second only to personnel costs for K-12 operating budgets[2], so there is a significant potential for financial savings that can then be made available for reinvestment. Any reinvested savings could be spent more directly on students, increasing the value of per-pupil spending, which in 2014-2015 ranked North Carolina 46th in the country.[3]
- **Educational Opportunities**: Many of the careers of tomorrow require expertise in science, technology, engineering, and mathematics (STEM), yet many indicators show that U.S. students are falling behind in these subjects. On-site renewable energy systems offer many firsthand opportunities to teach STEM principles using real-world experiences and data. Additionally, learning about the renewable energy powering their school teaches tomorrow's leaders to better understand energy and where it comes from.
- **Economic Development**: The investments required to generate electricity with wind and solar systems create local jobs and save energy spending that largely goes to purchase out-of-state fuels. According to the North Carolina Sustainable Energy Association's 2014 North Carolina Clean Energy Industry Census, 450 firms working in solar energy employed over 4,300 solar energy workers in North Carolina.[4]
- **Environmental Protection:** Solar and wind energy systems do not emit pollution, and the energy they generate reduces the pollution released by existing coal and natural gas power plants. This results in cleaner air, soil, and water for the students and the rest of the community.
- **Community Resiliency and Emergency Response:** Schools often serve as community shelters in times of emergency, such as severe weather. The electric grid can be down in these emergency situations, making an on-site source of power extremely valuable. Although today's grid connected PV systems are generally not able to operate when the grid is down, there is an emerging trend of battery integration and thus power availability during grid outages.

This study seeks to explore ways for Durham Public Schools to maximize use of renewable electricity, which, as described later, is limited in this analysis to on-site solar energy and off-site solar or wind energy. DPS is North Carolina's 8th-largest school district. It employs 2,300 people, has 49 schools, and over 35,000 students. North Carolina is among the top three or four states in terms of installed solar capacity, indicating that our state has a robust solar industry. However, nearly all of this capacity is in the form of utility-scale ground-mounted PV systems, commonly referred to as solar farms. The policies and electricity rates in North Carolina have been

[1] Adapted from Brighter Maryland, A Study on Solar in Maryland Schools, The Solar Foundation, August 2015 www.thesolarfoundation.org/brighter-maryland-report/

[2] www3.epa.gov/statelocalclimate/documents/pdf/k-12_guide.pdf

[3] www.wral.com/nc-still-lags-in-teacher-pay-student-spending/14522762/

[4] http://c.ymcdn.com/sites/www.energync.org/resource/resmgr/Docs/2014census.pdf

sufficient to stimulate this large utility-scale PV market but have not been very successful in creating a robust commercial PV market.

There are two major aspects to this study--the technical feasibility and the economic feasibility of achieving 100% renewable electricity within DPS. Before starting any analysis, we reviewed other studies and schools' experiences related to renewable electricity use, with a focus on electricity generated from solar energy. We then began the examination of the technical feasibility by analyzing the energy usage at each school in the DPS district. Once a reasonable baseline for future electricity use was established, we then analyzed the physical potential for solar electricity production at each school. Next, we considered today's policies, costs, markets, and technologies in order to explain the schools' options to 'go solar.' Finally, where possible, we considered potential policy and market changes, and we show how these would affect the school district's solar options and their rewards. This analysis produced an economic comparison of the many possible options for DPS to acquire solar energy for the district while also showing the impacts of potential state policy changes and varying rates of utility cost escalations. It is our hope that this analysis provides enough information about renewable energy options for DPS decision-makers to begin closely considering short-term solar development options as well as long-term renewable electricity commitments.

2. Renewable Energy – Background, Trends, and Examples

North Carolina is among the leaders in solar installation in the quickly growing U.S. solar market. In 2014, over 40% of all new electrical generation capacity installed in the country was solar PV. That fraction is likely to be higher in 2015 and higher still in 2016. The more than 22 gigawatts (GW) of solar installed in the U.S. is a combination of ground-mounted utility-scale systems and roof-mounted residential and commercial systems. In 2014, North Carolina installed more solar capacity than any state other than California. Cumulatively, North Carolina currently has about one and a half GWs of solar capacity, ranking fourth among all states.

100% Renewable Energy and Electricity

School districts are not the only entities that are making plans to transition to 100% renewable energy. Stanford professor, Mark Jacobson, leads a team of researchers who have spent years studying the potential of powering 100% of our energy needs with renewable energy. Their most recent technical report provides a roadmap for how each of the 50 states can get to 100% renewable energy by 2050.[5] Their roadmap calls for swift action to achieve this long-term goal, including no fossil fuel power plants built after 2020. Greenpeace has been releasing the "Energy [R]evolution" report for a number of years that also maps out a path to 100% renewable energy by 2050.[6, 7]

The state of Hawaii recently passed legislation requiring 100% renewable electricity generation by 2045. In the last 10 years in Hawaii, renewables' share of electricity generation has grown from 10% to 20%, primarily through the installation of solar PV. About the same time, Vermont enacted a 75% renewable electricity requirement by 2031. Several Fortune 500 companies, including IKEA: 2020, Mars: 2040, Google, and Walmart, have committed to 100% renewable power; a few, such as the German software giant SAP have already achieved it.[8] Beyond long-term renewable energy pledges, many corporations and others are investing heavily in renewable energy systems, in particularly solar PV, at their facilities. Walmart, Costco, Kohl's, and Apple are the current leaders in renewable energy investments.[9] Additionally, numerous towns, cities, universities, and non-profits have committed to becoming 100% powered by renewables, such as Vancouver, British Columbia, Burlington, VT, and Georgetown, TX.[10] The U.S. Army has a net zero energy program that is working on making nine selected bases net zero energy by 2020.[11]

Renewable Energy at Schools

Renewable energy comes in several forms, including biogas, biodiesel, sunlight, wind, and hydropower. However, not all of these resources are equally clean or useful for meeting the energy needs of K-12 schools in general, or for K-12 schools in central North Carolina in particular. In fact, of this list, sunlight is the only feasible source of energy for Durham County. This location has plenty of sunshine, more than enough to meet all

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[5] http://web.stanford.edu/group/efmh/jacobson/Articles/I/USStatesWWS.pdf

[6] www.greenpeace.org/international/en/publications/Campaign-reports/Climate-Reports/Energy-Revolution-2015/

[7] http://motherboard.vice.com/read/guess-who-accurately-predicted-the-explosion-of-the-clean-energy-market

[8] http://there100.org/

[9] www.seia.org/research-resources/solar-means-business-report

[10] www.theclimategroup.org/_assets/files/Unlocking-Ambition-Brochure---Final-NM.pdf

[11] www.nrel.gov/docs/fy14osti/60992.pdf

electricity needs, and as described in Section 4, PV is the best type of energy system for an existing school. In new school construction, PV should be used along with daylighting.

Solar PV on schools has been gaining the attention of people across the country in recent years. In late 2014, The Solar Foundation released a report entitled *Brighter Future: A Study on Solar in U.S. Schools*[12] and a follow-up report on the possibilities for solar on schools in Maryland entitled: *Brighter Maryland: A Study On Solar In Maryland Schools.*[13] Also, a group called the National Solar Schools Consortium has several goals for solar on schools by 2020, including 20,000 solar installations at schools and universities.[14]

There are numerous examples of schools installing solar across the country. For example, a small school district in Crawfordsville, Iowa is currently installing its second solar system to reach its "100% Solar Goal." The PV systems are saving the school money each month, freeing up funds for reinvestment in the schools.[15] An example of a solar school that uses a combination of rooftop and ground-mounted solar PV systems is Duplin High School in Duplin, GA (Figure 1).

Figure 1: The Approximately 1-MW System at Duplin High School, Duplin, GA (Photo: Greenavations Power)

[12] www.thesolarfoundation.org/brighter-future-a-study-on-solar-in-us-schools/
[13] www.thesolarfoundation.org/brighter-maryland-report/
[14] www.solarschools2020.org/about-the-consortium.html
[15] www.kcrg.com/subject/news/iowas-first-fully-solar-powered-school-district-should-happen-this-summer-20150602

Three schools in North Carolina announced the opening of net-positive energy schools that produce more energy than they use each year. The oldest of the three is Sandy Grove in Hoke County.[16] When Sandy Grove opened in August 2013, it was publicized to be the "first net positive energy, LEED platinum designed, leased public school" in the country. The facility includes 2,300 solar panels, which generate more power than the 76,000 square foot school consumes; a geothermal system that uses ground temperature as a moderate-temperature heat sink; energy-efficient heating, ventilation and air conditioning (HVAC); and LED lighting. Two new net-positive solar schools in Wayne Co., Grantham Middle School and Spring Creek Middle School[17], were recently completed.

Figure 2: Solar PV on the Roof of Sandy Grove Elementary, in Lumber Bridge, NC (Photo: SfL+a Architects)

Numerous school districts in California are installing large PV systems on one or more schools in their district. Often these schools are choosing parking lot shade structures to hold the panels rather than racks on the school roof due to the simplicity and shading benefits of these systems and to avoid the costs and scheduling limitations of planning around re-roofing projects. A driver of the development of these solar PV systems at schools is the significant economic savings to the school district, made possible by the high electricity costs and solar-friendly policy in CA.

Nearly two megawatts of aggregated solar capacity for the Santa Clara Unified School District (CA) have been installed at the Santa Clara High School, Wilcox High School, Buchser Middle School, Peterson Middle School, and Wilson Education Options Campuses, much of it on parking lot shade structures (Figure 3).

[16] http://sges.hcs.k12.nc.us/ and http://sges.hcs.k12.nc.us/ and http://thejournal.com/articles/2015/07/30/nc-middle-school-sets-bar-for-k12-energy-efficiency.aspx

[17] www.metconnc.com/news/wayne-county-public-schools-celebrates-final-solar-panel-installation-grantham-spring-creek-middle-schools-wednesday-may-20th/

Figure 3: Example Parking Lot PV Shade Structures at a School in the Santa Clara Unified School District in California (Photo: Borrego Solar)

As seen in Figure 2 and Figure 4, an on-site ground-mounted PV systems is an option for some schools. Where adequate unused land is available, these systems can often supply as much energy as the school needs and do so for a lower cost than a rooftop or parking lot PV system. Therefore, these systems should be strongly considered as an option for schools where there is appropriate land, however few DPS schools appear to have land available for such a system. Off-site solar systems are also a possible source of renewable energy through retirement of the renewable energy certificates (RECs) that they generate. With policy changes, third party energy sales coupled with net metering could be a viable low cost option.

Figure 4: A 796 kW System at Colonel Richardson Middle and High Schools, Caroline County, Maryland (Photo: Caroline County Public Schools)

Plymouth Public Schools in Plymouth, Massachusetts has 13 schools serving over 8,000 students. The school district contracted with a solar company to install a 10-MW solar farm that is virtually net metered to their schools, offsetting a significant portion of their electricity needs[18]. The school district is purchasing the electricity under a 20-year power purchase agreement at a rate significantly below their utility retail rate. The solar

[18] http://borregosolar.com/solar-projects/education/plymouth-public-schools/

company is selling the Solar Renewable Energy Credits (SRECs) generated by the solar panels, meaning the school is reaping the financial benefits but cannot claim its environmental benefits[19]. The sale of SRECs is typical in these types of project arrangements, as the SRECs are an incentive designed to lower project costs when monetized.

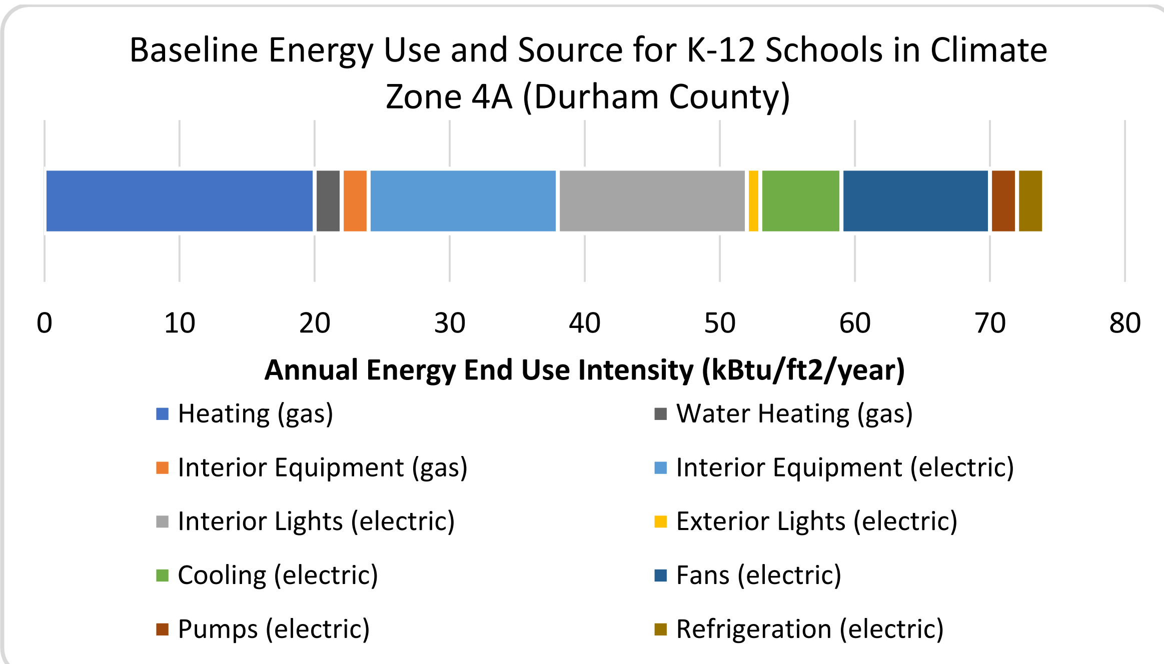
Figure 5: An Approximately 5-MW Solar Farm Virtually Net Metered with Plymouth Public Schools in Plymouth, MA (Photo: Borrego Solar)

[19] www.plymouth.k12.ma.us/page.cfm?p=3016

3. Energy Use and Efficiency

Energy Use and Energy Efficiency

Like most buildings, schools use a lot of energy. Also like other buildings, there is a wide variety of energy efficiency initiatives among school districts and individual schools. The energy use intensity of schools (aka energy efficiency) is measured in either site or source energy use per square foot of conditioned building floor space. Site energy is all of the energy used at the site of the school, primarily natural gas (used for space and water heating) and electricity (used for everything else). Source energy is the amount of energy needed to supply the site energy, such as the energy in the coal or natural gas used to generate the electricity. Because the average central electric generation plant is about 33% efficient, a school's source energy use is much greater than its site energy use. Before we examine the potential to produce renewable electricity, it only makes sense to examine how and how much energy these schools are using.



Source: ASHRAE Advanced Energy Design Guide for K-12 School Building, 2014 Update

Figure 6: Baseline Energy End Use Intensity Estimates for a Generic K-12 School

Figure 6 shows the estimated annual energy end use (aka site energy) and energy type (natural gas or electricity) for K-12 schools in climate zone 4A (which includes Durham County) and agrees well with the natural gas and electricity usage data collected by DPS. This American Society of Heating, Refrigeration, and Air Conditioning Engineers (ASHRAE) model predicts a site energy intensity of 74 kBtu/ft^2/year, which is a little more than 10% higher than the average of 67 kBtu/ft^2/year in the data provided by Durham Public Schools. The model predicts 24 kBtu/ft^2/year of natural gas usage (38% of total estimated energy), and the Durham data showed 25 kBtu/ft^2/year (38% of total energy use). The presented ASHRAE energy use breakdown is further validated by examination of the EPA Energy Star Building Manual chapter on K-12 School Facilities, which provides a similar energy use breakdown for K-12 schools.[20]

The ASHRAE publication that contains the above end use estimates is their Advanced Energy Design Guides for K-12 School Buildings. The most recent version, published in 2011 and updated in 2014, is subtitled: *Achieving 50% Energy Savings Toward a Net Zero Energy Building.*[21] The subtitle of this comprehensive guide on energy savings in school buildings underscores the value of reducing energy use when seeking a net zero (100% renewable electricity) energy building. As described in this guide, there are often significant energy saving actions that can result in a better economic investment than adding renewable energy. Thus, these energy saving actions should logically be completed before adding renewable energy.

STATUS AND OPPORTUNITIES IN DURHAM PUBLIC SCHOOLS

There are many energy saving changes and improvements that can be made at little or no net cost in new and existing buildings. These improvements, along with behavior-based changes, are the most cost effective way to reduce the non-renewable energy consumption of a building. In addition, any electricity not consumed will always be environmentally superior to even the cleanest renewable sources. A roadmap to energy efficiency improvements is beyond the scope of this report, but we will briefly explore some of the energy saving successes and possibilities at Durham Public Schools. There are many great resources available to support energy savings in schools, including the ASHRAE guide mentioned above and several local architecture firms specializing in energy efficient and net zero energy schools.[22]

The Energy Star schools program uses an Energy Star score that takes into consideration the activities at that school, such as the number of computers as well as the local climate. As seen in Figure 7 and Figure 8, comparing the DPS average source energy intensity to national K-12 data can put into perspective the relative energy efficiency of DPS schools. Schools with a score over 75 can be certified as an Energy Star school. DPS has completed many energy efficiency measures including lighting upgrades, daylighting, lighting controls, and more, but they still have many more energy efficiency projects planned.

[20] www.energystar.gov/ia/business/EPA_BUM_CH10_Schools.pdf

[21] www.ashrae.org/standards-research--technology/advanced-energy-design-guides/50-percent-aedg-free-download

[22] Sfl+a Architects: www.sfla.biz/work/k12/, Innovative Design: www.innovativedesign.net/Projects-K-12.html

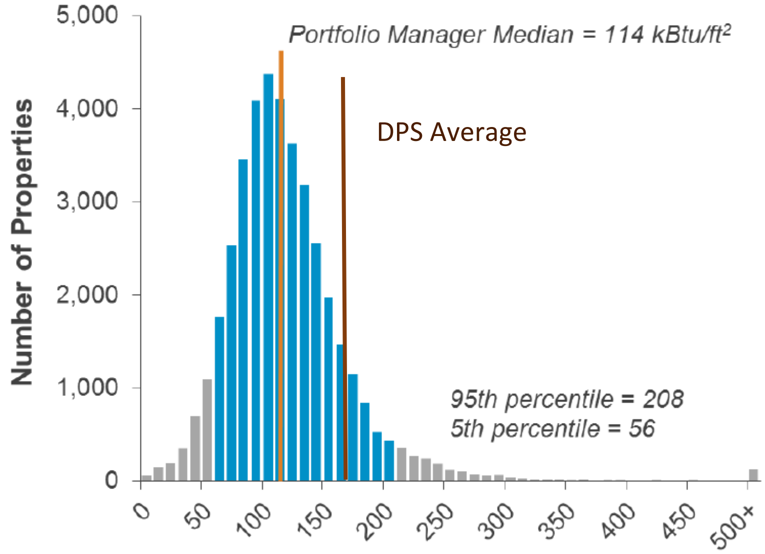


Figure 7: Spread of Source Energy Intensity (kBtu/ft²) of US K-12 Schools. According to DPS data, the district has a source energy intensity of 156 kBtu/ft², which is significantly above the national K-12 average of 114 kBtu/ft²

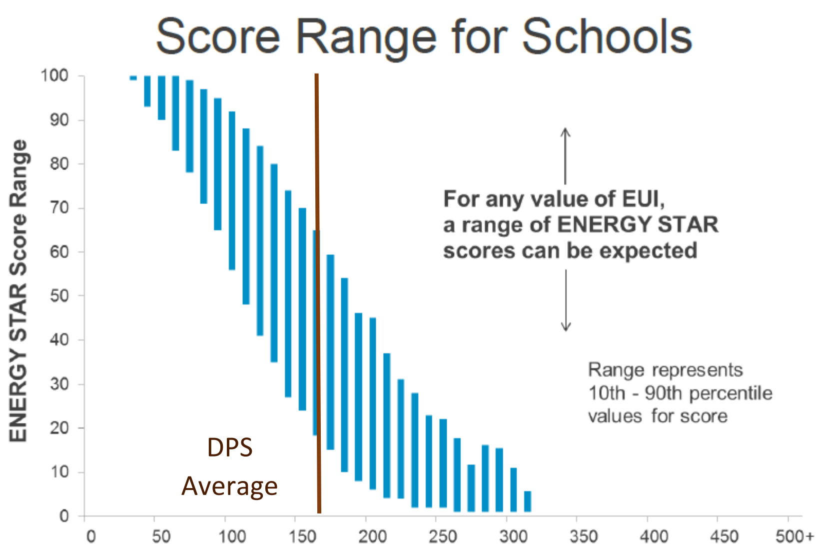


Figure 8: ENERGY STAR Score Range by Source Energy Intensity. Nationally, the middle eighty percent of schools with a source energy intensity of the average DPS school (156 kBtu/ft²) have ENERGY STAR Scores of about 20 to 65 (out of 100)

An example of another North Carolina school district having great success reducing its energy usage is Nash-Rocky Mount Public Schools (NRMPS), whose efforts have led to a 26% energy use reduction and utility savings of $11,284,000 over the past ten-year period.[23] Most of the Nash-Rocky Mount savings came from physical improvements to the schools, but it is also possible to achieve significant savings with behavior-based improvements. A report by the Center for Green Schools highlighted case studies of five U.S. schools that saved 20% to 37% of their annual energy usage with just behavior-based improvements.[24] A simple and powerful example of an intervention is raising awareness among faculty, staff and students about energy-saving

[23] www.ednc.org/2015/09/22/common-sense-energy/

[24] www.centerforgreenschools.org/sites/default/files/resource-files/Behavior-based-Efficiency.pdf

opportunities such as ensuring that lights are turned off in unoccupied rooms and that electronic equipment is put to sleep or turned off when not in use. In 2011, Cumberland County Schools participated in a Sustainable Sandhill's initiative to reduce their schools' energy use through conservation, and several participating schools achieved year over year savings of 14% to 23%.[25]

While Durham Public Schools has achieved some energy savings with recent energy efficiency (EE) upgrades, we are confident that there are significant economically-viable energy efficiency improvements still available, including behavior-based improvements. While even greater savings are certainly possible with adequate resources and leadership, our renewable energy analysis conservatively assumes that on average the schools will reduce their site energy use per square foot by 25% of their 2014 energy usage via a combination of behavior-based improvements and physical improvements. Our estimate is based on several things: (1) comparison of DPS site energy intensity to North Carolina and national schools, (2) interviews with DPS facility energy staff, (3) literature on energy savings potential in K-12 schools. For simplicity, this 25% reduction to the past usage data is applied evenly to each school, although in practice it is likely that some schools will be able to make much greater savings than others. This new, reduced usage is considered to stay constant for future years and is referred to as the post-EE electricity usage.

[25] www.ednc.org/2015/09/22/powered-schools-spotlight-cumberland-county/

4. 100% Renewable Energy for the School District

Definitions and Considerations

In order to explain the key issues in defining and achieving 100% renewable energy, consider the following ways to approach these topics.

100% Energy or 100% Electricity: The focus of this study is 100% renewable electricity. However to help put that into context, 100% energy will be briefly explored. Currently, site energy use at DPS school buildings comes in two primary forms, natural gas and on-grid electricity. At DPS, on average, about one third (ranging from 0% to 54%) of the energy use at each school is in the form of natural gas, primarily for space heating. Therefore, a goal of 100% renewable energy would require about 50% more renewable energy generation than a 100% renewable electricity goal. The use of both electricity and natural gas generally occurs because this is the most economical way to meet a building's energy needs. There are renewable energy options to directly offset natural gas usage, such as methane from landfills, hog waste, or on-site small-scale bio-digesters, but the ability to store and transport these fuels is limited, making the feasibility of them limited and very site dependent. Currently natural gas is a very cost effective source of heating fuel, but there are also very efficient and cost effective electricity-powered heating options such as air-source or ground-source heat pumps that can move space heating loads from natural gas to electricity. An example of how to achieve 100% renewable energy is the Stanford University study, which lays out plans for 100% renewable energy for each state in the country. These plans call for converting all space heating, space cooling, and water heating loads and many transportation loads to electricity. The plans use electricity from wind, concentrated solar power (CSP), geothermal, solar PV, tidal, wave, and hydroelectric power to meet 100% of the total energy needs.[26] A final option for the current natural gas usage to meet a 100% renewable energy goal is to offset each Btu of natural gas usage with a Btu (equal to about one third of a watt-hour) of solar electricity put on the local electric grid. This option still results in natural gas use at the school and thus might not be accepted as meeting at 100% renewable energy goal.

School-Level or District-Level Metric: A 100% renewable energy/electricity goal could be applied at either the school-level or the district-level, meaning that each and every school is 100% renewable, or when all schools are grouped together, as occurs naturally at the school district level, they are 100% renewable as a group. Section 6 assesses the technical on-site possibility at the school-level, and thus also at the district-level. Sections 8 and 9 evaluate the economics and finance of PV projects for DPS and considers options both at the school and district levels.

On-Grid or Off-Grid: The electric grid is often called the greatest engineering achievement of the 20th century. It is very big and complex, and it reliably meets the electricity demands of millions of consumers. A PV system connected to the grid is called an on-grid system, and it takes advantage of the size and flexibility of the grid, avoiding the need to be a self-contained system responsible for meeting a changing and unpredictable 24-hour demand. An on-grid PV system can achieve 100% renewable electricity, also called net zero energy**,** by producing the same amount of energy used on an annual basis. Such a system is likely not to be 100% renewable every month, or even every season, but does achieve 100% renewable by the completion of the year. The alternative to an on-grid system is an off-grid system, which does not have access to the benefits of the grid. An off-grid system must contain both energy generation and energy storage so that there is always energy available whenever it is demanded. While the technology exists to create successful off-grid PV and battery systems, they

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[26] http://web.stanford.edu/group/efmh/jacobson/Articles/I/USStatesWWS.pdf

are not currently economic for a large varying load such as a school. Off-grid systems are common where the grid is not available or the loads are small and consistent. Only on-grid systems are considered in this study.

On-Site or Off-Site: Because of the connected nature of the electric grid, it is technically possible for a school or other building to use solar energy from a PV system installed on-site or off-site. The grid can be thought of as a large pool of energy, such that energy put into that pool from any point is equivalent to energy put into the pool somewhere else. When pulling energy from the pool, it is impossible to tell the source of that energy. This metaphor works well for generation close to the site of use, but the further apart the source and the end user are, the less apt the metaphor. It would be technically possible, for example, for DPS to use energy from an off-site system in Georgia, but this energy has many 'locks and dams' to cross before finding its way to North Carolina. The focus of the technical study is on-site solar, which is found to be capable of achieving net zero energy status for the vast majority of DPS schools. Off-site renewable electricity generation from within North Carolina may also be considered as an option to meet a 100% renewable electricity goal. This could be in the form of a solar farm (a ground-mounted PV system, usually over 2-MW) owned by the school and selling its production to the electric utility. If third party energy sales become available, the school could sign a power purchase agreement (PPA) with the owner of a solar PV or wind system. If the net metering capacity limit is increased and the project is adjacent to the school, or virtual net metering becomes available, the purchased energy could be net metered by the school; otherwise the school would have to sell all the generation to the local electric utility.

Net Metered (Direct Use) or Sell-All to the Utility: A net-metered system directly serves the loads of the building, but at times of excess production, which are common during the day, the excess solar electricity is sent to the grid for use by other customers with demand at that moment. The PV system owner is given credit for any excess electricity sent to the grid by turning the meter backwards as energy flows back onto the grid. The use of the grid in net-metered arrangements can result in a stand-by charge where the utility is able to set a fixed charge to cover a utility's costs to be prepared to provide power that is sometimes provided by the renewable energy generator. A sell-all to the utility, on-site solar system sends all of its production to the grid for use by customers with demand at that moment, and because the school is the closest customer, with the path of least resistance, the majority of that energy would go to serve the school's loads. In both cases, the solar-generated energy is going to the same places at the same times. The key distinction is that with net metering the school owns the energy and with sell-all the utility owns the energy (until some of it is purchased from the pool of grid electricity at retail rates for use at the school). In both cases, RECs are used to help clarify the potentially confusing distinctions between energy usage, solar energy generation, and solar energy usage/ownership.

Renewable Energy Credits (RECs): RECs are tradable, non-tangible energy commodities that represent proof that one megawatt-hour (MWh) of electricity was generated from an eligible renewable energy resource. These certificates can be sold, traded, or bartered separately from commodity electricity. When the REC owner "retires" one REC, he/she can claim to have generated/used one MWh of renewable energy. According to the U.S. Department of Energy's Green Power Network, even with a net-metered PV system that is directly supplying the loads of the building, if the RECs generated by the PV system are sold rather than retired by the building owner, the building cannot legally claim to be powered by solar energy. In many states, including North Carolina, it is common for PV systems to sell the RECs that they generate to the electric utility in order to increase the solar system's cash flow. In this case, the school and the local community can still reap many of the benefits of the PV system but cannot claim solar energy generation or use. The utility then retires these RECs, counting them toward its state-mandated renewable energy requirements in the state renewable portfolio standard (RPS). In this case, the PV system owners have sold away their right to claim generation or use of solar or renewable energy. Therefore, whether or not the solar system is on-site or off-site, net metered or sell-all, school-owned or third-party owned, the RECs must be retired by the school in order for the school to claim it is powered by renewable electricity. In September 2015, the Center for Resource Solutions published an "Issue Brief" that offers additional exploration of RECs and renewable energy-powered claims.[27]

School-Owned or Third-Party Owned: As discussed in the economic section of this report, renewable energy systems may be site-owned (school-owned) or third-party owned (e.g. solar developer, solar investors, school donors, electric utility). The tax and economic implications of these two options are at the core of the economic drivers of the project. However, either can provide renewable electricity to the school as long as the school retires the RECs that the systems generate. Under current North Carolina utility regulations, a third-party owned PV system may only sell its energy to the electric utility. In many states, the third-party system owner is allowed to sell the solar electricity it produces directly to the electricity end user (e.g. DPS) who is able to then net meter the purchased solar energy. The terms and conditions of this sale of electricity to either the utility or the end user are defined in a power purchase agreement (PPA). A PPA is a contract between an electricity generator (the seller) and the electricity purchaser. The PPA defines all of the commercial terms for the sale of electricity between the two parties, including when the project will begin commercial operation, schedule for delivery of electricity, penalties for under delivery, payment terms, and termination. An additional option in North Carolina today is a green power option *Green Source Rider* offered by Duke Energy that makes renewable energy available to large energy customers that are building a new facility or significantly expanding an existing facility. The first application of this pilot tariff was signed just before publication of this report in December 2015. In this initial use of the tariff, Google agreed to purchase the output of a 61-MW solar farm to provide renewable electricity to its data center in Lenoir, North Carolina.[28]

Roof-Mounted, Parking Lot-Mounted, or Ground-Mounted: Other than slight differences in their electricity generation performance, there is no difference in the electricity produced by PV systems mounted on either a school's roof, parking lot, or on the ground. There are significant differences in the cost of each type of system, with ground-mount generally being the cheapest and parking lot mount being the most expensive. There are also logistical differences in the systems, such as roof warranty impacts, car shading benefits, and ease of access.

Leasing Options: Leasing as it applies to commercial scale solar PV can refer to several different concepts: (1) roof lease, (2) capital lease, or (3) operating lease. The first two types of leases are allowed in North Carolina, but the third is not allowed because operating leases function so similar to a third party sale of electricity. North Carolina has seen some examples of roof leases, including a Duke Energy solar power initiative launched 2009 in which Duke Energy leased commercial rooftops in order to install solar PV systems on them. This demonstration program installed 10-MW of PV on 25 leased roofs, including one school in Gaston County. Due to the significantly lower construction cost and the economies of scale advantages of large ground-mounted systems, developers of large solar PV projects prefer undeveloped land to commercial rooftops, resulting in little to no demand for leasable commercial roof space. Capital leases are used as a financing mechanism for commercial PV systems in North Carolina. In a capital lease, the solar customer has control over the asset and is entitled to the benefits and the risks of economic ownership, which includes tax credits and depreciation.

[27] www.resource-solutions.org/pub_pdfs/Guidelines%20for%20Renewable%20Energy%20Claims.pdf
[28] www.bizjournals.com/charlotte/blog/energy/2015/11/google-taps-duke-energy-pilot-program-to-provide.html

POSSIBLE SOURCES OF RENEWABLE ENERGY FOR DPS

As previously discussed, there are several forms of renewable energy, but very few of them are feasible for use by DPS. Biomass, such as wood, biogas, and biodiesel, get their energy from the sunlight used to grow plants, however converting them into electricity for use at a school is complicated, difficult, costly, and polluting. Hydropower and wind energy resources are site specific and unfortunately, central North Carolina does not have enough elevation change or wind for either of these technologies to be economically feasible for use by schools.

There are several uses for the energy in sunlight, including several that do not directly involve electricity, including; daylighting, heating water, and generating electricity. Daylighting, the practice of placing windows or other openings and reflective surfaces so that during the day natural light provides effective internal lighting, in schools is an excellent use of solar energy and can play a major role in reducing the electricity needs in a school, while also improving the learning environment. As such, daylighting should be strongly considered in any new construction and even considered as a retrofit option when reroofing existing schools. Solar water heating systems are very efficient collectors of solar energy but cannot compete economically with today's natural gas prices, and therefore are not included as an option in the study.

The third option, and the focus of this study, is solar electric, or photovoltaics (PV), which generates electricity from solar panels, also known as solar modules. PV's greatest value is the simplicity, durability, and the versatility of the electricity it produces. They do not need to be located above a certain room or provide an output that must be timed in coordination with its use. Rather, the energy they produce can be sent across the school and excess can be sold to the utility for use by the school's non-solar-powered neighbors.

Off-Site Wind Power is an additional option that could be considered as a source of renewable electricity for DPS. As a global industry, wind power is more mature than solar power, however, locally commercial scale wind is just starting to break ground on its first project in North Carolina. Due to the lack of projects in-state and in-region, wind energy options are not investigated in detail in this study. There is significant wind energy potential along the coast, on- and off-shore, and along the mountain ridges of North Carolina. The off-shore wind resource is very large. According to a 2012 National Renewable Energy Laboratory (NREL) study, North Carolina has the largest technical potential for offshore wind generation capacity along the east coast, with a capacity of over 300 GW.[29] However since DPS is at least 100 miles from any of these potential sites for large scale wind power, and there are currently no mechanisms for DPS to purchase and use off-site wind electricity, wind power is not a viable near-term consideration at this time. The cost of electricity from large-scale wind is currently one of the lowest cost sources of electricity, renewable or nonrenewable, making off-site wind power a potential future source of renewable electricity for DPS if long-distance purchasing mechanisms become available. In 2015, the first off-shore wind lease areas were opened, making it possible to begin development of this valuable resource.

RENEWABLE ENERGY OPTIONS FOR DPS

Based on the system definitions provided above, the possible sources of renewable energy for Durham Public Schools can be grouped into the following seven project types, listed in approximate declining order of direct connection between the renewable energy generation and its use by the school. Of these seven technically feasible options, the three third party energy sales options (labeled as PPA) in the list are currently not legally possible in North Carolina.

[29] NREL, U.S. Renewable Energy Technical Potentials: A GIS-Based Analysis, www.nrel.gov/docs/fy12osti/51946.pdf

Option	System	Billing Inter-connection	Owner	Retire RECs[31]	Pros	Cons	Summary
Direct Ownership, Net Meter	On-site Solar	Net Meter	School	NO unless on financially unattractive demand-TOU rate	Simple, school-owned, offsets retail electric rate	No tax benefits, no RECs today without unwanted tariff, currently limited to less than 100% load, standby charges	Limited attractiveness today due to lack of access to tax credits & RECs, becomes more attractive without standby charges and REC ownership on any rate schedule.
On-Site Power Purchase Agreement (PPA), Net Meter	On-site Solar	Net Meter with PPA between 3rd Party Owner and School	3rd Party	NO unless on financially unattractive demand-TOU rate	Very simple, uses tax benefits, no upfront cost, offsets retail rates	Not currently available in NC, currently limited to less than 100% load, standby charges	Very attractive but not currently available in NC, more attractive with more solar-friendly net metering rules
Direct Ownership, Sell All	On-site Solar	Sell All to Utility	School	YES keep RECs	Keep RECs, size for 100%+ of annual load, school-owned	No tax benefits, electricity valued at less than retail rate	Not attractive due to lack of access to tax benefits & being valued at less than retail rate
PPA, Sell All	On-site Solar	PPA to School, then Sell All to Utility	3rd Party	YES buy RECs and energy	Access to RECs, no upfront cost, uses tax benefits	Energy valued at less than retail rate	Not currently available in NC, not as attractive as PPA with net metering
Partnership Flip (3rd Party Investor, Sell All)	On-Site Solar or Off-site Solar/ Wind (NC)	Sell All to Utility	School and 3rd Party	YES	Access to RECs, can flip ownership to school after 6 years, potential to be a positive-return investment, little or no upfront cost, may avoid income tax on revenue starting in year 7	Administratively burdensome to develop, energy valued at less than retail rate, capital investment	Potentially economically attractive to both school & 3rd party, especially if the school provides low cost investment via bond
Off-Site PPA, Virtual Net Meter	Off-site Solar/ Wind (NC)	PPA between 3rd Party Owner and School	3rd Party	YES buy RECs and energy	Access to RECs, simple large low-cost projects, potential to provide savings	Not currently available in NC	Not currently available in NC
Renewable Energy Credit (REC) Purchase	Off-site Solar or Wind (NC)	Sell All to Utility	3rd Party	YES buy RECs	Simple, single agreement could cover many schools	No chance for positive return, additional expense beyond the purchase of all energy from utility, provides questionable environmental value[32]	Contract to purchase RECs, simple & quick way to acquire RECs, no on-site energy use, no chance for direct financial return

Table 1: Summary of Possible Solar Financing Options for DPS School District [30] [31]

[30] Renewable Energy Credits (RECs The) must be retired by the school district for their electricity to be considered renewable
[31] www.closedloopadvisors.com/greenpowertrap/

5. POLICY ENVIRONMENT

Renewable energy development, including solar, is driven by a combination of technical, economic, and political factors. As evidenced by the success of the solar market in North Carolina, the policy landscape is often the differentiating factor among markets, clearly indicating its importance. North Carolina has an average amount of sunshine and low to moderate electricity prices, but we have had some policies that are very attractive to utility-scale solar photovoltaic projects, especially 5 to 20-MW systems, as evidenced by the over 1,500 GW of PV capacity installed in the state by the end of 2015. In contrast, the very small amount of commercial scale PV development is a strong indicator that the state market is not ripe for making such systems financially attractive.

Current renewable energy policies available in North Carolina include: tax incentives (30% federal investment tax credit and accelerated 5-year state and federal depreciation), a state renewable portfolio standard (RPS), state-wide net energy metering, a standardized interconnection process, and a requirement for utilities to offer a fairly priced sell-all 15-year power purchase agreement (PPA) for projects up to 5-MW_{AC}.

However, some of these North Carolina regulations are not particularly friendly for the solar customer, as compared to similar polices in other states. All of these policies interact with one another, which can also determine their applicability and impact on financing commercial-scale installations at schools or utility-scale projects offsite. Below we review the current conditions for these policies and their impact on school solar installations. The economic analysis later in this report helps illustrate the financial impacts of more solar-friendly policies.

Net Metering

The net metering policy has a few significant shortcomings as it applies to a school interested in taking advantage of this simple and intuitive interconnection billing scheme. *Freeing the Grid* grades North Carolina's net metering policies as a "C".[32] The following aspects of the net metering policy of the electric utilities serving DPS are hurdles for its widespread use by schools:

- **REC Ownership Defaults to Utility**: The utility owns the RECs unless the customer chooses to net meter under a demand, time-of-use tariff (demand-TOU), which means that the school's electricity bill is structured such that it pays a monthly demand charge based on the peak amount of power draw during the month and it pays different rates for each kWh of electricity depending on the time of the electricity use, generally divided between on-peak and off-peak times. For schools, which are most active during the day when peak energy rates apply, it is very unlikely for a time-of-use tariff to offer a lower total cost of electricity. In fact, an analysis conducted for this report found that the time-of-use tariff available to DPS (DEC-OPTV) would result in little to no savings for the typical school, even with a PV system capable of producing 100% of its annual electricity. This is a major barrier to any customer, such as DPS, that desires to retire the RECs produced by their PV systems, because the only economically feasible net metering option results in the electricity utility owning/retiring the RECs, not the customer (see Section 4 for more information on the importance of REC retirement for renewable energy projects).

- **No Annual Carryover of Net Excess Generation**: Monthly net excess generation is credited to the customer's next bill at the retail rate each month only until the end of May each year, at which point any net excess generation is granted to the utility with no compensation to the solar system owner. Due to annual fluctuations in solar energy available and total electricity use, it is impossible to design and install

[32] http://freeingthegrid.org/state-grades/north-carolina/

a solar system that on average provides 100% of the annual energy needs of the facility without risking giving away 10-20% of its production in some years. Some other states' net metering policies allow any monthly net excess generation to carry forward indefinitely, or they provide payout of any net excess generation at either retail or wholesale rates at the end of the year. Either of these policies allow a PV system to be designed to economically meet 100% of the annual load, rather than being limited to a design that meets 80% or 90% of annual load with the current North Carolina net metering policy.

- **No Meter Aggregation**: North Carolina net metering is limited to connecting one solar PV system to one utility service meter. However, the most solar-friendly practice is to allow meter aggregation, allowing one solar system to net meter against a group of meters, as commonly exists at many non-residential sites, including schools. Without a meter aggregation policy, designing and installing net-metered systems to match up to each of the several meters across a typical school's campus adds costly complexity and inefficiencies. The best practice is to not only allow meter aggregation across meters at a single site, but to also allow meter aggregation across all of a customer's meters across a utility's territory, called **virtual net metering**. Such a policy would be very attractive to a school district interested in pursuing a 100% renewable electricity goal, because it would allow development of sites most physically suited for solar, without limiting those sites to the net metering limits of the meter(s) at that property.

- **Standby Charges**: Duke Energy Carolinas' customers with PV systems over 100 kW are required to pay a monthly standby charge of $1.16/kW of PV capacity, which is equivalent to a charge of $0.010/kWh for all of the electricity generated by the PV system. A standby charge is a charge paid by an electric utility customer who is served in part by on-site generation and in part by services delivered through the electric grid. Such customers pay standby charges so that in the event of an outage of the customer's on-site generator, either planned or unplanned, the customer has the guaranteed ability and the right to purchase power to replace what would normally be self-generated. Standby charges for photovoltaic systems are often contentious because the PV supplies benefits to the grid that are generally not accounted for in the standby charge rate.[33] A lower standby charge rate would significantly improve the economic attractiveness of net-metered solar installations at schools.

- **1-MW Size Limit**: While not a significant limitation for DPS schools looking to net meter their school's energy, this limit would become a more significant limitation if meter aggregation (i.e. virtual net metering) were available and the best solar sites wanted to net meter against an aggregation of DPS meters, or if the school district would like to develop a larger ground-mounted PV system off-site and net meter it against one or more nearby schools.

- **PEMC Net Metering Limitations and Charges**: Two DPS schools receive their electricity service from Piedmont Electric Membership Corporation (PEMC), a rural membership cooperative electric utility. They are not regulated by the North Carolina State Utilities Commission, so therefore PEMC does not have to follow the state net metering rules or offer net metering at all. They do, however, offer net metering, but it is of limited value to DPS because it only applies to PV systems of 200 kW or less. Additionally, customers must pay a standby charge of $1.75/kW/month.

[33] www.michigan.gov/documents/energy/NRRI_Electric_Standby_Rates_419831_7.pdf

Avoided Cost

Sell-all arrangements in North Carolina are standardized with a defined avoided cost rate for utilities to compensate solar generation. For projects up to 5-MW_{AC} that are interconnected using a sell-all arrangement, there is a set avoided cost rate that is fixed over a 15 year period. This rate is comprised of two components that vary by the season and time of day. When these components are applied to the typical solar PV annual generation profile result in an effective average rate of about 6.5 cents/kWh, which is generally 20% to 40% lower than the commercial or residential retail rate. The avoided cost rate is evaluated and updated every two years by the North Carolina Utilities Commission. New rates are expected to be published in early 2016. Based on the avoided cost calculations submitted by the utilities in this process, it is possible that the updated rate could be up to one cent/kWh lower than the current rates.

Interconnection

North Carolina's interconnection process is fairly solar-friendly but has some room for improvements. *Freeing the Grid* grades North Carolina's interconnection policies as a "B".[34]

- **Possible Utility Interconnection Fees for PV Systems Larger than the Meter's Recent Peak Demand**: While not a part of the net metering policy, there is an additional limitation that is reported to often limit the economically feasible size of a net-metered PV system. Duke Energy Carolinas often requires significant upgrades to Duke's facilities/equipment when a customer applies to net meter a PV system larger than their recent peak energy demand. In many cases, these upgrade charges (which are the responsibility of the interconnection customer per state interconnection rules) are large enough to make a system that is larger than the current peak demand uneconomical. Based on our analysis of full billing details for ten randomly selected schools in the DPS district, we estimate that the capacity of a PV system to meet the post-EE annual electricity use is roughly 50% larger than the current peak demand. Thus at most DPS schools, Duke Energy Carolinas is likely to have grounds to require upgrade charges for interconnection of on-site PV systems large enough to meet the school's post-EE annual electricity usage.

- **Interconnection Delays:** Currently, there are significant backlogs in the processes of interconnecting solar projects in North Carolina, especially projects over 2-MW_{AC}. The primary delay is in the completion of an engineering study required for each project to determine its impacts on the utility's system, if any facility upgrades are required to mitigate negative grid impacts, and what these upgrades would cost. Solar installations smaller than 2-MW_{AC} generally quality for a fast track interconnection process that avoids a detailed study and results in a much faster interconnection process. While not an official policy, this industry condition often makes it challenging for customers to be able to schedule when their PV projects will start construction or be online, and therefore what economic incentives will be applicable to their projects. In an attempt to improve and speed the interconnection process, the North Carolina Utilities Commission led updates to the North Carolina Interconnection standard that went into effect July 2015.[35] This update is expected to speed and improve the process, but so far it is difficult to quantify its impact.

[34] http://freeingthegrid.org/#state-grades/north-carolina

[35] DSIRE page on North Carolina Interconnection Standards: http://programs.dsireusa.org/system/program/detail/354

Third Party Sales and Tax Credits

An additional energy policy that has the potential to strongly impact the financial attractiveness of solar electricity for DPS is a policy known as third party energy sales. Third party energy sales are currently allowed in at least 25 states and are disallowed in just five states, including North Carolina.[36] This policy allows non-tax paying entities, such as DPS, to take advantage of economic incentives for renewable energy installations that they otherwise would not be able to access because of their non-profit status. See Section 8 for additional discussion.

- **Third Party Energy Sales:** Third party energy sales, also known as third party solar power purchase agreements (PPA), have been a major market driver in many of the largest and fasting growing residential and commercial solar state markets, such as California, Arizona, and Massachusetts. Many schools with large PV systems have done so with a third party energy sales contract.[37] Without this policy, a third party owned PV system on the property of a utility customer (such as a school) cannot sell the energy the PV or wind system generates to the end user of the electricity. Instead, the PV system's generation can only be sold to the local utility, which occurs at an 'avoided cost' rate approved by the North Carolina Utilities Commission that is generally 20% to 40% lower than the commercial or residential retail rate. Allowing third party solar energy sales in North Carolina would open up a new financially attractive option for North Carolina schools and many other non-profit and for-profit building owners. It is especially valuable to non-tax-paying entities, because it allows them to experience the economic benefits of investment tax credits.
- **State and Federal Tax Credit Expiration**: In 2015, the North Carolina legislature voted to not extend the 35% renewable energy tax credit that had been a major driver of solar installations in the state, allowing it to expire at the end of 2015. At the federal level, the 30% renewable energy investment tax credit was recently extended to 2019 and is scheduled to decrease to 10% by 2022. If third party energy sales were allowed in North Carolina, tax credits could play a significant role in changing the financial feasibility of a solar installation, because the third party owner would be able to realize those economic benefits to finance the project.

Conclusion

The policy landscape is a major factor influencing renewable energy installations. The types of policies in place can incentivize residential, commercial, or utility-scale installations differently. North Carolina has had strong legislation to support the construction of utility-scale PV systems, as evidenced by the 1,500 GW of PV capacity installed in North Carolina through 2015. However, North Carolina's current solar policy and market conditions do not create the same degree of economically attractive options for commercial-scale solar projects. Solar-friendly updates to the existing state net metering and interconnection regulations, as well as new legislation to allow third party energy sales and to reinstate the state tax credit, would significantly impact the economic feasibility for on-site solar powered schools.

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[36] http://ncsolarcen-prod.s3.amazonaws.com/wp-content/uploads/2015/08/3rd-Party-PPA_072015.pdf

[37] www.seia.org/research-resources/brighter-future-study-solar-us-schools-report

6. TECHNICAL ASSESSMENT OF SOLAR POTENTIAL ON SCHOOL PROPERTIES

This section evaluates the technical potential of Durham Public Schools to produce on-site solar electricity, primarily from the schools' rooftops and parking lots, at their 49 schools (see list and results in Appendix E: Results for All Schools). In addition to these on-site options, the school district also has some options for off-site siting of large ground-mounted solar facilities, which is explored further in the economic section of this report. While this technical assessment looks at the potential for each school to achieve 100% renewable electricity on-site, a transition to 100% renewable electricity does not necessarily need to happen through individual schools each going to 100%, but instead will likely include a combination of on-site school projects and off-site ground-mounted PV systems.

For the on-site assessment, we manually assessed a random sample of 20 of the 49 schools for their technical rooftop and parking lot shade structure solar PV capacity. This sample size was chosen, because it provides a 90% confidence that the average PV capacity (Watts) per square foot of building floor area of this sample is within 15% of the average PV capacity (Watts) per building square foot of the full population of DPS schools (see Appendix A: Sampling Calculations). Thus, the average finding from the manually-mapped sample of 20 schools is used to estimate the PV capacities possible at the 29 non-sampled schools. On average, the PV capacity estimates for the non-sampled schools should be within 15% of the actual average value, however due to the differences in schools, this average value will not be correct for each individual school (see Appendix A: Sampling Calculations).

Using satellite photos (Figure 9), and 3D Google Earth data (Figure 10) when needed and available, the roof and parking lot of each of the sampled schools was manually mapped into measured areas where PV systems could be installed (Appendix D: Maps of each Sampled School). Most school roofs are low slope, commonly referred to as flat roofs. On these roofs, the areas that are not shaded or obstructed with roof-top equipment and are at least six feet away from the edge are potentially feasible for solar. Sloped roofs need to face in the correct direction (within up to 90 degrees of south-facing) in order to be considered feasible for solar. Because there are varying factors and opinions when deciding if a given square foot is feasible for a PV installation and limited site data available for this analysis, the analysis used three different levels of system capacity for a given roof section: conservative, standard, and aggressive. Each of the three capacity-density levels are described briefly below and in more detail in Appendix B: PV Capacity and Production Methodology Details.

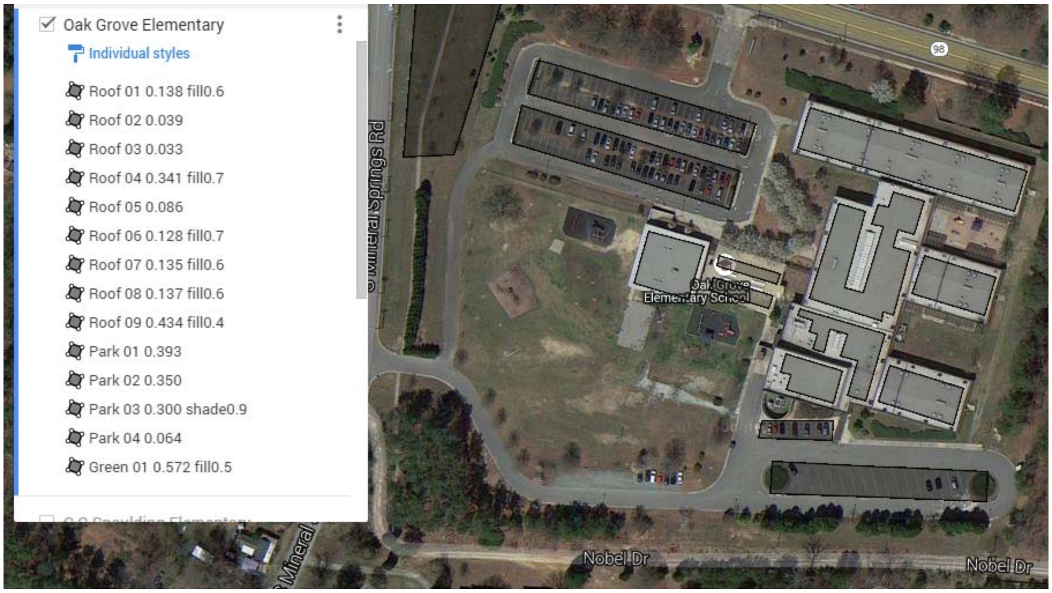

Figure 9: Example of Roof and Parking Lot Area Mapping of PV Capacity Assessment (Oak Grove Elementary)

Figure 10: Example of 3D Model Available in Google Earth for Many DPS Schools (Oak Grove Elementary)

No green space (i.e. open space for ground-mount PV) was mapped for several reasons. Few schools have significant area available and without knowledge of the school's current and planned use for the space, it is impossible for us to determine the feasibility of covering the area with a solar array. Certainly, there are areas at some schools that are suitable for PV development, and this should be considered on a school-by-school basis. There is also the possibility of installations on adjacent private land.

Conservative PV System Capacity: This model represents a conservative density and acceptance of suitability of a given area for a PV installation, which primarily affects rooftop PV capacities and has little impact on parking lot PV capacities. This level uses 15.5% efficient modules and a 6-foot roof edge buffer but is more conservative regarding minimum section size, shading, row-to-row shading, etc. than the standard level. This results in systems that are smaller and slightly simpler to design and install (lowering cost) and slightly less shaded (slightly increasing performance). See Appendix B for details on methodology and assumptions.

Figure 11: Example Conservative PV System Capacity Rooftop

Standard PV System Capacity: This model represents the full PV capacity of the given school's rooftops or parking lots using today's most common technology and performance expectations. This corresponds to a 15.5% efficient PV module, 6-foot buffer to the building edge, minimal row-to-row shading (only occurs early and late in the day around the winter solstice), avoiding small isolated areas, no covering of vents or other structures, and minimal shading from existing structures and vegetation. All of the economic calculations are based on the performance at this design density.

Figure 12: Example Standard PV System Capacity Rooftop

Aggressive PV System Capacity: This level represents the maximum system size technically feasible today. There are often cost and production tradeoffs in achieving this maximum energy density, so it may not be as financially attractive as the conservative and standard density designs. The only difference in the aggressive model and the standard model for sloped roofs and parking lot shade structures is that the module efficiency jumps from a common 15.5% to the near-top-of-the line 20%. There is an additional change for flat roofs, rather than using south facing (actually southern-most roof-edge facing) 10° tilt racking, the aggressive version uses an alternating East-West facing 20° tilt racking system (stationary and aligned with the building sides so not exactly E-W facing) (Figure 13). Such a system offers a greater roof power density (20% or more) and is better able to cover small, low roof penetrations. If adequately elevated, some such systems may be able to span many small obstacles on the roof that would typically be avoided by PV racking.

Figure 13: Example of East-West Racking by Zep Solar (Photo courtesy of Zep Solar)

Model validation of the estimation of PV capacities and their annual electricity generation was successfully completed using Helioscope software from Folsom Labs (see Appendix C: Validation of Capacity and Production Modeling).

Roof Condition

Roof type and condition were not considered in the PV capacity assessment of each school. However, it is of utmost importance to consider roof type and condition when considering installing a PV system. PV systems have a long life, at least the 25 years of the module power warranty, which means that a newly installed PV system on the average existing school roof will need to be removed and replaced during its lifetime to allow for re-roofing. Removing and replacing a commercial roof PV system currently costs about $0.50/watt, which is approximately 25% of the initial installed price of the solar system. It is generally advised that PV systems be installed on roofs less than five years old, other than metal roofs that have a much longer life and therefore do not have this restriction. Due to the very large cost of reroofing, it is rarely fiscally practical to reroof prematurely in order to facilitate an earlier PV installation.

An additional benefit of installing solar on metal roofs is that the mounting structure is simpler, cheaper, and lighter than flat-roof mounting systems, as well as non-penetrating like most flat-roof racking options. This is accomplished with hardware that clamps onto the seams, providing a solid attachment point for solar panels. In addition, if properly oriented toward the south, the higher slope of most metal roofs allows for greater PV density (of that roof section) and production per module.

DPS have a variety of roof types across its 49 schools, including built-up roofing (asphalt based), metal, shingles, or other materials. There are many roofs on DPS schools that need a new roof now or in the next few years, but it is beyond the scope of this report to analyze the available roofing surveys to further quantify the re-roofing need. It may be possible to facilitate some re-roofing projects by combining with a rooftop PV installation.

When roof conditions, budgets, or schedules do not warrant installation of a PV system on any or all of a roof, the school may consider installation on parking lot shade structures, which cost close to $1/watt more than rooftop systems (approximately 50% more), but provide great added benefits of shading for cars and buses. This shade improves vehicle life, saves air conditioning energy, and increases comfort.

School by School Results

According to our estimates[38], on average, all 49 schools have adequate roof and parking lot area to feasibly meet their annual electricity usage. On average, installing just the conservative rooftop and parking lot PV systems will meet at least 100% of the annual (after a 25% reduction through increased conservation and energy efficiency upgrades, aka post-EE) electricity consumption across all schools owned by the Durham Public Schools district. The average capacity of the conservative rooftop system on one school is 350 kW_{DC}, which is slightly larger than the average capacity of the conservative parking lot system of 340 kW_{DC}. Twenty-three of the forty-nine schools can meet 100% of their post-EE annual electricity usage with the full conservative system (rooftop and parking lot shade structure). Out of 49 schools, at least 41 could meet their annual post-EE electricity usage with a standard system, and all but three schools could meet its annual usage with the aggressive system design on its rooftops and over its parking spaces. These values do not take into consideration the limitations that arise from year-to-year variations coupled with a lack of annual net excess generation carryover or from a lack of net metering meter aggregation.

Some schools can produce more than 100% of their post-EE electricity usages with solar, and other schools can't quite achieve 100%. However since it is possible to take a district-portfolio approach to renewable electricity and the over-producing schools can compensate for the under-producing schools, DPS can consider the average across the district. When averaged across the district, the conservative system could serve 100% of post-EE electricity usage; the standard could serve 142%, and the aggressive could serve 215%. Net-metered systems are generally limited to providing 100% or less of a school's annual electricity, but sell-all systems do not have this limitation.

On average, the conservative rooftop-only system can meet 51% of the post-EE electricity usage, and only two schools in the district can meet 100% of this usage with just the conservative rooftop system. On average, the standard rooftop system can meet 78% of the post-EE electricity consumption at DPS, and eight schools can meet all of their post-EE electricity consumption with the standard rooftop PV system. On average, the aggressive rooftop system can meet over 100% of the schools' post-EE electricity usage, and 34 schools can meet all of this usage with the aggressive rooftop system. The parking lot system capabilities are slightly lower based on both the average percentage of total electricity usage and the number of schools able to reach 100% with just parking lot system.

[38] Our methodology did not involve site visits or detailed engineering or economic analysis of any site, therefore it is possible the actual system sizes may be smaller or larger than estimated in this report

Table 2 below shows the total PV capacity possible for DPS if each school installed the full conservative-density or standard-density capacity found in our analysis, totaling almost 49-MW for the standard rooftop and parking lot systems at all 49 DPS schools.

	Conservative Rooftop	Standard Rooftop	Conservative Parking Lot	Standard Parking Lot	Conservative Total	Standard Total
Total PV Capacity for all 49 DPS Schools (MW)	17.1	26.3	16.7	22.3	34.0	48.9
Total Annual PV Production for all 49 DPS Schools (MWh)	24,200	36,500	23,100	29,900	47,500	67,400
Percent of Post-EE Annual Electricity Provided (%)	51%	78%	49%	63%	100%	142%

Table 2: Total Feasible PV Capacities and Annual Production Across the School District

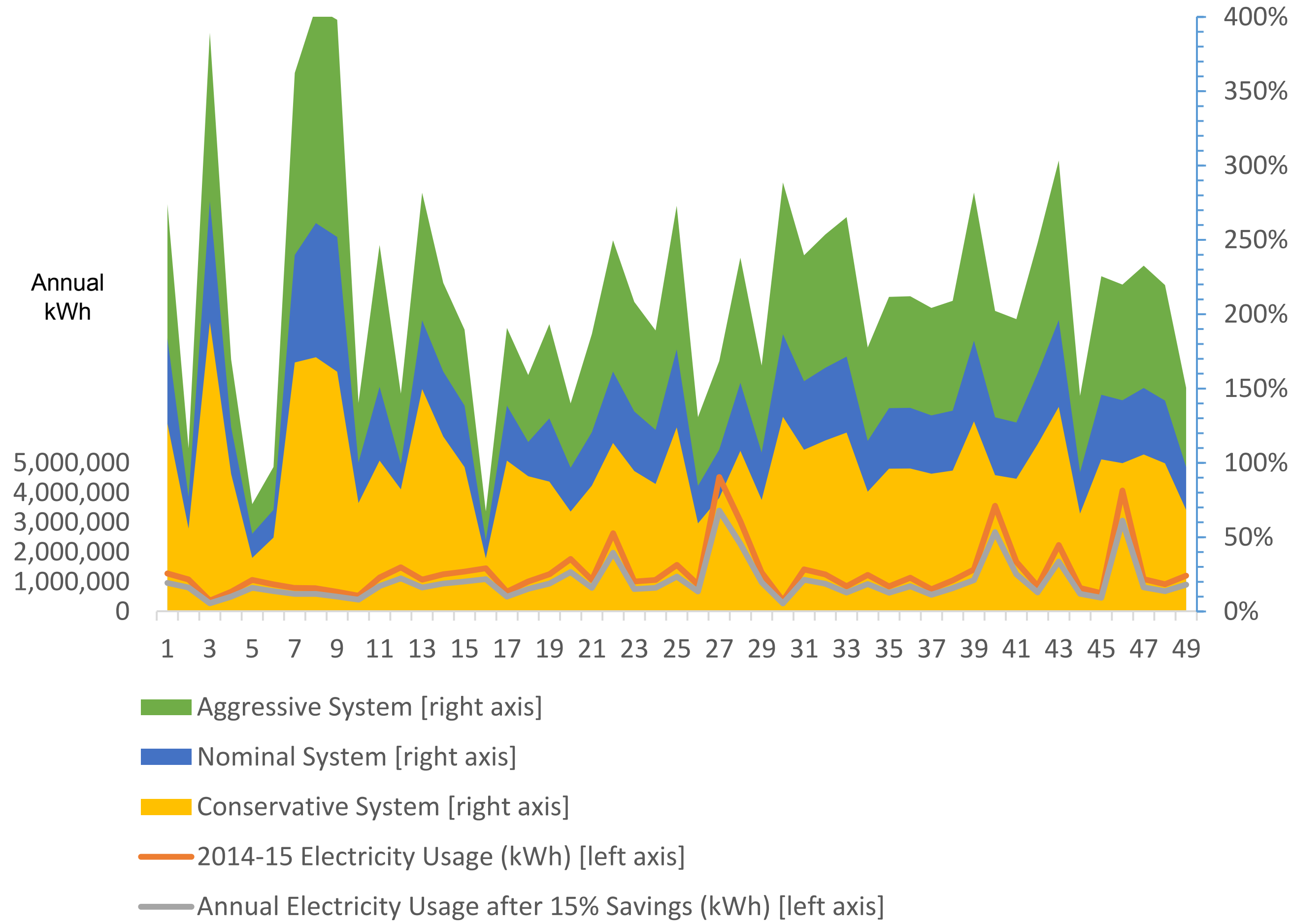

Figure 14: Percentage of Post-EE Annual Electricity Usage Producible By On-Site PV (Rooftop and Parking Lot Structures) at 49 DPS Schools

In Figure 14, the left-most 20 schools in this dataset were manually assessed, the remaining 29 schools are estimated based on the average watts/ft^2 of building area, which smooths out some of the real school-to-school variation. Therefore, there is greater variability of the first 20 schools in this graph; and the variability of the remaining 29 only accounts for the variability of the floor areas of the schools and not the additional variability of their relative areas suitable for solar installation. If all schools were manually assessed, the average of the right-most 29 schools in Figure 14 would change very little, but the values of individual schools would change significantly and would include more school-to-school variation than shown in the current estimates. Thus, the district-wide averages presented earlier are expected to remain near-constant if all schools were individually assessed. However, it is expected that the estimates of the numbers of schools able to achieve 100% with each system design provided above are slight overestimates of the real number of schools able to achieve 100% with that system type. On the other hand, none of these generation estimates include any ground-mounted solar, which will be an option at some schools and will generally be large enough to make up any capacity shortcomings of the roof and parking lot in the school's potential to provide 100% renewable electricity. Additionally, none of these estimates consider off-site installations, which may be an option and are effectively unrestrained in terms of area and PV capacity limits. The results of all 49 schools are provided in Appendix E: Results for All Schools.

7. Case Study of On-Site PV Capacity: Oak Grove Elementary

As an example of the on-site solar capacity at DPS, Oak Grove Elementary was chosen at random as a representative typical school for a case study (see Appendix A for selection method). The table below provides the results of the manual-mapping of the school's roof and parking lot, as described in Appendix B: PV Capacity and Production Methodology Details. As seen below, Oak Grove Elementary can fit 293 to 944 kW of PV on its roof, depending on the aggressiveness of the design and the efficiency of the PV modules. Its parking lots can support a very similar capacity of 488 to 916 kW. However, the upper end of these ranges is likely too aggressive to be economical. A system sized to meet 100% of the school's post-EE electricity usage, starting first with a standard density rooftop system, requires a 523 kW rooftop system (the full standard capacity density) and 164 kW of parking lot shade structure PV, which covers close to one third of the school's parking spaces. The age of the roof was not investigated in this analysis.

Total Students	2014-2015 Total Electricity Usage (kWh)	Electricity Usage after 25% Savings (Post-EE) (kWh)
553	1,279,933	959,950

Table 3: Oak Grove Elementary's Student Population and Annual Electricity Usage

Conservative Roof PV Capacity (kW)	Standard Roof PV Capacity (kW)	Aggressive Roof PV Capacity (kW)	Conservative Parking Lot PV Capacity (kW)	Standard Parking Lot PV Capacity (kW)	Aggressive Parking Lot PV Capacity (kW)
293	523	944	488	651	916

Table 4: Case Study: PV Capacity Results of Manual-Mapping of Oak Grove Elementary's Roof and Parking Lot

Table 5 shows the least-cost on-site, non-ground-mount, standard design capacity PV system that can met 100% of the post-EE electricity usage for Oak Grove Elementary. Because rooftop PV is cheaper than parking lot PV, the least-cost system first fills the roof with PV (523 kW), which is the full roof PV capacity using the standard capacity density. It then requires an additional 164 kW of more expensive parking lot PV capacity to meet the full post-EE electricity requirement. These PV capacities consider the tilt, orientation, and shading of the actual Oak Grove roofs and parking lots. Because most of the roofs and parking spaces face 15 degrees off south, the PV systems do not quite produce the full 'base performance' of 1,400 kWh/kW as defined in Appendix C for these standard capacity density systems. The average per watt cost of this system is a combination of $2.00/watt for the rooftop portion of the system and $2.95/watt for the parking lot portion of the system. The full 449 kW standard rooftop system alone would provide almost 77% of the post-EE electricity needs. It would be possible to meet the post-EE electricity demand with a rooftop-only system using the aggressive capacity density. A price estimate for the aggressive rooftop system was not developed for this study, so it is difficult to say if it would be more or less expensive than the least-cost standard capacity density system. Table 6 provides some simple financial metrics of this system.

Today, a turnkey installation of this combined roof and parking lot system would cost about $2.23 per watt of PV capacity, for a total cost of $1.5 million, which is a cost of $2,765 per student. To put this cost in perspective, one could consider the annual payment to finance the turnkey system cost with a 25-year 2.88% CREBs bond (as may be done if owned by the school), which is $157 per student. This is less than the school's expected annual 25-year-average electricity cost per student. The PV system would provide many other benefits in addition to the economic incentives explored in the introduction including STEM teaching opportunities for all grade levels.

PV Capacity Required to Provide 100% of Post-EE Usage	Rooftop Capacity (Standard Density)	Parking Lot Capacity (Standard Density)	Average Cost of System to Meet 100% Post-EE ($/W)
687 kW	523 kW	164 kW	$ 2.23

Table 5: Case Study: Least-Cost Standard Capacity Density PV System Capacities to Meet 100% of Post-EE Electricity usage

Average Cost of System to Meet 100% Post-EE ($/W)	Cost System to Meet 100% Post-EE	Cost of System to Meet 100% Post-EE Energy Per Student	Annual Debt Service on system per student (CREBs 2.88% 25-year bond)	Annual Average Cost Per Student of Post-EE No-PV Electricity from Utility (25 years, 3% Annual Escalation)
$ 2.23	$ 1,528,963	$ 2,765	$ 157	$ 209

Table 6: Case Study: Economic Figures on the Combined Rooftop and Parking Lot PV System Outlined in Table 5

8. Solar PV Economics and Finance

The economic viability of solar PV projects for DPS depends on many factors. Like most investments, two of the most important factors are the initial cost and the operating net revenue from the project. For solar PV, other variables such as the ability to monetize tax benefits, as well as net-metering rules, also play important roles in determining economic success. We will begin this section with a brief discussion of the cost of PV in North Carolina, and the trend it is likely follow. Next, we will discuss how operating revenue or savings can be generated via two basic forms: *Net Metering* and *Sell-All*. We will then examine the merits of *Direct Ownership* versus that of *Third Party Ownership (TPO),* and the major reasons for choosing each in the context of financing. This chapter will be followed by two types of economic analysis (Levelized Cost of Electricity and Nominal Savings) that incorporates all the different choices and variables in making an informed and comprehensive economic decision to invest in PV.

Cost of PV Systems in North Carolina

Solar photovoltaic project costs for North Carolina can vary widely, as they do in all markets. Recent data collected from dockets at the North Carolina Utility Commission and from national industry publications suggest that prices range from \$1.68/$watt_{DC}$ to \$2.70/$watt_{DC}$ for commercial scale PV systems (generally rooftop projects ranging between 100 kW and 1,000 kW). Additional sources were referenced to determine typical or average values, which appear to be trending towards \$2.00/watt. Notably, the 2015 Q2 SEIA/GTM *Market Insight* Report provides a best-data modeled price for a turnkey 200 kW commercial system for second quarter of 2015 at \$2.13/watt, on pace to hit \$2.00/watt by Q2 of 2016.[39] Holding the most relevance in our analysis is data obtained through interviews with leadership of two leading commercial PV installers in North Carolina, who both indicated market pricing for a typical school rooftop system was currently about \$2.00/watt. It is worth noting here that these costs are for a turnkey installation and do not include any internal costs to the school district such as staff time to manage the project, legal fees, accounting fees, or other additional costs. They also include best-case conditions, such as no roof repairs or atypical site complications.

Based on conversations with two leading national suppliers of parking lot PV shade structures and with three local commercial solar PV firms with experience installing or developing parking lot PV systems, it is estimated that the parking lot PV solar systems (including the shade structures) are about \$1.00/watt more than similar capacity school rooftop systems. The price differentials received from these sources ranged from \$0.75/watt to \$1.25/watt more, resulting in a typical full installed price of about \$3.00/watt today.

The Lawrence Berkeley National Laboratory (LBNL) *Tracking the Sun* report and the SEIA/GTM Market Insight Reports show steady recent cost reductions for commercial scale PV systems with annual price declines of \$0.25/watt per year for the last two years. If price reductions continue at such aggressive rates, North Carolina could see consistent \$1.50/watt pricing for commercial rooftop systems and \$2.50/watt for parking lot shade structures within the next five years. Discussions with North Carolina PV developers and review of North Carolina Utilities Commission filings for large projects indicate that the turnkey cost for utility-scale ground-mounted systems are already around \$1.50/watt today.

39 www.seia.org/research-resources/solar-market-insight-report-2015-q2

COST OF ELECTRICITY FOR DPS

For the 2014-2015 school year, on average, DPS paid about 8.9¢/kWh, which was calculated by simply dividing the total electricity budget by the total number of kWh purchased. The actual price paid for electricity varies from account to account, by season, and in other ways as well. Every school has more than one account or meter with the electric utility, and many schools have five or more. The rate schedule, or tariff, for each account/meter is determined by the size and characteristics of the loads connected to it. The tariff coupled with the usage pattern determines what DPS pays for the electricity delivered. The vast majority of the largest energy-using accounts are on Duke Energy Carolina's Large General Service (LGS) rate, which consists of a monthly facilities charge, a peak demand charge, and an energy charge rate per kWh that changes depending on the peak demand and the amount of energy used. Our modeling of a generic school on the LGS tariff found the demand charge to be about 15% of the total bill. The smaller energy-using accounts generally use much less electricity and are on other rate schedules, including Small General Service (SGS) or a special flood lighting rate schedule.

BILLING AND COMPENSATION ARRANGEMENTS: NET METERING AND SELL-ALL

Now that we have introduced *cost* of PV in North Carolina, it is appropriate that we follow with a discussion on the ways PV can generate *savings* or *revenues* for the DPS district. Depending on the point of view, these can be either billing, revenue, compensation, or savings arrangements. The two most important forms of arrangements are variations of net metering and sell-all.

Net Metering

Net metering can be viewed as a billing and crediting method for electric customers who generate their own electricity. Typically, if the customer is consuming all electricity generated by the PV system at a given point in time, then revenue is expressed as savings from not having to pay the retail rate to the servicing utility for that quantity of electricity. When a customer's generation exceeds the customer's use, electricity from the customer flows back to the grid, offsetting electricity used by the customer at a different time during the same (or future) billing cycle. Although 44 states plus the District of Columbia have mandatory net metering, policy and regulations vary widely.[40]

One of the most important factors in determining the benefits of net metering is the local retail rate (or rate structure) for the customer. The offsetting or credit of a higher average retail rate equates to higher savings or corresponding compensation for excess generation. A low retail rate means that for each unit of electricity credited (or not purchased from the servicing utility), less cash flow is received. In North Carolina, customers may net meter under any available rate schedule. However, customers who choose to take service under any tariff other than a time-of-use demand (TOUD) tariff must surrender to the utility all renewable energy credits associated with the customer's generation – with no compensation for the customer. Finally, any customer's net excess electricity generation (NEG) during a billing period is carried forward to the following billing period at the utility's full retail rate. Any credit in excess of the total billing year for net metering is surrendered to the utility without any compensation.

[40] http://ncsolarcen-prod.s3.amazonaws.com/wp-content/uploads/2015/04/Net-Metering-Policies.pdf

Sell-All

In contrast, electricity generated by the PV system in a sell-all arrangement is compensated by the utility via a rate structure or tariff. The PV system is in essence a power plant that sells all of the generated electricity to the servicing utility independently of what the customer is using locally. In fact, in the case of solar farms there is no local consumption, only generation.

The most important factor for sell-all is the rate offered by the utilities for the PV generation. Rates can be as simple as a single flat rate applied to all generation at all times or encompass more complicated structures that take into account the timing of the generation, such as peak hours, seasonality, and inflation. In a sell-all arrangement, the PV system owner can choose to either sell the RECs to the utility (or other entity) or retire them (see Section 4 for additional discussion of RECs).

Analysis of Net Metering and Sell-All Values for PV Electricity

As we have now introduced net metering and sell-all arrangements in North Carolina, we can proceed to normalize how each savings/revenue model can be valued so that we have a basis of comparison. In essence, normalizing the two arrangements dictates that we must have a methodology to express both in the same unit, which in this case is the dollar per kilowatt hour ($/KWh).

Valuing the Net Metering Arrangement

As described in Section 4, a net-metered system directly serves the loads of the utility customer. At times of excess production, the solar electricity is sent to the grid for use by other customers with demand at that moment. The value of the solar electricity in a net-metered system is best expressed as the net solar value and defined in the equation below.

$$Net\ Solar\ Value\ (\frac{\$}{kWh}) = \frac{Bill\ without\ solar - Bill\ with\ solar}{Solar\ generation}$$

For this report, we conducted an analysis to find this net solar value for a typical DPS school. This was done with a full year hourly simulation of a school's electricity loads and the PV system's production. The school's load was derived from a dataset for a generic primary school operating in the central North Carolina climate provided by the U.S. Department of Energy's OpenEI.[41] The standard model loads were then scaled such that their annual total equaled that of the post-EE annual loads of a sample school. The PV production figures were derived from the Helioscope model of a 575 kW system (combination of 75% rooftop and of 25% parking lot shade structure), which was sized to meet approximately 100% of the annual electricity need. A spreadsheet model of Duke Energy's Large General Service (LGS) tariff was then incorporated in order to calculate the school's bill before and after solar. Using this net-metered PV system sized to meet approximately 100% of the school's load, the average annual net solar value of the PV generated electricity was found to be $0.060 with current net metering rules, which include a solar standby charge, and $0.070 without standby charges. As described in Section 5, current North Carolina net metering regulations allow the utility to charge a monthly standby fee based on the capacity of the connected PV system. For Duke Energy Carolinas, this standby fee is $1.155/kW/month, which when converted to its impact on the net solar value of the PV system, resulted in a reduction in value of $0.010/kWh.

[41] Commercial and Residential Hourly Load Profiles for all TMY3 Locations in the United States, http://en.openei.org/datasets/dataset/commercial-and-residential-hourly-load-profiles-for-all-tmy3-locations-in-the-united-states

This analysis also showed that the PV system reduced the monthly kW demand (peak power usage in a 15-minute period in the month) by an average of about 10% of the PV capacity, ranging between 5% and 15% in individual months. The remaining monthly demand charges are the bulk of the utility bill for a school with a net-metered PV system that meets 100% of its annual electricity needs.

Valuing the Sell-All Arrangement

A sell-all solar system sends all of its production to the grid for use by customers with demand at that moment. A sell-all arrangement, or contract, usually appears in two forms: (1) a standard offer with tariffs designed in compliance with Public Utilities Regulatory Policy Act of 1978 (PURPA) using the utility's "avoided cost", or (2) a customized agreement with terms and conditions negotiated internally amongst the parties involved. Both forms are often referred to as a power purchase agreement (PPA). In order to have a working value from which we can conduct comparative economic analysis, we utilized the tariff under Duke Energy Carolinas' standard offer for small producers to calculate an average annual rate that is appropriate to a PV asset in North Carolina. This was done by applying the estimated hourly production data of PV for an entire year over the tariff's time-varying energy and capacity rates. Of the options that are available under this tariff, we chose the one that yielded the highest average annual rate. Using this methodology, we estimated that PV generation under this tariff equates to an average annual rate of $0.065/kWh. In North Carolina, the standard sell-all offer includes a flat 15-year PPA, which is the most often used option. The North Carolina Utilities Commission leads a process to update the avoided cost rate every two years, in which the utilities are expected to release new avoided costs rates in early 2016.

Project Financing and Ownership

Armed with the understanding of PV project costs as well as savings and revenue arrangements now allows us to tackle the subject of financing. Accordingly, the fundamental purpose of different types of ownership models for PV is to accommodate different types of financing. It is with this premise that we address financing through two major avenues of ownership*: Direct* and *Third Party*. The choice and distinction between the two avenues for DPS can be generalized in the following terms.

a. Direct ownership has the advantage in that a school district is unique in its ability to access low cost debt instruments and special programs that are usually not available to for-profit entities.
b. Third Party Ownership (TPO) allows for monetization of tax benefits.

The economic decision between direct ownership and TPO is therefore one of weighing the value of the lower cost of capital achievable by the DPS district versus the monetized value of the tax benefits (federal ITC and accelerated depreciation). In this section, we will introduce each ownership scenario as well as a corresponding financing option that should be considered.

Direct Ownership

Direct ownership of PV represents an investment similar to other capital improvements that a school can choose to engage. The required funding is typically derived from the school system's annual budget allowances or issuance of bonds via the referendum process. Other sources of capital can come from grants and periodic opportunities such as the Qualified Energy Conservation Bonds. Though many of these opportunities have limited timeframes of availability, a long-term plan for increased renewables should always include a ready stance to pursue such opportunities as they are announced. One such opportunity for financing direct ownership of PV is the Clean Renewable Energy Bond (CREB). The Internal Revenue Service reopened the rolling application window of CREBs for government entities, including schools, in March of 2015.

Clean Renewable Energy Bonds (CREBs)

CREBs are an especially powerful tool for financing solar on schools. Under the current rules for securing Clean Renewable Energy Bonds, a Qualified Issuer (or a Conduit Issuer on behalf of the school district) sells taxable CREBs with a maturity period of up to 25 years to investors. The discount rate, or the Applicable Federal Rate (AFR), is set by the Internal Revenue Service and published on a monthly basis, currently at 2.88% for a 25-year maturity[42]. The AFR is in turn defined by market rates for U.S. Treasuries. The potential benefit of this financing mechanism is lower borrowing cost, stemming mainly from two factors: (1) the AFR is based on federal treasury instruments, which are usually considered by the financial public as the "risk free" benchmark and thus have a lower discount rate than that of most municipal bonds, (2) a direct rate subsidy is paid by U.S. Treasury to the issuer of the CREBs. The issuer must apply for an allocation from the U.S. Treasury and the successful approval of the bond is contingent upon submission of detailed project plans.[43]

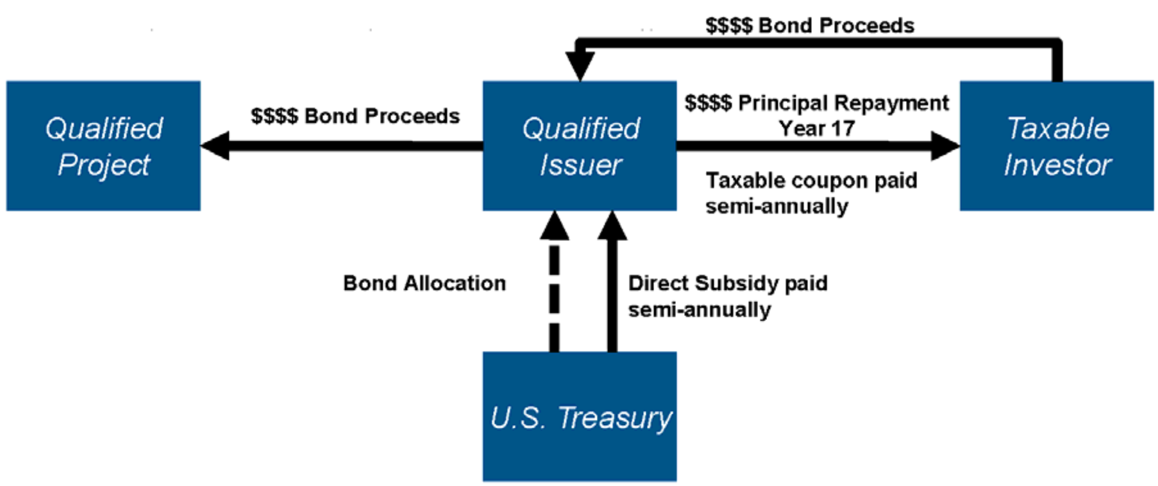

Figure 15: Mechanics of CREBs Program, Source: U.S. Department of Energy

[42] www.treasurydirect.gov/GA-SL/SLGS/selectQTCDate.htm
[43] http://energy.gov/savings/clean-renewable-energy-bonds-crebs

THIRD PARTY OWNERSHIP

From an investment perspective, third party ownership (TPO) has the advantage of allowing a tax paying entity to own the project and monetize tax credits and depreciation in the form of positive cash flows. Third party ownership improves the economics for non-tax-paying entities because tax benefits can be considered as additional cash inflows independent of the value of the electricity and RECs generated by the renewable energy system.

Partnership-Flip

The partnership-flip is a special case of third party ownership that has been used extensively in North Carolina. Table 7 is a summary of benefits to the school under this *specialized case* of TPO. In this model, the project is owned by a partnership between the school and the investor. The partnership legal entity, usually a limited liability company (LLC), allocates up to 99% of the economic returns to the investor until the investor reaches a predetermined target annualized rate of return, at which point the allocations "flip" and the investor's interest in the project may drop to as low as 4.95%. This flip may not occur until at least five years after the project is put into service or a portion of the tax credits may be subject to recapture. Once the flip has occurred, the school has the option to purchase the remaining interest from the investor at fair market value. In most cases, the solar project partnership entity, i.e. the LLC, will take on debt to finance most or all of the remaining needed capital after the injection of tax equity investment. Additionally, there is often a need for the project sponsor (the school in this case) to invest capital in the project in order to minimize the debt payments so that they can be easily covered by the project's annual revenue. In cases whereby the district can borrow at a lower cost than the project developer, the debt portion of the financing can come from the issuance of municipal bonds or other equivalent local debt instruments, including CREBs. This approach is often referred to as the *Hybrid Morris Model.*

Third Party Investor	School
Claims up to 99% of tax credits Claims up to 99% of depreciation Ability to meet target returns and then exit the project	Little upfront investment required Ability to purchase project at greatly reduced cost in a future date Ability to have project utilize the available tax benefits

Table 7: Summary of Benefits from Partnership-Flip

Table 8 further illustrates the mechanics of the transactions between the investor and the school district. The percentages listed are negotiated between the school and the tax equity investors prior to the project in a partnership flip. Since the goal of a partnership ownership structure is to allocate as much of the tax benefits as possible to the investor, the maximum allocations are used in the table below. Once the investor reaches its target return, the allocation of ownership will change in order for the investor to easily exit the project. Typically, the investor will exit the project immediately following the flip by selling its remaining equity to the school. For the purposes of the model, fair market value at time of sale is determined as the net present value (NPV) of the future cash flows over the remaining life of the project.

Cash Flows Allocated to:	Year Zero to Flip Year (Years 0–6)	Post Flip but before Sale of Equity to School (Years 7–25)	Upon Sale of Equity to School (Years 7–25)
Tax Equity Investor	**POSITIVE** 100% of Tax Credits 100% of Depreciation 99% of Project Income	**POSITIVE** 4.95% of Remaining Depreciation, Tax Credits and Project Income	**POSITIVE** Fair Market Value of Remaining Equity (i.e. 4.95%)
	NEGATIVE 99% of Operating Costs	**NEGATIVE** 4.95% of Operating Costs	
School	**POSITIVE** 1% of Project Income	**POSITIVE** 95.05% of Project Income	**POSITIVE** 100% of Project Income
	NEGATIVE 1% of Operating Costs	**NEGATIVE** 95.05% of Operating Costs	**NEGATIVE** 100% of Operating Cost Fair Market Value of Remaining Equity (i.e. 4.95%)

Table 8: Assignment and Nature (Positive versus Negative) of Cashflows

Property Assessed Clean Energy (PACE)

Another potential avenue for third party owners or direct owners to acquire low interest rate debt is through a Property Assessed Clean Energy (PACE) financing program. In August 2009, North Carolina enacted legislation (Senate Bill 97) that authorized counties and cities to make special assessments in order to finance the installation of "distributed generation renewable energy sources or energy efficiency improvements that are permanently fixed to residential, commercial, industrial or other real property."[44] Counties and cities that choose to adopt such programs may finance them by revenue bonds, general obligation bonds, or general revenues. While this approach may achieve a lower interest rate than the traditional lending instrument that a third party owner can access, the case is less compelling when the PV system is to be installed on public schools. Since the school district can already raise low cost capital through its own bond referendum process, it is preferable to simply have the school participate in a partnership flip or other joint ownership arrangements. PACE financing provides an advantage to entities that do not otherwise have access to low interest rates, need long term financing, or have trouble obtaining private financing, but it is not necessarily a lower cost option than a publicly issued bond. No cities or counties in North Carolina have implemented a PACE program to date, in part because the mechanism as required by the state law can create a significant administrative burden and credit risk for the municipality. In summary, PACE can be considered when: (1) the school district does not wish to participate in any part of the financing (either through its own bond issuance or other instruments such as CREBs), and (2) the local government for the school district has established an efficient conduit or internal infrastructure to manage such a financing program.

[44] http://programs.dsireusa.org/system/program/detail/3647, www.ncleg.net/Sessions/2009/Bills/Senate/PDF/S97v6.pdf

Third Party Energy Sales

It is important to note that in North Carolina, sale of electricity can only be conducted by a "public utility" as defined by N.C. General Statutes 62-3 and authorized by the North Carolina Utilities Commission[45]. As such, the owner of a PV system in North Carolina may either net meter its output or sell its output to an authorized public utility, but may not sell the output to any other party. This is not the case in many leading solar states, where third party owners (TPOs) regularly sell the output of their PV systems directly to their customers, most often at a long-term, fixed or slowly escalating rate. The practice where the TPO can transact directly with the system host or customer is commonly referred to as third party energy sales. As a third party owned system, the investors in the third party sales scenario can still monetize the tax benefits, much in the same manner as in the partnership flip. If this practice becomes legal in North Carolina's future, then the LLC or any qualified company can sell directly to the school under its own customized power purchase agreement. To allow for long-term planning for the school district, our economic analysis includes third party sales PPAs should they become available in the future. The working mechanism of third party sales is shown in Figure 16.

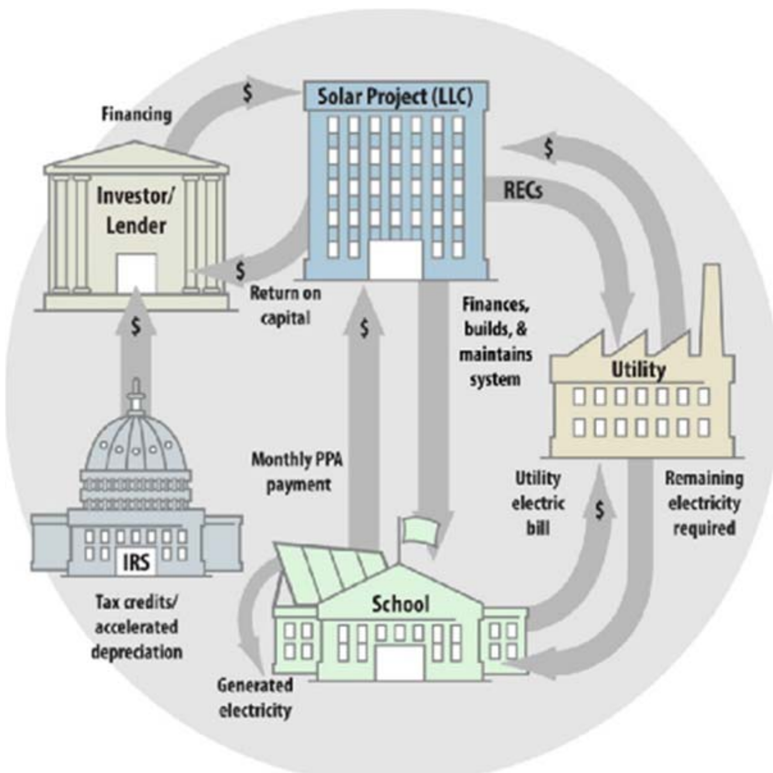

Figure 16: Third Party Sales Flowchart (NREL 2010)

Note: In this figure, the sale of the REC from the LLC to the utility would mean that the school would not be allowed to claim to be powered by renewable energy according for this financing mechanism.

45 www.ncleg.net/EnactedLegislation/Statutes/HTML/BySection/Chapter_62/GS_62-3.html

9. Economic Analysis - Levelized Cost of Electricity and Nominal Savings

In this section, two types of economic analysis are presented—Levelized Cost of Electricity (LCOE) and Nominal Savings. A third economic analysis, simple payback period, is available in Appendix G. The LCOE analysis applies the time value of money to all the revenue and cost components of a solar PV project and compares the economics of various pricing, technological, policy, and market conditions. Nominal savings analysis employs the same variables, assumption, and methodology but leaves out the time value of money. Section 8 on Solar PV Economics and Finance covers some of the assumptions and conditions that inform these analyses.

Levelized Cost of Electricity (LCOE) Economic Comparison

Putting into practice the concepts and policies previously covered, we conducted a comprehensive side-by-side economic comparison of important possible combinations of ownership (direct vs. third party), interconnection (net meter vs. sell-all), tax credit policy, North Carolina net metering policy, and North Carolina third party energy sales policy. This economic analysis was conducted from the school's point of view. The results of this detailed economic modeling effort are described in the analysis below and illustrated in Table 9. Each row in the table represents a separate potential option for DPS to acquire renewable electricity, arranged in approximate order of most direct ownership and use to the least direct ownership and use (see Section 4 for in depth explanation of these potential options). The final line of the table is the reference case of doing nothing; i.e. business as usual or the status quo. In order to compare the economics of each system to each other and to the do nothing case, the levelized cost of electricity per kilowatt hour ($/kWh) for the school over the next 25 years was calculated for each case. Calculation of the LCOE considers all of the costs and any revenues associated with the school's electricity and takes into account the time value of money, which allows a fair comparison of projects with their costs and savings/revenue spread differently across the 25-year project lifetime. Some of the scenarios being compared are available today, and others represent possible future policy and/or market scenarios.

For each case, the analysis was run at three different PV price points. All of these prices are in dollars per $watt_{DC}$ ($/$watt_{DC}$), are for turnkey installed systems, assume near-ideal conditions (for example, no roof repair before or after installation), and do not include DPS staff costs. The highest of the price points is $2.25/watt, which represents today's retail cost for a typical DPS school to install enough solar capacity to provide 100% of its annual electricity needs. This price assumes that the PV system is split 75% on the rooftop and 25% on parking lot shade structures. A PV system that is 100% rooftop is less costly than the system that includes parking lot shade structures. A single school's rooftop PV system costs around $2/watt today. It is speculative as to how much lower the per-watt price would be for the installation of a group of similar large rooftop PV projects constructed under a single contract (5-MW or more in total), but right between the high and low modeled prices ($2.25 and $1.50), or $1.88/watt, is believed to be a reasonable estimate, which is reflected in the middle modeled price point. The lowest price point of $1.50/watt represents either a future (perhaps five years from now) price for an on-site PV system that today costs between $2.00/watt and $2.25/watt, or a large (perhaps 5-MW_{AC} or larger) ground-mounted solar PV system today. The large ground mount system, or solar farm, currently only applies to the partnership-flip system type. However, a solar farm could use a third party energy sales structure if that becomes available in North Carolina, although that would be of little benefit to DPS without changes to net metering rules to allow virtual net metering and net metering of systems over 1-MW.

Because the results of this analysis are sensitive to the average annual escalation rate of the school's electric utility rates, each case was also calculated at three different annual utility escalation rates. The combinations of the three different PV system costs and three different annual utility escalation rates results in a total of nine scenarios for each row/case. The calculated 25-year costs of electricity per kWh for the school are color-coded relative to the electricity cost in the do nothing case. Green values show that this scenario results in an equivalent or lower net present value cost of electricity for the school over the next 25 years. Yellow values are slightly more costly than the do nothing case, and red values are significantly higher than the do nothing cost of electricity. Of course, this accounting of the costs only considers the direct economic costs and benefits and does not consider any of the additional benefits of solar for the school and community.

Many of the specifics of the model are covered in the list of assumptions below, so the following description of the method used to perform the analysis does not cover each of these case-by-case specifics. The resulting LCOE for the next 25 years is the combination of all expenses the school has related to electricity for the school. These expenses can be broken down into two groups: (1) utility electricity bills, and (2) solar PV net cost. For sell-all systems, the utility electricity bill is the cost to purchase all of the school's electricity from the utility company (see Valuing the Sell-All Arrangement in Section 8 for further explanation). For net-metered systems, the utility electricity bill is the annual utility bill the school pays even after approximately 100% of their electricity has been provided by the net-metered PV system. This bill consists mainly of demand charges, which are estimated to be reduced by only about 10% by the PV system (see Valuing the Net Metering Arrangement in Section 8 for further explanation).

The solar PV net cost is the net of all of the school's costs for the PV system and any electricity sales (sell-all) revenues. For the direct ownership case, the school's PV costs are the financing costs, the operating costs (system operations and maintenance (O&M), property taxes, legal fees, etc.), and future inverter replacement cost. In this case, the school's total cost of electricity is its utility bill after PV, plus all of its PV costs. For the third party energy sales case, the school's PV costs are only the PPA payments to the third party owner and their utility bill after net metering the purchased solar electricity. This same methodology is used for each of the other cases, but always from the school district's financial point of view, with future costs and revenues discounted at 4% per year. This is most completed in the partnership-flip systems where the school's costs and revenues for the solar system change dramatically in year seven.

Each case assumes the following characteristics (where applicable):

1. Twenty-five year project life.
2. PV sized to meet approximately 100% of the annual load at the school, based on analysis of a 575 kW_{DC} PV system example.
3. \$1.50, \$1.88, and \$2.25 $\$/W_{DC}$ turnkey system price cases (see above for complete description).
4. Production of 806,500 kWh in Year 1, which is 1,400 kWh/kW_{DC}, assumes due south facing with no shading.
5. 0.5% annual PV module production degradation, which assumes proper operations and maintenance of PV system for a 25-year system life.
6. No re-roofing during life of project.
7. School discount rate of 4%, which is used to discount future utility costs, REC purchases, PPA payments, and revenue to the school. This value is based on the estimated cost of capital for DPS. Higher discount rates will place more emphasis on near term cash flow and lower discount rates treat far-future cash flows very similarly to near-term cash flows.

8. Utility annual price escalation rates of 1.5%, 3.0%, and 6.0%, which represent a likely range of average escalation for the next 25 years. The U.S. Energy Information Administration (EIA) predicts that the average rate between now and 2040 will be 2.6%.[46] These are nominal rates, meaning that the rate includes inflation, e.g. if the inflation rate is 2% and the escalation rate is 3% the utility escalation rate is one percentage point higher than inflation.
9. At a 3% utility escalation rate, the LCOE for the next 25 years of a school's utility bill for all of their electricity needs (do nothing case) is calculated to be 6.9¢.
10. At a 3% utility escalation rate and the current PV standby charge, the NPV per kWh for the next 25 years of a school's electric utility bills is calculated to be 1.9¢, and without the PV standby charge it is 1.0¢.
11. Net metering electricity value (net solar value) calculated month by month as described in section 8: Valuing the Net Metering Arrangement. If the net-metered system is sized for between 80% and 100% of the total annual load there is very little change in the net solar value.
12. Sell-all electricity is valued at an annual average of 6.5¢/kWh for the life of the project, which is an estimate of the annualized rate for the current 15-year Duke Energy Carolina's sell-all tariff. This consists of an initial 15-year flat rate contract followed by a second contract at the same rate (simplest possible assumption considering lack of agreement on predictions of future avoided cost rates).
13. Third party energy sales PPA rates are fixed (i.e. an annual escalation rate of 0%).
14. The levelized cost of electricity (LCOE)[47] for the system owner was calculated using the NREL CREST solar model, which is designed to calculate PV LCOE values.[48] The CREST model was used for years 1-25 of direct ownership and third party energy sales (PPA) cases. The CREST model was only used for years 1-6 (pre-flip) for partnership-flip models.
15. In CREST, the debt fraction for all of the third party owned systems (PPA and partnership-flip) ranged between 47% and 65%. For each case, the debt fraction was set in CREST as high as possible (to use as much lower-cost capital as possible) for the project's revenues to adequately cover the annual debt service payment (defined as a minimum debt service coverage ratio, or DSCR, of 1.15 and an average DSCR of 1.20, based on guidance in CREST).
16. For directly owned systems, the LCOE calculated by CREST was used as the levelized cost of solar electricity for the school.
17. For third party energy sales (PPA) projects, the LCOE calculated with CREST is defined as the flat PPA rate paid by the school, which was then discounted to determine the school's PV LCOE. This PPA rate could be optimistically low since it does not attempt to model for profit margin beyond the

[46] EIA predicts commercial electricity prices to rise at a rate of 2.6% between now and 2040: they predict the same basic rate for the US as a whole, and slightly higher for residential and industrial users: www.eia.gov/beta/aeo/#/?id=3-AEO2015&cases=ref2015&region=1-2

[47] From SunShot vision Study: 2012 "LCOE is the ratio of an electricity-generation system's costs—installed cost plus lifetime operation and maintenance (O&M) costs—to the electricity generated by the system over its operational lifetime, given in units of cents/kilowatt-hour (kWh). The calculation of LCOE is highly sensitive to installed system cost, O&M costs, local solar resource and climate, PV panel orientation, financing terms, system lifetime, taxation, and policy. Thus, PV LCOE estimates vary widely depending on the assumptions made when assigning values to these variables."

[48] NREL CREST: https://financere.nrel.gov/finance/content/crest-cost-energy-models

equity investment IRR and does not account for any additional operating costs that may be specific to this model.

18. The partnership-flip projects used CREST to find the flat energy payment (LCOE, in cents/kWh) required in order for the project to service its debt and provide the required rate of return to its equity investors at year 7 of the project. This project 'LCOE' was then compared to the sell-all rate, and the difference was used to calculate the project's surplus or shortfall of revenue in the first 6 years. Any revenue shortfall was supplied by an initial cash investment by the school (per 1-MW_{DC} of PV capacity), which ranged between $0 and $180,000 for the cases analyzed. Finally, the school's LCOE was calculated as the NPV of the school's cash flows for all years of the project, including any initial cash investment.
19. Debt interest rate of 6%, 15 year term for the third party energy sales systems, and 25 year term for the partnership-flip systems, both with a 3% lender's fee.[49,50,51] The 25 year term is longer than the typical loan period, but was used to greatly simplify the partnership-flip model. The change in loan term from 15 or 20 to 25 years has a small impact on the final total cost of electricity.
20. CREBs bonds of 25-year maturity at a (subsidized) rate of 2.88%.
21. Equity investment required internal rate of return (IRR) of 10%. In their annual LCOE analysis, Lazard, a financial advisory and asset management firm, uses 12% equity cost of capital[52]. Woodlawn Associates published that non-tax-equity investors have an expected rate of return of 8% to 11%.[53] A May 2015 Lawrence Berkley National Laboratory (LBNL) report analyzing the low PPA rate of some recent utility-scale PV projects modeled sponsor equity at a 10% IRR. Another LBNL report from 2014 assumed sponsor equity at 12% and tax equity at 8.25%[54]. We believe 10% represents a reasonable estimate of the cost of third party equity investment in the next five years. In the case of higher rates, third party energy sales PPA rates would be somewhat higher and the capital investment by the school in Partnership-Flips would increase.
22. Inverter replacement in year 10 at a cost of $0.15/$kW_{DC}$ (in that year's dollars). This is slightly less than the installation cost of similar sized inverters today since it is expected that their prices will continue to decline more quickly than inflation. No additional inverter replacement is included for the last 15 years of the project because it is assumed that the new inverter at year 10 will have substantially better reliable lifetime than today's inverters.
23. Federal and state 5-year MACRS accelerated depreciation used where applicable.
24. Operating expenses of $10/$kW_{DC}$/year, escalating annually at 1.6% (CREST default rate). Operating expenses include both the physical operations and maintenance (O&M) of the project as well as administrative costs such as insurance, property tax, land lease, and legal and accounting fees. Unfortunately, much of the available literature on these values is not consistent in their use of the

[49] The debt in SolarCity's recent securitization carried an interest rate of 4.80%.

[50] Mark Bolinger, Samantha Weaver, Jarett Zuboyl. Lawerence Berkley National Labs. $50/MWh Solar for Real? Falling Project Prices and Rising Capacity Factors Drive Utility-Scale PV Toward Economic Competitiveness https://emp.lbl.gov/sites/all/files/lbnl-183129.pdf

[51] 5.75% returned by securities of SolarCity residential PV systems, www.solarcity.com/invest

[52] www.lazard.com/media/2390/lazards-levelized-cost-of-energy-analysis-90.pdf

[53] www.woodlawnassociates.com/solar-cost-of-capital/

[54] Mark Bolinger. Lawrence Berkeley National Laboratory. An Analysis of the Costs, Benefits, and Implications of Different Approaches to Capturing the Value of Renewable Energy Tax Incentives https://emp.lbl.gov/sites/all/files/lbnl-6610e.pdf

terms operating expenses and O&M. The modeled rate falls in the middle of early (2010: commercial: $23.50, utility: $19.93) and expected (2020: commercial: $7.50, utility: $6.50) O&M costs (appears to include all operating expenses) according to the DOE SunShot Vision Study published in 2012.[55] The 2015 Lazard LCOE study assumed O&M costs (appears to include all operating expenses) ranging from $10/kW/year to $16/kW/year for utility-scale and commercial PV systems respectively.[56] The NREL *2015 Standard Scenarios Annual Report: U.S. Electric Sector Scenario Exploration and ReEDS Model Description* assumes utility-scale O&M costs of $7.61/kW/year by 2020. The LBNL studies referenced earlier use $30/kW/year. Depending on the location and nature of a PV system, the operating costs per kW of solar capacity could vary greatly, and in many cases may be higher than $10/kW$_{DC}$/year. For example, consider the following illustrative scenarios: (1) On-site systems would not have land leasing costs and may not have insurance costs, (2) The cost of DPS to perform O&M may be less than the cost to hire a solar O&M contractor, (3) Projects in the city limits will experience higher property taxes than ones outside of the city limits, (4) Larger systems, or portfolios of similar projects, will have economies of scale that limit legal and accounting costs per kW.

   i. A simple analysis for a 5-MW$_{AC}$ solar farm on leased land in Durham County estimates non-O&M operating costs of $9/kW$_{DC}$ in the first year of the project. The same system on non-leased land and after the 15-year property tax depreciation is estimated to have annual non-O&M operating costs of $2.5/kW$_{DC}$.
   ii. Operating costs of $10/kW$_{DC}$/yr. roughly translates to 0.5¢/kWh of production.

25. Federal income tax rate of 35%.[57]
26. State income tax rate of 8.5%.[58]
27. Projects owned solely by the school, either direct ownership or as the sole partner in partnership-flip LLC, do not pay income tax on revenue from electricity sales to the utility.
28. The price of unbundled RECs on the voluntary market varies, and there is no local market data available. 3 cents/kWh, or $30/MWh, is based on published comments by REC advisor Sol Systems.[59,60] It is expected that the available market rate for unbundled RECs in North Carolina could vary significantly from this best-estimate in both the near- and long-term.

[55] http://energy.gov/eere/sunshot/sunshot-vision-study
[56] www.lazard.com/media/2390/lazards-levelized-cost-of-energy-analysis-90.pdf
[57] default value in CREST
[58] default value in CREST
[59] http://ultrasolarandwind.com/solutions/solar-pv/srecs/
[60] www.solsystems.com/our-resources/srec-prices-and-knowledge

RESULTS OF COMPARATIVE LCOE ECONOMIC ANALYSIS

The results of the economic analysis are first summarized for each of the general project types, and then the results are summarized for the case of current North Carolina policies and for the case where solar policies are friendlier for commercial scale projects.

Direct Ownership, Net Meter

Direct ownership is the simplest way for DPS to provide itself with solar electricity. It is not, however, very economically attractive at this time. Since the school district is not able to utilize the available tax benefits that are available to the TPO arrangements, the LCOE is higher for direct ownership. With current North Carolina net metering policy, even at the $1.50/watt price point and a high 6% utility annual price escalation rate the school's LCOE for the life of the PV system is 1.5 cents/kWh higher than the do nothing case. Furthermore, the RECs for the system would be attributed to the utility and therefore unavailable for the school to retire. With more solar-friendly net metering policy, this scenario provides electricity at a price only 0.2 cents/kWh higher than the business as usual case.

PPA, Net Meter

This system type has two primary variables—net metering policy and debt source—that results in four different cases of net-metered third party energy sales PPA. Additionally, each of these cases could be an on-site system or a larger off-site system if net metering capacity limits are increased and virtual net metering becomes available. Current North Carolina policy does not allow any third party energy sales, so none of these cases are an option for DPS today. However, many states do allow third party energy sales, and there have been attempts to pass similar rules in North Carolina, so it is possible that these will become viable options for DPS in the future.

Direct Ownership, Sell-All

This is a simple but unattractive option. This option is included because it is the simplest way for a school to provide itself with renewable electricity (including the RECs) under current North Carolina policy. In this case the LCOE is 50% to 100% more than the do nothing case.

PPA, Sell-All

This arrangement is similar to the *PPA, Net Meter* setup except that the PV electricity purchased by the school is sold to the utility rather than net metered. As can be seen in the results table, this option is not as attractive as the net metering options. In fact, in the modeled scenarios there is not a single case where *PPA, Sell-All* saves the school district money over the life of the system.

Partnership-Flip

The partnership-flip option is by far the most complicated for the school to implement but is the only option legally available today in North Carolina that has the potential to both provide the school with renewable electricity (i.e. RECs) and save them money over the life of the system. The most attractive option, which uses the current 30% ITC and CREBs financing, can provide net savings to the school with systems at both the $1.88 and the $1.50 price points. Furthermore, our model shows that no upfront cash is required from the school for these price points. Systems without CREBs financing will require the school to provide upfront cash investment in order to attract the needed tax equity investors.

REC Purchase

This is the simplest of the currently available options for the school district to provide itself with renewable electricity, but has no chance of providing an economic savings to the school district and, as shown earlier, provides the least environmental benefit.

WITHOUT CHANGES TO NORTH CAROLINA SOLAR POLICIES

The results of this analysis, as seen in Table 9, show that there are economically attractive options for DPS to 'go solar' today. The results also make it clear that as PV prices come down, even if policies do not become more solar friendly, there are economically viable solar options for DPS. According to this analysis, the most financially attractive option for DPS schools today is the partnership-flip model. In this case, the school works with third party investors to utilize the available tax benefits in the first six years of the PV system's life and then the school takes full ownership of the PV system in year seven of the project. Using the current 30% federal investment tax credit and subsidized clean energy bond financing (CREBs), a partnership-flip project at today's commercial PV pricing ($1.88 to $2.00/watt) can provide onsite rooftop renewable energy to DPS for very close to the same cost of doing nothing, i.e. continuing to purchase all electricity from the traditional local electric utility.

As long as the federal tax credit is 30%, today's PV prices allow rooftop partnership-flip projects to supply the school with 100% renewable electricity for roughly the same cost as continuing to purchase traditional electricity from the local utility.

WITH CHANGES TO NORTH CAROLINA SOLAR POLICIES

There are several potential solar-friendly policy changes that would improve the economic attractiveness of DPS's solar PV options. Most notable is the impact of the addition of third party energy sales, because TPO allows non-tax paying entities to materialize the currently available tax incentives. *With the 30% ITC and a third party energy sales PPA at a PV price of $1.50/watt, DPS would be able to achieve 100% renewable electricity at similar or lower long-term cost than doing nothing and without the need to provide any upfront capital or operate and maintain a PV system.*

When several potential solar-friendly policies are combined, the financial attractiveness of DPS's PV options improves greatly. With changes to the state net metering rules that remove PV standby charges and leave REC ownership with the PV system owner, a third party energy sales PPA can provide very attractive electricity costs. For example, under this condition with the 30% ITC and a utility annual escalation rate of 3%, the school's long-term cost of electricity would be 5.9 cents/kWh compared to 6.9 cents/kWh in the do nothing case. The same system with a 10% federal tax credit provides renewable electricity at a similar cost to the do nothing case. With the combination of third party energy sales, removal of the 1-MW net metering size cap, and the addition of virtual net metering, it may be possible for DPS to purchase renewable electricity from North Carolina solar farms, taking advantage of the low cost of these large, simple projects.

As a degree of model verification, it may be insightful to compare the third party energy sales flat PPA rates (the CREST LCOE for the third party owner) calculated in our model to available PPA market data. In our model, these PPA rates ranged from $0.083/kWh ($1.50/watt and 30% ITC) to $0.142/kWh ($2.25/watt and 10% ITC). The latest national data on large utility-scale PV PPA rates shows a 2014 industry average of $0.05/kWh, primarily from very large solar farms in very sunny regions of the US.[61] If you convert this PPA rate from these high-

[61] https://emp.lbl.gov/sites/all/files/lbnl-1000917.pdf

radiation areas to central North Carolina, where the radiation is roughly 80% of these sunnier areas, this average PPA rate equates to $0.0625/kWh. This rate is slightly less than the lowest rate we calculated. Considering the much larger scale of the projects in the national data, and the fact that some of these projects take advantage of state incentives (such as REC sales), the PPAs calculated in our analysis are unsurprising and appear to be reasonable estimates of potential PPA rates.

System Type***	Case Summary	System Location	Billing Inter-connection	RECs Available	Current Availability	Other Considerations	$/W_DC Installed Cost: $2.25/W, Utility Annual Escalation Rate 1.5%	$2.25/W 3.0%	$2.25/W 6.0%	$1.88/W 1.5%	$1.88/W 3.0%	$1.88/W 6.0%	$1.50/W 1.5%	$1.50/W 3.0%	$1.50/W 6.0%
							School's Levelized Cost of Electricity (LCOE) for Next 25 years (¢/kWh)								
Direct Ownership, Net Meter	Net metering policy as is	On-site	Net meter	NO**	**YES** uses CREBs	No tax benefits. Simple structure, but school responsible for operations and maintence	12.8¢	13.3¢	14.5¢	11.2¢	11.7¢	12.9¢	9.6¢	10.1¢	11.3¢
Direct Ownership, Net Meter	Solar-friendly net metering policy	On-site	Net meter no standby	YES	NO requires no standby charges and no less of RECs	No tax benefits. Simple structure, but school responsible for operations and maintence	12.1¢	12.4¢	13.2¢	10.5¢	10.8¢	11.6¢	8.9¢	9.2¢	10.0¢
PPA, Net Meter	Netmetering policy as is, bank loan, 30% ITC	On-site	Net meter (PPA between 3rd Party owner and school)	NO**	NO requires 3rd Party Sales, uses 30% ITC	Very easy for the school to implement, as simple as signing the PPA. 3rd party is responsible for operations and maintenance	8.6¢	9.0¢	10.2¢	7.7¢	8.1¢	9.3¢	6.8¢	7.2¢	8.4¢
PPA, Net Meter	Solar-friendly netmetering policy, bank loan, 30% ITC	On-site or Off-site with Virtual Net Metering	Net meter, no standby (PPA between 3rd Party owner and school)	Yes buy RECs in PPA	NO requires 3rd Party Sales and no standby charges or less of RECs. Uses 30% ITC	Very easy for the school to implement, as simple as signing the PPA. 3rd party is responsible for operations and maintenance	7.9¢	8.2¢	9.0¢	7.0¢	7.3¢	8.1¢	6.0¢	6.3¢	7.1¢
Direct Ownership, Sell All	Policy as is	On-site	Sell-All to Utility (@$0.65/kWh)	YES	**YES** uses CREBs	No tax benefits. Simple structure, but school responsible for operations and maintence	12.6¢	13.7¢	16.6¢	11.0¢	12.1¢	15.0¢	9.4¢	10.5¢	13.4¢
PPA, Sell All	30% ITC	On-site or Off-site	PPA to School, then Sell-All to Utility (@$0.65/kWh)	Yes buy RECs in PPA	NO requires 3rd Party Sales, uses 30% ITC	Very easy for the school to implement, as simple as signing the PPA.	8.4¢	9.5¢	12.4¢	7.5¢	8.5¢	11.4¢	6.6¢	7.6¢	10.5¢
Partnership Flip (3rd Party Investor, Sell All)	CREBs and 30% ITC	On-Site or Off-site	Sell-All to Utility (@$0.65/kWh)	Yes buy RECs	**YES** uses CREBs and 30% ITC	Complicated and costly to setup, which will require school staff or consultant time	6.2¢	7.2¢	10.1¢	5.7¢	6.7¢	9.6¢	5.4¢	6.4¢	9.3¢
							$88,583*			$0*			$0*		
Partnership Flip (3rd Party Investor, Sell All)	Bank loan and 30% ITC	On-Site or Off-site	Sell-All to Utility (@$0.65/kWh)	Yes buy RECs from system	**YES** uses 30% ITC	Complicated and costly to setup, which will require school staff or consultant time	7.2¢	8.2¢	11.1¢	6.5¢	7.6¢	10.5¢	5.9¢	6.9¢	9.8¢
							$180,221*			$100,802*			$27,491*		
REC Purchase	Policy as is	Off-site (NC)	Sell All to Utility	YES direct REC purchase	**YES** but limited market available	Simplest option to implement, but least environmental benefit and no financial returns	8.9¢	9.9¢	12.8¢	8.9¢	9.9¢	12.8¢	8.9¢	9.9¢	12.8¢
Do Nothing			-	-	-	-	5.9¢	6.9¢	9.8¢	5.9¢	6.9¢	9.8¢	5.9¢	6.9¢	9.8¢

* School cash input at project start, per 1 MW_{DC}. This is included in LCOE.
** Demand TOU rate is not financially feasible
*** LCOE values are for solar PV, there is potential for wind in off-site cases

Shading Key: Grey = Do Nothing Cost Green = equal or less costly electricity for the school than the Do Nothing cost Yellow = slightly more costly than the Do Nothing cost Orange/Red = significantly more costly than Do Nothing cost

Table 9: Summary of LCOE for Renewable Energy Options

NOMINAL SAVINGS COMPARISON

In this section, we introduce what we term the *nominal savings analysis* in order to achieve simplicity on two fronts: (1) to express economic benefits with a simple analysis without the time value of money and (2) to express the various results using a 1-MW_{DC} standard system size so that this unit can be easily scaled to apply to various scenarios. We conducted this analysis for six 25-year scenarios with a combination of different compensation arrangements, ownership structures, North Carolina solar policies, PV price points, and costs of debt. These six scenarios represent some of the most viable approaches for DPS in the near future and include the potential of third party energy sales as an important element of the long-term analysis. The assumptions and parameters are identical to those used in LCOE analysis, although for simplicity this analysis covers just one estimate (3%) of the annual utility price escalation rate. The savings in each case is shown as the difference between continuing with status quo (do nothing) and installing a 1-MW_{DC} system.

The analysis results ranged from $480,000 in *savings* for an off-site virtually net-metered system with a third party energy sales PPA ($1.50/watt partially financed by traditional bank loan) to a *loss* of $322,000 for an on-site sell-all system under a partnership-flip ($1.88/watt partially financed by traditional bank loan). This is a range of 11% savings to 8% increased cost over 25 years. The degree of savings/loss depends primarily on the price point and the cost of debt. This analysis was completed for a 1MW_{DC} standard-density PV system for easy scalability. However, an average school in the DPS district only requires 0.7-MW_{DC} of solar PV to supply its annual electricity need. Over 25 years, such a school would pay approximately $2.9M for electricity consumption under the current utility tariff, assuming a three percent annual price escalation. The complete results of this analysis are shown in Table 10. Since the values for each scenario have been standardized to a 1-MW_{DC} system, each of the corresponding figures can be scaled to fit different project sizes or for single schools, such as Oak Grove Elementary.

The best current opportunity for DPS to maximize financial return on a solar investment is a large ground-mounted partnership-flip project in which DPS provides low-cost debt financing with CREBs and a tax equity investor monetizes the 30% federal tax credit and accelerated depreciation. *Such an arrangement can provide DPS with lower-cost electricity over the 25-year life of the system, saving the school district $370,000 over the life of each 1-MW_{DC} of PV installed, or on average of about $259,000 for each school that achieves 100% renewable electricity.* This is a savings of 9% from the business as usual case. Another perspective we can take is via the entire budget of the DPS school district, which is recommending a total of close to $6M for electric services for FY2015-2016. *Under the partnership-flip options utilizing CREBs at both $1.88/watt and $1.50/watt the entire DPS district can theoretically achieve 100% renewable electricity today and still realize savings on its annual expense for electric services.*

System Type	Case Summary	Billing Inter-connection	RECs Available	Current Availability	PV price per Watt$_{DC}$	Total 25-year Electricity Cost per 1 MW_{DC} of PV (2015 Dollars)	Savings from Do Nothing (2015 Dollars)	Percent Savings from Do Nothing
PPA, Net Meter	$1.88/W, Solar-friendly Netmetering policy, bank loan, 30% ITC	Net-Meter, no standby (PPA between 3rd Party owner and school)	YES buy RECs in PPA (assumes policy update)	**NO** requires third party energy sales, no standby charges, & no loss of RECs	$1.88	$4,250,000	-$50,000	-1%
	$1.50/W, Solar-friendly netmetering policy, no size cap, virtual net metering, bank loan, 30% ITC	Net-Meter, no standby (PPA between 3rd Party owner and school)	YES buy RECs in PPA (assumes policy update)	**NO** requires third party energy sales, no standby charges,no loss of RECs, increased size cap, & virtual net metering	$1.50	$3,720,000	$480,000	11%
Partnership Flip (3rd Party Investor, Sell All)	$1.88/W, Sell-All to Utility (@$0.65/kWh), CREBs, and 30% ITC	Sell-All to Utility (@$0.65/kWh)	YES buy RECs	**YES** uses CREBs and 30% ITC	$1.88	$4,040,000	$160,000	4%
	$1.50/W, Sell-All to Utility (@$0.65/kWh), CREBs, and 30% ITC	Sell-All to Utility (@$0.65/kWh)	YES buy RECs	**YES** uses CREBs and 30% ITC	$1.50	$3,830,000	$370,000	9%
	$1.88/W, Sell-All to Utility (@$0.65/kWh), bank loan, and 30% ITC	Sell-All to Utility (@$0.65/kWh)	YES buy RECs	**YES** uses 30% ITC	$1.88	$4,522,000	-$322,000	-8%
	$1.50/W, Sell-All to Utility (@$0.65/kWh), bank loan, and 30% ITC	Sell-All to Utility (@$0.65/kWh)	YES buy RECs	**YES** uses 30% ITC	$1.50	$4,166,000	$34,000	1%
Do Nothing		-	-	-	-	$4,200,000	$0	0%

Shading Key: Grey = Do Nothing Savings Green = equal or less costly electricity for the school than the Do Nothing cost

Light Red = slightly more costly than the Do Nothing cost Red = significantly more costly than Do Nothing cost

Table 10: Summary of Nominal Savings Analysis

10. Conclusions and Next Steps

It is both technically and economically feasible for DPS to meet all of its annual electricity needs with solar PV systems, although not without challenges. Achieving 100% renewable electricity will take strong leadership and a new approach to energy management over the long-term, but provides an opportunity to not only reduce electricity costs but also provide additional benefits to students and the surrounding community.

There are multiple pathways to 100% renewable electricity for the district, and each is likely to change over time as policies, technologies, and markets grow and develop. Some pathways include mostly school-by-school projects and others include more focus on development of large portfolios of on-site solar PV or even large, utility-scale off-site solar farms. Below we summarize the concepts we detailed in the report, and our key technical and economic findings to aid DPS in developing the simplest path to investing in renewable energy.

Policy and Market Considerations

Solar-friendly updates to certain state policies could significantly increase the economic feasibility for commercial-scale solar installations. Similarly, the trends in market conditions may open up more financial options for schools to go renewable. The best pathway to 100% renewable electricity at a given time depends on current policies (e.g. third party energy sales, net metering, rate structures, and tax incentives) and market conditions (e.g. interest rates, PV pricing, electric rates, and avoided cost rates).

Policy Considerations

There are many policies regulating renewable energy that could be made more solar-friendly to allow increased access and more affordable options for solar in North Carolina. Most significant according to the economic findings in this report, is the availability of state and federal investment tax credits (ITC), hand in hand with allowing for third party energy sales in North Carolina and making net metering more solar-friendly. In late 2015, the Federal ITC of 30% was extended to the end of 2019, followed by yearly step-downs to 10% by 2022. On the other hand, the North Carolina ITC of 35% ended on December 31, 2015. Permitting third party energy sales would allow schools and other nonprofit entities to more easily monetize cost reductions for renewable energy installations such as the ITC. Other policy changes in North Carolina that can improve solar economics include updates to net metering (e.g. reduced standby charges, meter aggregation, annual net excess carryforward), increasing avoided cost rates for sell-all arrangements, and improving interconnection standards.

Market Considerations

Current market trends provide strong indication for continued price reduction and technology improvement for solar PV and wind technology. Commercial solar installations are projected to decrease significantly in the next few years, going from $2.00/watt today to $1.50/watt for rooftop and $3.00/watt to $2.50/watt for parking lot structures by 2020. Similarly, utility-scale solar farms are also set to decrease with turnkey installation prices dropping from $1.50/watt today to less than $1.00/watt by 2020[62]. This continued drop in solar costs is happening while utility electricity prices increase and natural gas prices continue to fluctuate, making purchasing

[62] http://energy.gov/eere/sunshot/sunshot-vision-study

electricity from the grid increasingly more expensive. Together these trends suggest that the road to 100% renewable electricity will continue to become cheaper, clearer, and easier.

TECHNICAL AND ECONOMIC CONCLUSIONS

Technical Analysis Summary

According to our estimates, DPS has adequate roof and parking lot area to meet all their annual electricity usage with on-site solar power. We assessed the on-site roof and parking lot areas feasible for PV systems and estimated the output of PV installed in these locations, taking into account the structure orientation and local shading. This analysis did not consider on-site or adjacent property areas for ground-mounted systems, but some of these sites surely exist. Also, this analysis did not consider off-site availability, because such sites are beyond the scope of this analysis.

A detailed technical assessment of a significant sample of DPS schools found that with conservatively-sized systems there is ample roof and parking lot space to provide 100% of the school district's annual post-EE electricity needs from on-site solar photovoltaic (PV) systems. We estimate that close to half of the district's schools can meet 100% of their individual post-EE annual electricity usage with conservatively-sized rooftop and parking lot shade structure PV systems. District wide, conservatively sized rooftop-only systems could provide over 17-MW_{DC} of PV capacity and 24,200,000 kWh per year, which on average meets 51% of each school's post-EE electricity demands. Adding the conservatively sized parking lot systems nearly doubles the total PV capacity and annual energy production, bringing the combined system to 34-MW, and in total meeting 100% of the DPS total annual electricity usage.

Economic Analysis Summary

The economic analysis shows that there are options for schools to finance solar installations today and save money, but they are limited due to current policy and market conditions. The most attractive option available today is a partnership-flip arrangement. As shown in the results of the levelized cost of electricity (LCOE) and nominal savings analysis, even with the elimination of the State ITC, a partnership-flip with CREBs financing can provide net savings to the school with systems at both the $1.88/watt and the $1.50/watt price points. Furthermore, our model shows that in this case no upfront cash is required from the school for either of these two price points.

Although current North Carolina regulations disallow third party energy sales, there are numerous versions of a third party energy sales PPA that could supply DPS with economic savings from renewable electricity if legal. These arrangements are attractive to school districts not only because they can save the school district significant money, but also because they allow the district to acquire renewable electricity with no upfront investment and very little upfront or ongoing administrative burden. In the most optimistic cases we've analyzed (which require not only the availability of third party energy sales but also removal of standby charges), it is possible for these systems to provide the school with lower cost electricity than the do nothing scenario at $1.50/watt PV and in cases with high utility annual price escalations at $1.88/watt and even at $2.25/watt PV. In the case of a 30% ITC, no standby charge, and a $1.50/watt PV price point, each 1-MW of third party sales PPA in use would save DPS close to $500,000 over the 25 year of the life of the system, which is an 11% nominal savings in the cost of electricity.

Summary of Attractive Project Options

Most attractive system type currently:
Partnership-flip project with school taking ownership at flip in year seven, in the form of a large on-site or off-site ground-mount system (~$1.50/watt), or a portfolio of on-site solar PV rooftop projects (~$1.88/watt). School providing low cost financing via CREBs.

Once ITC is reduced to 10% in 2022, the most attractive system type may be:
Partnership-flip project with school taking ownership at flip in year seven, in the form of off-site ground-mount system (~$1.00/watt). School providing low cost financing via CREBs (greater importance of utilizing CREBs or traditional municipal bonds for low-cost project financing).

If third party sales become legal in North Carolina, attractive financing options include:
Partnership-flip project with school taking ownership at flip in year seven, in the form of a large on-site or off-site ground-mount system (~$1.50/watt), or a portfolio of on-site solar PV rooftop projects (~$1.88/watt). School providing low cost financing via CREBs.
Third party energy sales PPA, net-metered or virtual net-metered with REC retirement by school.

Recommended Next Steps

Continue Energy Conservation and Energy Efficiency Improvements

While DPS have been making energy efficiency improvements in recent years, there is still room to economically reduce energy usage. Our roadmap to 100% renewable electricity assumed an additional 25% energy efficiency improvement across the district.

All New Schools Net Zero Energy (100% renewable energy)

Start by making any new schools energy efficient via use of daylighting and adding enough PV to be zero-energy. Due to the synergies of designing and financing the solar PV system along with an energy efficiency building, such a school is often the best economic option for the school district, with or without a goal of being 100% renewable energy powered.

Build Solar PV Experience, Expertise, and Relationships Starting Now

Start to consider the development of an on-site or off-site ground-mounted PV system and/or significant-sized PV systems on the best schools (new roofs or metal roofs with large, unshaded areas). To facilitate this, rooftop solar can be viewed as an opportunity to fund refurbishment of roofs in need of repair. This can begin with a more detailed analysis of the economics of partnership-flip projects, evaluation of the possibility to issue new bonds, including CREBs, and eventually running a Request for Proposals (RFP) to solicit bids to consider. The sooner DPS is able to start developing and installing solar PV projects, the higher on the solar learning curve it will climb and the stronger and deeper its relationships with the solar PV industry will be.

Monitor Policy, Market, and Technological Trends and Changes

DPS should continue to watch for policy, market, and technological triggers to reevaluate deployment strategy and tactics. It is possible that as the factors shift there will be a first mover advantage in the ability to access the limited installation capacity of the local industry during what could potentially be a limited period of attractive conditions. Also, DPS could develop a detailed, long-term plan to study and forecast the impact of the current solar policies, utility rates, and PV prices at the end of each fiscal year and convert them to a metric for economic analysis. Part of that plan could be performance of an internal solar assessment at the onset of any reroofing project to determine if it is an attractive time and place for a rooftop PV installation.

Be Powered by 100% Renewable Electricity

Achievement of 100% renewable electricity could bring with it numerous benefits to the school district, including financial savings and stable electricity costs, benefits to the students, such as the in-school solar PV laboratory, and benefits to the greater community with a cleaner and more sustainable environment.

APPENDIX A: SAMPLING CALCULATIONS

To make the most efficient use of resources, not every school's roof and parking lot was manually mapped. Doing so saves significant time and has minimal impact on the district-wide analysis because the sampled schools can be used to accurately (within a calculated margin of error) estimate the cumulative PV capacities for the full district. The results of the sampled schools are used to determine the average roof and parking lot PV capacity per square foot of school floor area for the sample. This average can then be applied to non-sampled schools to reasonably estimate each non-sampled school's rooftop, parking lot, and green space PV capacities, as well as their annual electricity production.

To begin, all DPS schools were placed in an alphabetically list and assigned a number, starting with one. Next, the schools were placed in a random order. This was done using one of the tools at random.org to put the numbers from 1 to 49 in a random order, and reordering the list according to this random order. Sampling began at #1 and continued down the list until the required number of schools to represent the average of the full population of district schools to an acceptable margin of error and confidence level had been sampled.

The variable on which the sample size was determined is the solar PV DC capacity (per school building square footage (W_{DC}/ft^2). We used a t-distribution to calculate the required sample size, which requires an estimate of the standard deviation of W/ft^2 for all schools in DPS. Since the standard deviation for the full population could not be known without mapping every school, a sample group of the first 10 schools on the randomized list were mapped and the standard deviation of this sample was used as an estimate of the full population. For the first 10 schools, this standard deviation is 2.6 W/ft^2. Once a larger sample was completed, the standard deviation of the larger sample was used as the estimate of the standard deviation of the full population of DPS schools.

Here are the values for the first 10 sampled schools:

	Building Square Footage	**Conservative W_{DC}/sf**	**Standard W_{DC}/sf**	**Aggressive W_{DC}/sf**
OAK GROVE ELEMENTARY	96,061	8.9	13.3	20.8
C C SPAULDING ELEMENTARY	69,486	4.7	6.7	10.0
LAKEVIEW SCHOOL	40,769	10.2	14.8	22.6
MANGUM ELEMENTARY	54,838	6.4	8.8	12.9
GEORGE WATTS ELEMENTARY	65,841	3.4	5.1	7.7
LAKEWOOD-MONTESSORI MIDDLE	71,278	3.4	4.8	7.1
HOLT ELEMENTARY	98,208	7.2	10.6	17.3
SOUTHWEST ELEMENTARY	91,170	7.8	12.2	20.0
EASLEY ELEMENTARY	71,170	8.1	12.9	21.5
CITY OF MEDICINE ACADEMY	40,519	5.0	7.0	10.4

Percent Confidence	Variable on which to base required sample size	Standard Deviation	Margin of Error results in this variation of PV total capacity for average school (kW)	Margin of Error as percentage of average school	Required Sample Size
90%	W/sf (total standard)	3.31	116	14.4%	20
95%	W/sf (total standard)	3.31	141	17.4%	20

Table 14: Required Sample Size at 90% and 95% Confidence Levels

For a W/ft^2 margin of error of less than 15% of the average school's PV capacity (combination of rooftop and parking lot), a sample size of 20 is required (90% confidence). For a 95% confidence, a sample size of 20 provides a margin of error of PV capacity of 141 kW, or 17.4% of the standard system size. This is very reasonable because the range from conservative and aggressive capacity is on the order of 500 to 1,000 kW for most schools.

APPENDIX B: PV CAPACITY AND PRODUCTION METHODOLOGY DETAILS

PV CAPACITY ESTIMATION METHODOLOGY

The roof area and parking lot area suitable for PV generation for each sampled school was manually mapped in Google's MyMaps platform, which allows layers of data to be added to Google Maps (satellite photos) and saved. Each non-contiguous roof area (or roof with different properties) was generally mapped separately. The same was done for parking lot areas and green space. As each area was mapped, the analysis added data about the area to that unique area, including the area of the polygon as calculated by MyMaps. This data was then exported to a spreadsheet. The key factors determining the capacity or production of an area are added to the name for easy import into excel. Notably, the "fill" label which represents what fraction of the mapped area to be covered in PV in a conservative density design (e.g. big groups of panels with very little shade, not too close to anything). See Figure 9 for an example.

An example of shading impact estimate is shown below. Figure 17 is the parking lot in question. At this site it was difficult to estimate shading from the satellite photos provided in MyMaps, but this school had 3D data available in Google Earth (available for many of the sampled DPS schools), making it quick to estimate the tree height and location. In this case, this data was put into HelioScope to estimate annual energy lost due to this shading, but in some cases shading impacts were estimated without taking this step.

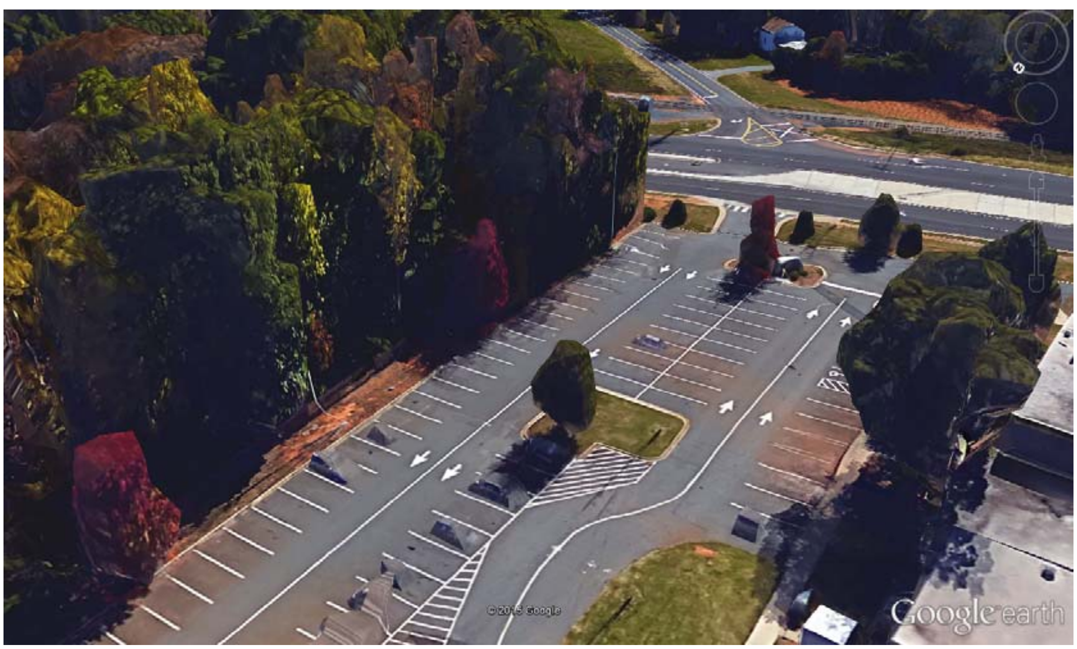

Figure 17: Example 3D Mode of School Parking Lot in Google Earth Used for Shading Analysis

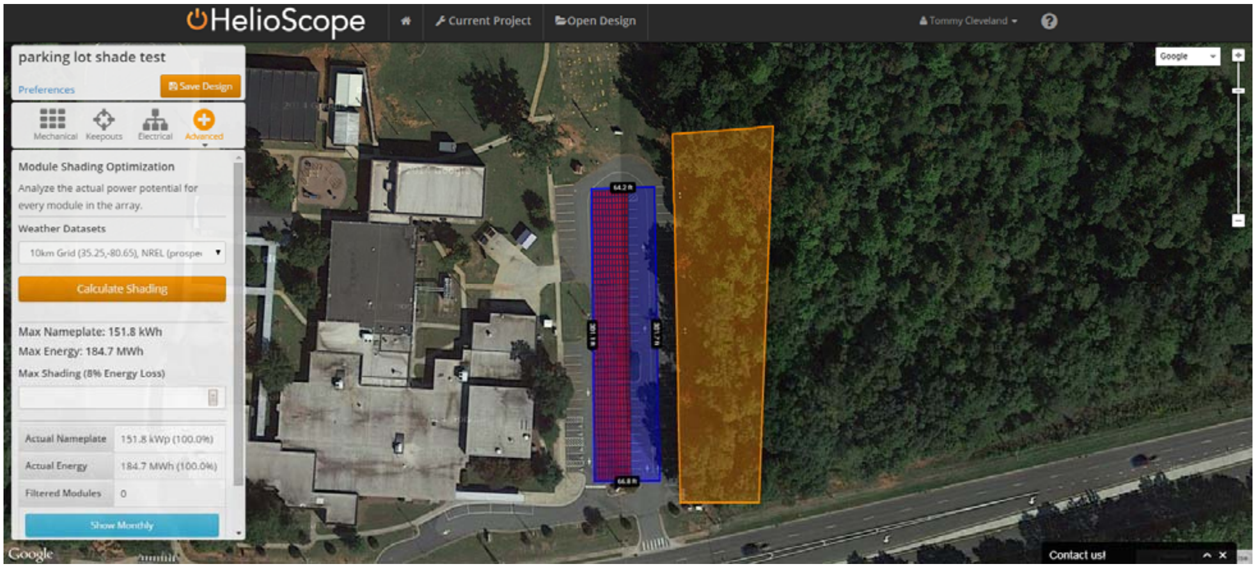

Figure 18: Modeling Shading's Impact on Energy Production in HelioScope

DPS uses mobile classrooms, but these structures were not mapped for PV installations given their temporary design. However, the square footage of these mobile classrooms are included in the school square footage and their energy use provided by DPS and included in the school's energy use data.

Conservative, Standard, and Aggressive Capacity-Density Systems

Depending on a number of variables, there is a rather wide range of PV capacities that one may consider as the maximum PV capacity for a given area. Rather than simply estimate one of these levels, we attempt to estimate a conservative, standard, and aggressive capacity for each mapped area.

In general, the standard system size is middle of the road capacity for the area (representing standard practice and equipment today), the conservative is a lower-cost and higher performing (in kWh/kW) system, and aggressive is the most capacity that today's commercial technology will allow.

The table below describes many specifics each of these levels for the three types of areas in more detail.

	Conservative	Standard	Aggressive
General	• No tree cutting to remove shade	• No tree cutting to remove shade around buildings, minor tree removal for parking lots	• Tree cutting single or small groups of trees if shading large area
Flat Roof	• Modules orientated to roof edge • 10° PV module tilt, landscape • 15.5% efficiency module • 1.5 ft between rows, very minimal inter-row shading • The above results in 8.8 W per ft^2 of plane-of-roof area [63] • ~6' border around roof edge, around obstacles • No more than 80% of array area of standard (some areas use lower %, manually estimated based on easy areas for each mapped area) • Base performance: 1450 kWh/kW	• Modules orientated to roof edge • 10° PV module tilt, landscape • 15.5% efficiency module • 1.2 ft between rows, minimal inter-row shading • The above results in 10.5 W per ft^2 of plane-of-roof area • ~6' border around roof edge, around obstacles • Walkway access to HVAC units • Base performance: 1425 kWh/kW	• Modules orientated to roof edge • 10° PV module tilt • 20% efficiency module in alternating E-W facing rows, covering some small obstacles, or N-S facing rows of TenK modules[64] • The above results in 14.5 W per ft^2 of plane-of-roof area • ~6' border around roof edge, around obstacles • Walkway access to HVAC units • Base performance: 1275 kWh/kW
Sloped Roof	• Modules orientated to roof edge • PV module flush to roof • 15.5% efficiency module • The above results in 14 W per ft^2 of plane-of-roof area • Base performance: 1450 kWh/kW	• Modules orientated to roof edge • PV module flush to roof • 15.5% efficiency module • The above results in 14 W per ft^2 of plane-of-roof area • Base performance: 1425 kWh/kW	• Modules orientated to roof edge • PV module flush to roof • 20% efficient module • The above results in 19.7 W per ft^2 of plane-of-roof area • Base performance: 1400 kWh/kW
Parking Lot	• 10° PV module tilt • 15.5% efficiency module • No more than 75% of array area of standard • Base performance: 1450 kWh/kW	• 10° PV module tilt • 15.5% efficiency module • Base performance: 1425 kWh/kW	• 10° PV module tilt • 20% efficiency module • Base performance: 1400 kWh/kW
Green Space (for reference)	• Modules orientated to South • 20° PV module tilt • 15.5% efficiency module • No more than 75% of array area of standard • Base performance: 1475 kWh/kW	• Modules orientated to South • 20° PV module tilt • 15.5% efficiency module • No inter-row shading on winter solstice 9M to 3PM • Base performance: 1475 kWh/kW	• Modules orientated to South • 20° PV module tilt • 20% efficiency module • No inter-row shading on winter solstice 9M to 3PM • Base performance: 1475 kWh/kW

Table 15: Defining Levels of PV Capacity Aggressiveness

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[63] A low power density design, built from multiple sources

[64] There are several factors that can increase the power density: module efficiency, module tilt, and module row orientation (i.e. S or E&W). Lower tilt rows increase power density some, but E-W design increases by about 20%
TenK DUO-A Rooftop (which has 16 deg tile S facing backed by 25 deg tilt N facing rows) data sheet specs 14.4 to 16.2 W/sf, which is at least 65% more peak power density than nominal, they claim up to 60% more kwh/sf as legacy systems. So, high power density is SunPower with E-W design (e.g. Zep), which is nominal * 1.40 * 1.20 = 68% higher than nominal. Alternatively is the TenK DUO-A system with a very similar increase in power density.

For example, here is the Oak Grove Elementary data collected from the manual mapping:

Type and ID	Area	(Conservative) Fill Factor	(Standard) Fill Factor	Shade Factor	Orientation (180 is south facing)	Roof Tilt (degrees)	Roof-Tilt-Adjusted Area (plane of roof area) (acre)
Roof 01	0.138	0.60	0.78	1.00	195	0	0.138
Roof 02	0.039	0.95	0.95	1.00	195	0	0.039
Roof 03	0.033	0.95	0.95	1.00	195	0	0.033
Roof 04	0.341	0.70	0.83	1.00	195	0	0.341
Roof 05	0.086	0.95	0.95	1.00	195	0	0.086
Roof 06	0.128	0.70	0.83	1.00	195	0	0.128
Roof 07	0.135	0.60	0.78	1.00	195	0	0.135
Roof 08	0.137	0.60	0.78	1.00	195	0	0.137
Roof 09	0.434	0.40	0.68	1.00	195	0	0.434
Park 01	0.393	0.95	0.95	1.00	195	0	0.399
Park 02	0.350	0.95	0.95	1.00	195	0	0.355
Park 03	0.300	0.95	0.95	0.90	180	0	0.305
Park 04	0.064	0.95	0.95	1.00	195	0	0.065

Here are the Roof PV capacity values for from Oak Grove Elementary

	CONSERVATIVE ROOF PV DC Capacity (kW_{DC})	STANDARD ROOF PV DC Capacity (kW_{DC})	AGGRESSIVE ROOF PV DC Capacity (kW_{DC})
Roof 01	27	47	89
Roof 02	12	17	25
Roof 03	10	14	21
Roof 04	78	129	219
Roof 05	27	37	55
Roof 06	29	48	82
Roof 07	26	48	87
Roof 08	27	49	88
Roof 09	57	134	278

The Parking lot areas, again Oak Grove Elementary as an example:

	CONSERVATIVE PARKING LOT PV DC Capacity (kW_{DC})	STANDARD PARKING LOT PV DC Capacity (kW_{DC})	AGGRESSIVE PARKING LOT PV DC Capacity (kW_{DC})
Park 01	173	231	325
Park 02	154	206	290
Park 03	132	176	248
Park 04	28	38	53

ANNUAL GENERATION ESTIMATION METHODOLOGY

Next, these three levels of PV capacity were each used to estimate annual energy production. Minimal horizon shading is considered on all areas, but additional shade is calculated as noted in data from maps. A custom combination of PV Watts and Helioscope results are the basis for the kwh/kW_{DC} values were used in order to convert the kW_{DC} capacities into annual energy (kWh). Additionally, as seen in the table below, module tilt and orientation are used in the calculations (these impacts calculated using PV Watts).

Area ID	Orientation and Tilt adjustment factor (used for Roof and Park)	CONSERVATIVE Annual Production (kWh)	STANDARD Annual Production (kWh)	AGGRESSIVE Annual Production (kWh)
Roof 01	0.991	38,771	65,796	111,853
Roof 02	0.991	17,348	23,933	31,611
Roof 03	0.991	14,679	20,251	26,747
Roof 04	0.991	111,770	181,725	276,390
Roof 05	0.991	38,255	52,775	69,705
Roof 06	0.991	41,955	68,213	103,747
Roof 07	0.991	37,928	67,584	109,421
Roof 08	0.991	38,490	68,585	111,042
Roof 09	0.991	81,287	189,234	351,769
Park 01	0.991	249,186	320,791	451,399
Park 02	0.991	221,922	285,692	402,010
Park 03	1.000	172,735	222,372	312,909
Park 04	0.991	40,580	52,241	73,510

Table 16: Example Annual Generation Results for Each Roof and Parking Lot Shade Structure Area

APPENDIX C: VALIDATION OF CAPACITY AND PRODUCTION MODELING

Out of the first 10 schools on the randomized list, Oak Grove Elementary was chosen as the 'typical' school on which to conduct a validation of the capacity and production model. In this case, 'typical' means 'not atypical', it does not mean average or median. This is a larger elementary school, which is much smaller than most high schools.

The rooftops and parking areas were modeled in detail using HelioScope PV design software. This package is leading the industry on the capabilities of its PV modeling software, especially for commercial rooftops. In creating this detailed model for Oak Grove, we are able to improve and validate the much quicker manual modeling process for system capacity and electricity generation accuracy, roof by roof, that was used on all of the sampled schools.

To facilitate model comparison, roof areas matching those in the manual model were defined in HelioScope. The spacing around rooftop equipment, such as HVAC units, are calculated based on annual shading impacts. The full details that are specified in *Table 10: Defining Levels of PV Capacity Aggressiveness* are modeled, with the exception of the E-W or N-S array designs in the aggressive flat rooftop system type. These array designs are not readily modeled in HelioScope, but can be compared to the manufacturer's claims of 20% increase in array density and the well understand benefits of increased module efficiency.

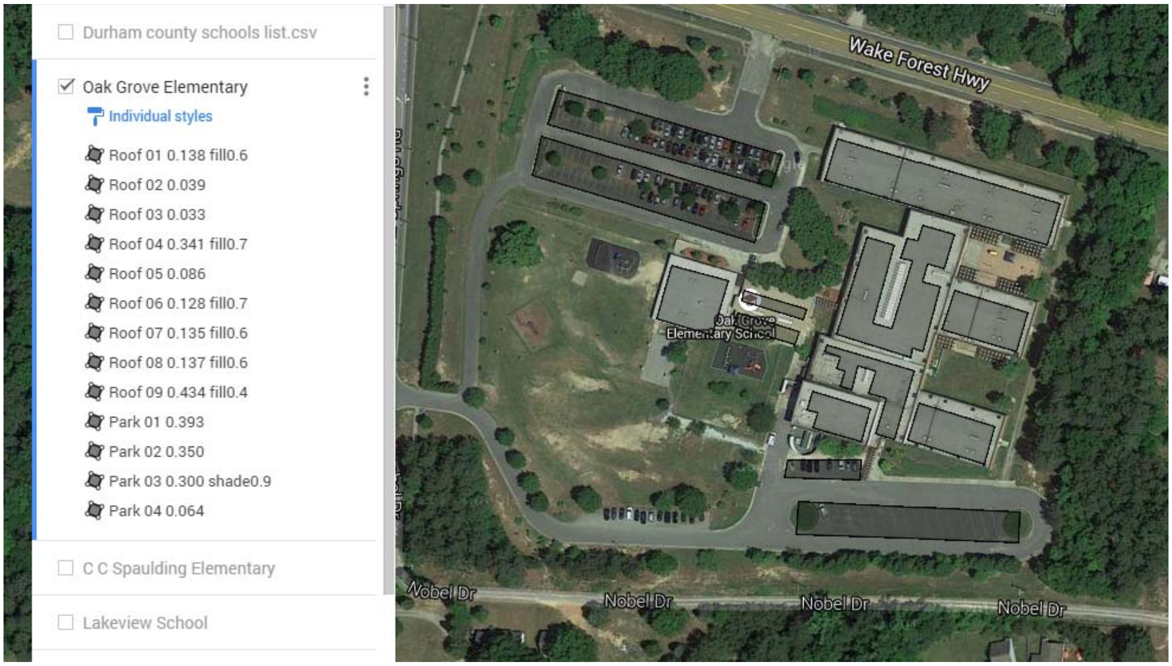
As can be readily seen in Table 17, the HelioScope model and the final custom methodology and model developed for this study are in excellent agreement for this sampled school. The initial custom methodology was improved slightly based on comparison to models of the same systems in HelioScope. The areas of the same color are the only values appropriate to be compared. The HelioScope conservative parking lot model did not conservatively downsize the system as the custom model did. In addition, the aggressive model was not simulated in Helioscope because it does not yet offer an east-west racking system.

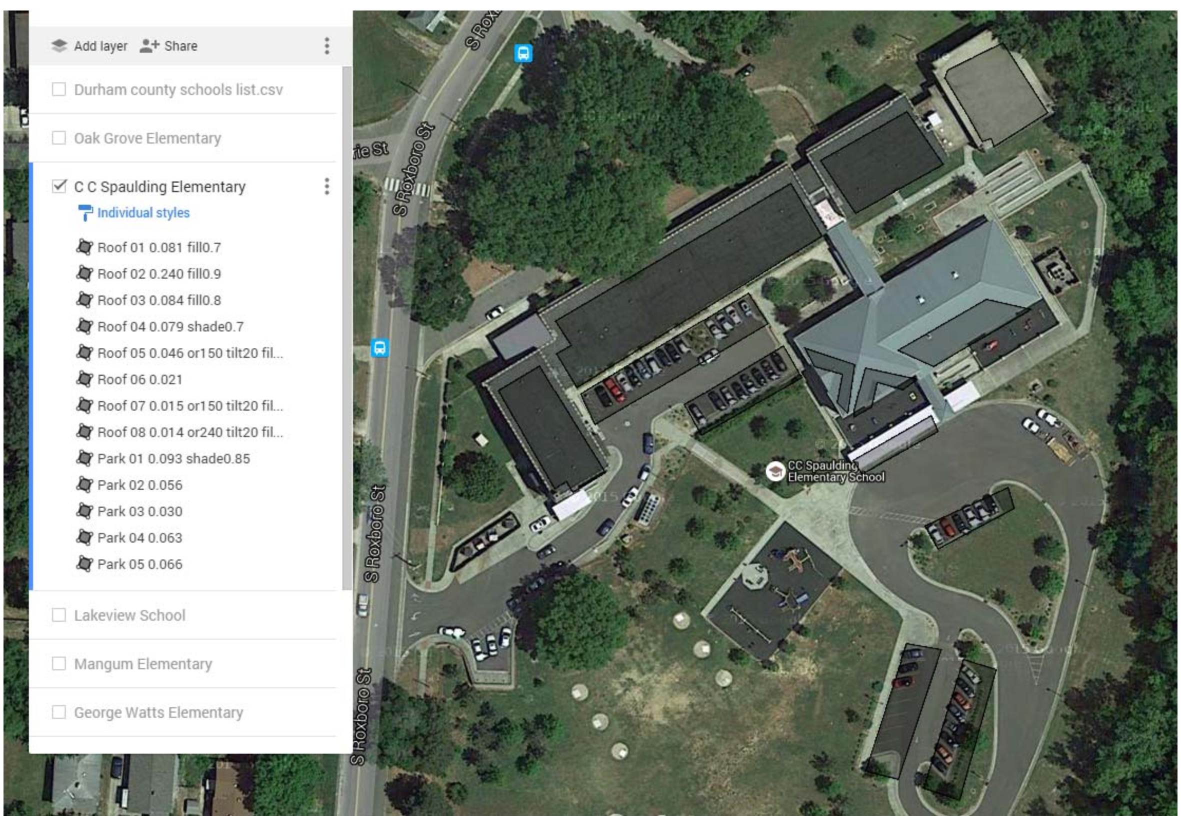
	HelioScope Production (MWh)	Manual Mapping Production (MWh)			HelioScope Production (MWh)
	Conservative	Conservative	Standard	Aggressive	Standard
Roof Total	664	420	738	1192	934
Parking Lot Total	799	684	881	1240	1000
Total	1210	986	1467	2432	1934

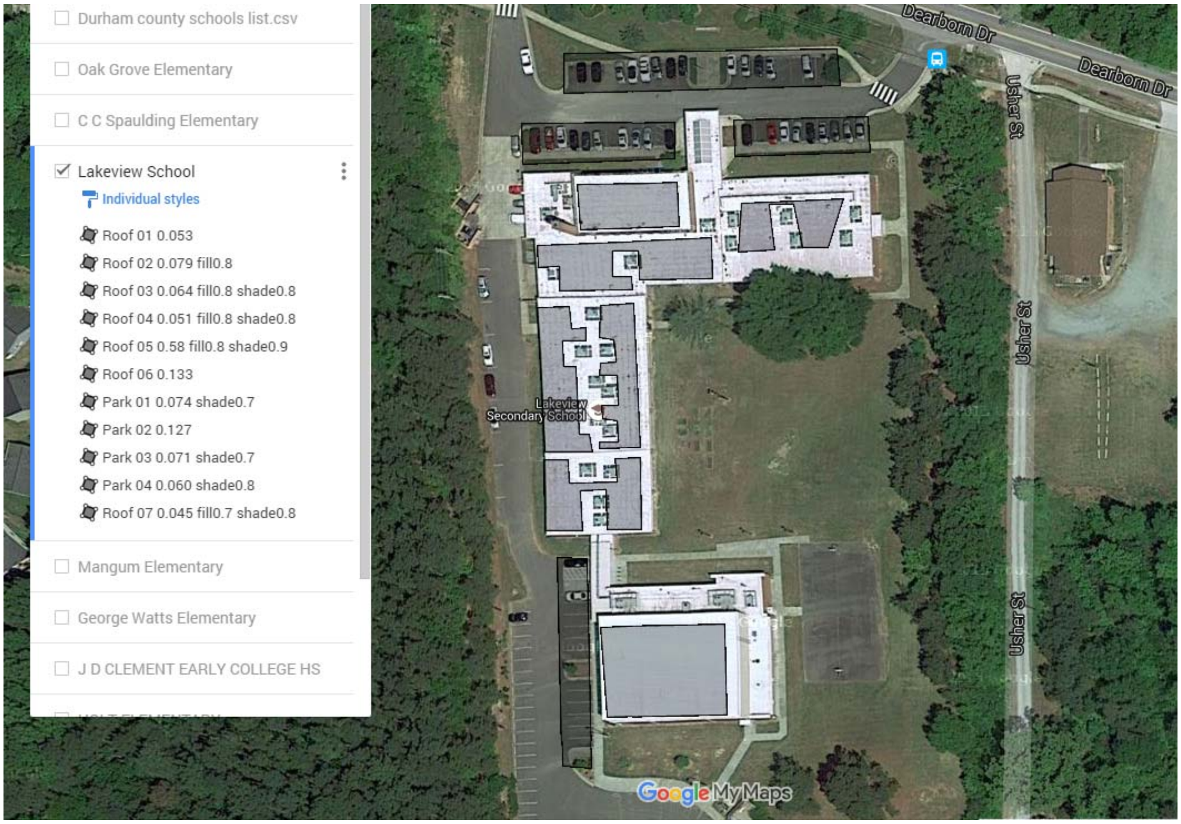
Table 17: Results of Comparison of HelioScope and Custom Models for Oak Grove Elementary (compare like-color cells)

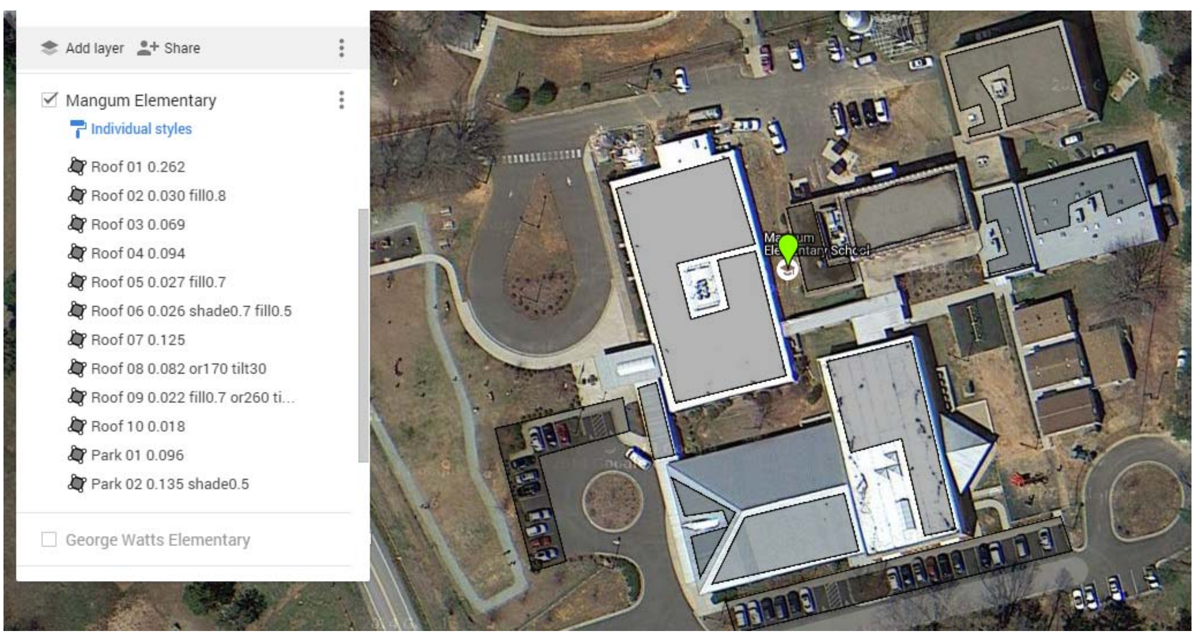
APPENDIX D: MAPS OF EACH SAMPLED SCHOOL

The school name is shown in the white box on the left of each image. Under the school name, you can see the label and attributes for each roof and parking lot surface mapped as suitable for solar PV.






Durham county schools list.csv
Oak Grove Elementary
C C Spaulding Elementary
Lakeview School
Individual styles
Roof 01 0.053
Roof 02 0.079 fill0.8
Roof 03 0.064 fill0.8 shade0.8
Roof 04 0.051 fill0.8 shade0.8
Roof 05 0.58 fill0.8 shade0.9
Roof 06 0.133
Park 01 0.074 shade0.7
Park 02 0.127
Park 03 0.071 shade0.7
Park 04 0.060 shade0.8
Roof 07 0.045 fill0.7 shade0.8
Mangum Elementary
George Watts Elementary
J D CLEMENT EARLY COLLEGE HS
Dearborn Dr
Dearborn Dr
Usher St
Usher St
Usher St
Lakeview
Secondary School
Google My Maps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Share
Mangum Elementary
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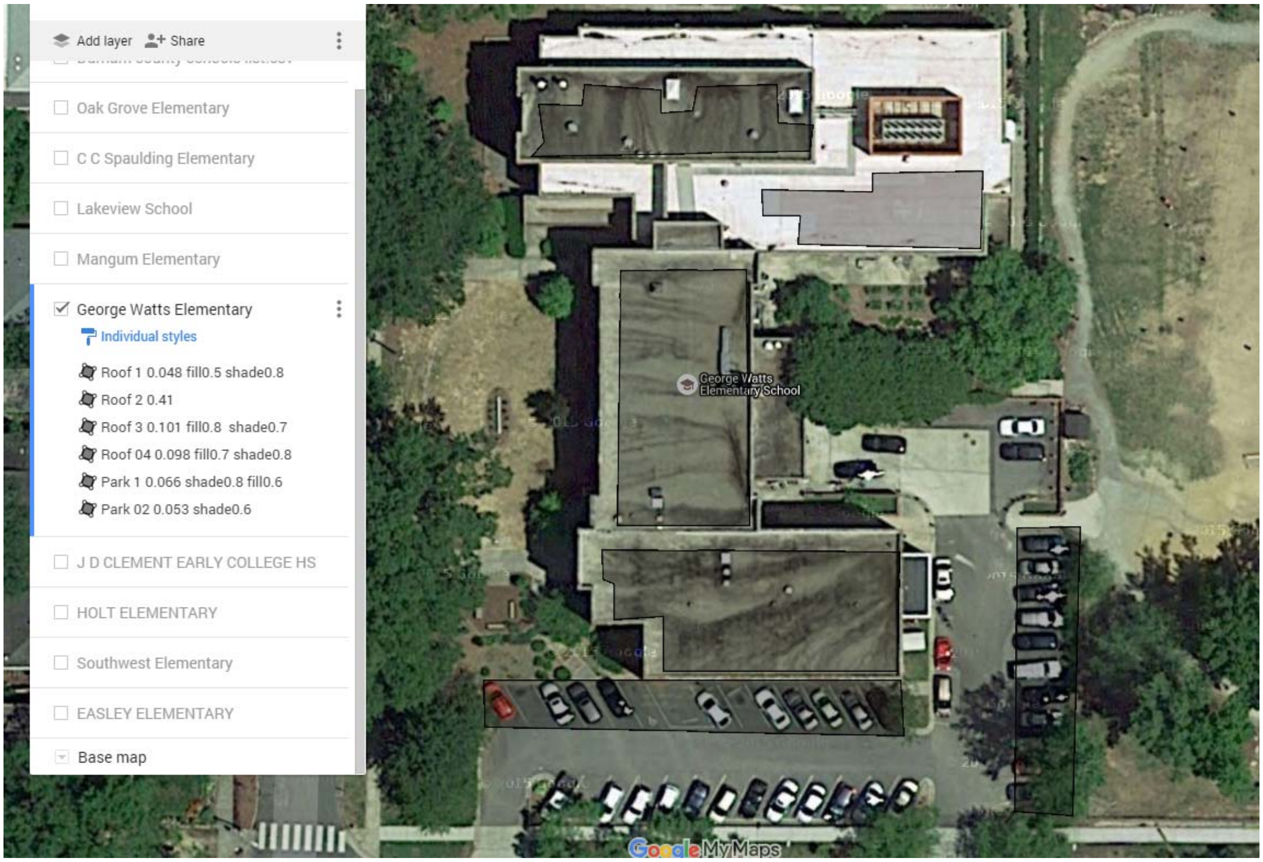
Roof 03 0.069
Roof 04 0.094
Roof 05 0.027 fill0.7
Roof 06 0.026 shade0.7 fill0.5
Roof 07 0.125
Roof 08 0.082 or170 tilt30
Roof 09 0.022 fill0.7 or260 ti...
Roof 10 0.018
Park 01 0.096
Park 02 0.135 shade0.5
George Watts Elementary


Add layer
Share
Oak Grove Elementary
C C Spaulding Elementary
Lakeview School
Mangum Elementary
George Watts Elementary
Individual styles
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Roof 2 0.41
Roof 3 0.101 fill0.8 shade0.7
Roof 04 0.098 fill0.7 shade0.8
Park 1 0.066 shade0.8 fill0.6
Park 02 0.053 shade0.6
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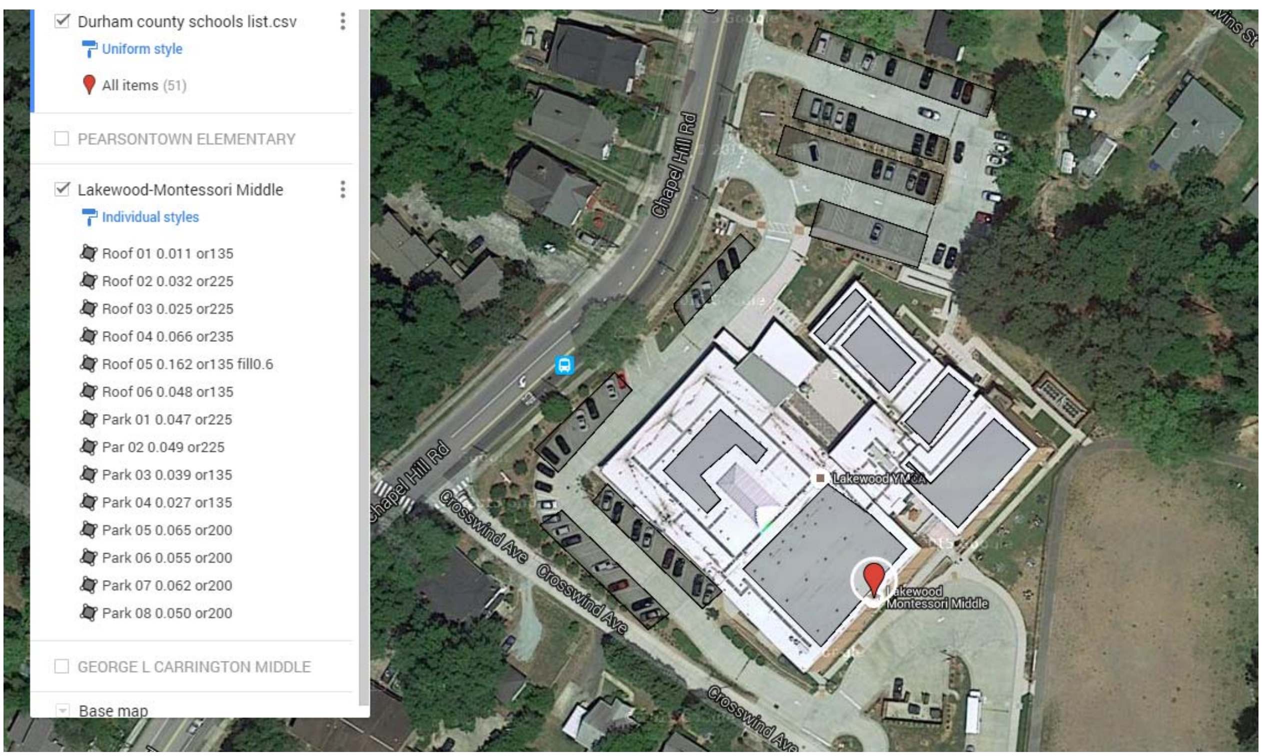
HOLT ELEMENTARY
Southwest Elementary
EASLEY ELEMENTARY
Base map
George Watts Elementary School
Google My Maps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All items (51)
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Lakewood-Montessori Middle
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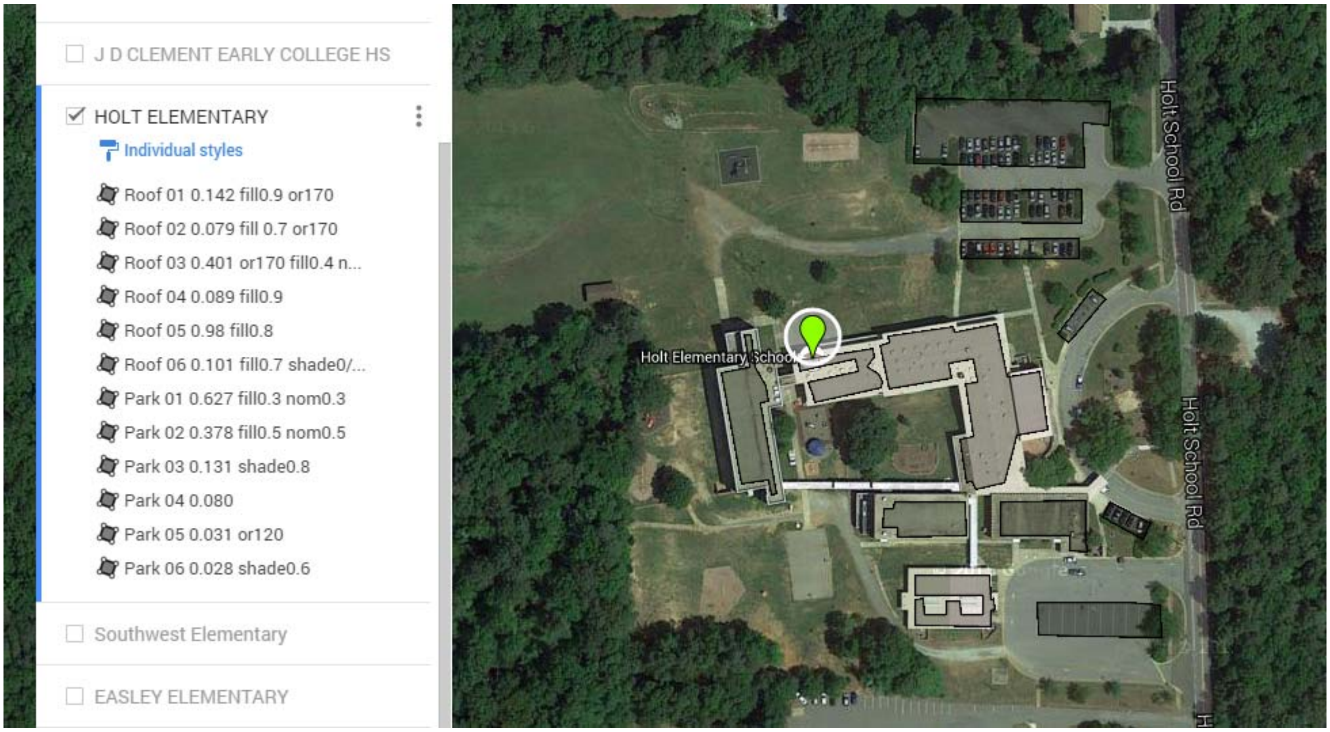
Roof 02 0.032 or225
Roof 03 0.025 or225
Roof 04 0.066 or235
Roof 05 0.162 or135 fill0.6
Roof 06 0.048 or135
Park 01 0.047 or225
Par 02 0.049 or225
Park 03 0.039 or135
Park 04 0.027 or135
Park 05 0.065 or200
Park 06 0.055 or200
Park 07 0.062 or200
Park 08 0.050 or200
GEORGE L CARRINGTON MIDDLE
Base map
Chapel Hill Rd
Crosswind Ave
Lakewood YMCA
Lakewood Montessori Middle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HOLT ELEMENTARY
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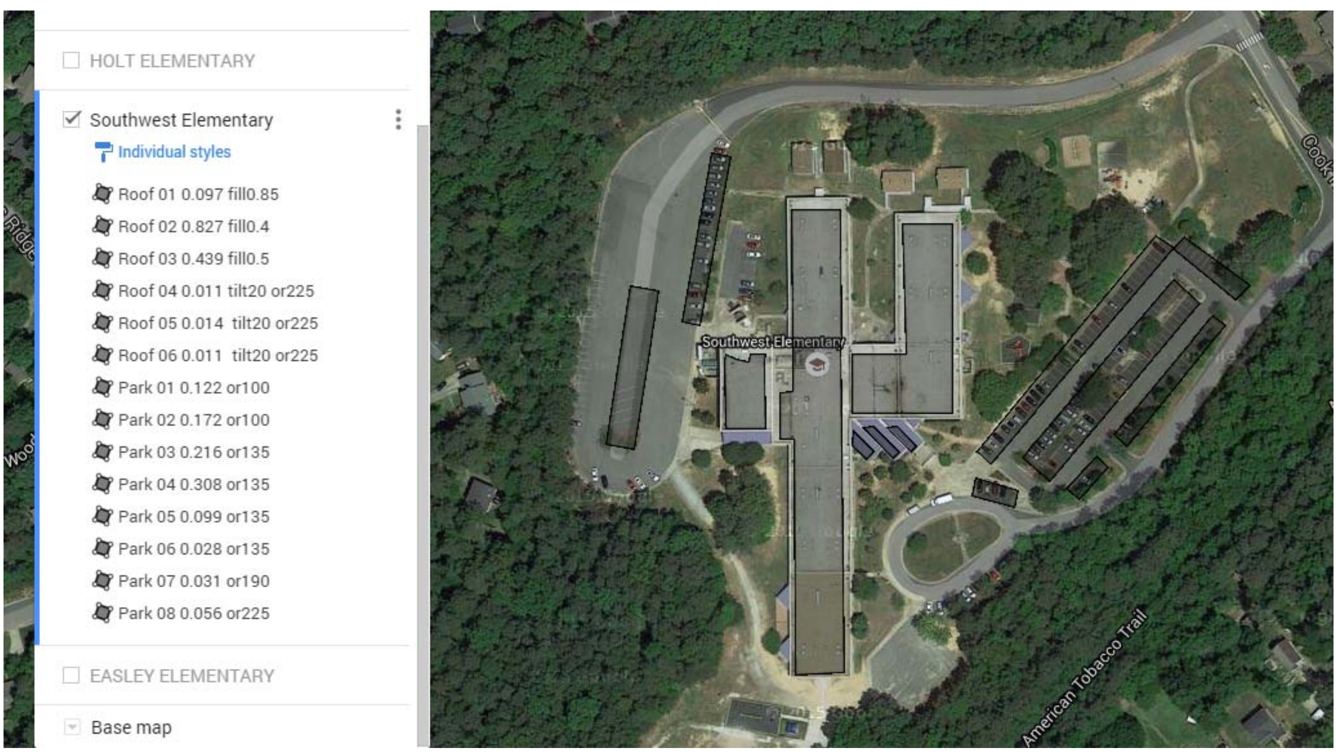
Roof 02 0.079 fill 0.7 or170
Roof 03 0.401 or170 fill0.4 n...
Roof 04 0.089 fill0.9
Roof 05 0.98 fill0.8
Roof 06 0.101 fill0.7 shade0/...
Park 01 0.627 fill0.3 nom0.3
Park 02 0.378 fill0.5 nom0.5
Park 03 0.131 shade0.8
Park 04 0.080
Park 05 0.031 or120
Park 06 0.028 shade0.6
Southwest Elementary
EASLEY ELEMENTARY
Holt Elementary School
Holt School Rd
Holt School Rd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Southwest Elementary
Individual styles
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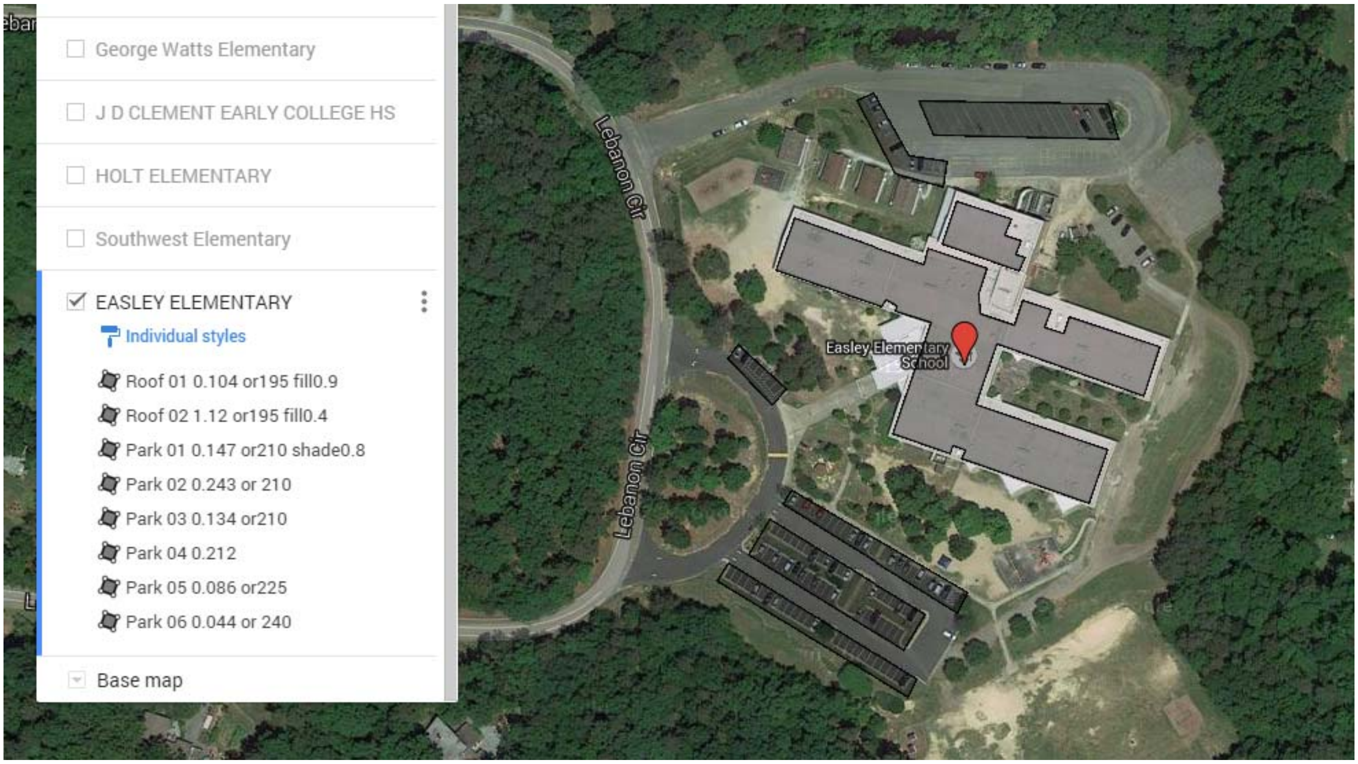
Roof 02 0.827 fill0.4
Roof 03 0.439 fill0.5
Roof 04 0.011 tilt20 or225
Roof 05 0.014 tilt20 or225
Roof 06 0.011 tilt20 or225
Park 01 0.122 or100
Park 02 0.172 or100
Park 03 0.216 or135
Park 04 0.308 or135
Park 05 0.099 or135
Park 06 0.028 or135
Park 07 0.031 or190
Park 08 0.056 or225
EASLEY ELEMENTARY
Base map
Southwest Elementary
American Tobacco Trail


George Watts Elementary
J D CLEMENT EARLY COLLEGE HS
HOLT ELEMENTARY
Southwest Elementary
EASLEY ELEMENTARY
Individual styles
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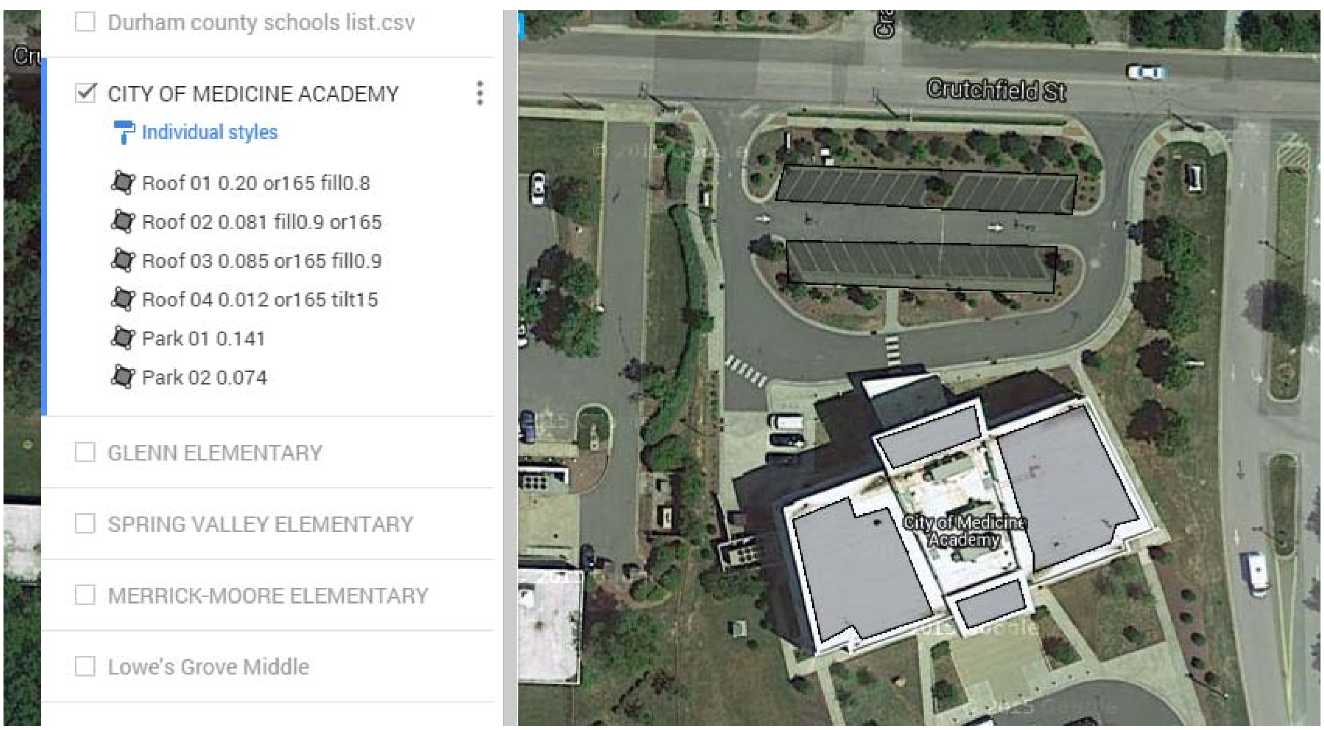
Roof 02 1.12 or195 fill0.4
Park 01 0.147 or210 shade0.8
Park 02 0.243 or 210
Park 03 0.134 or210
Park 04 0.212
Park 05 0.086 or225
Park 06 0.044 or 240
Base map
Lebanon Cir
Easley Elementary School


Durham county schools list.csv
CITY OF MEDICINE ACADEMY
Individual styles
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Roof 02 0.081 fill0.9 or165
Roof 03 0.085 or165 fill0.9
Roof 04 0.012 or165 tilt15
Park 01 0.141
Park 02 0.074
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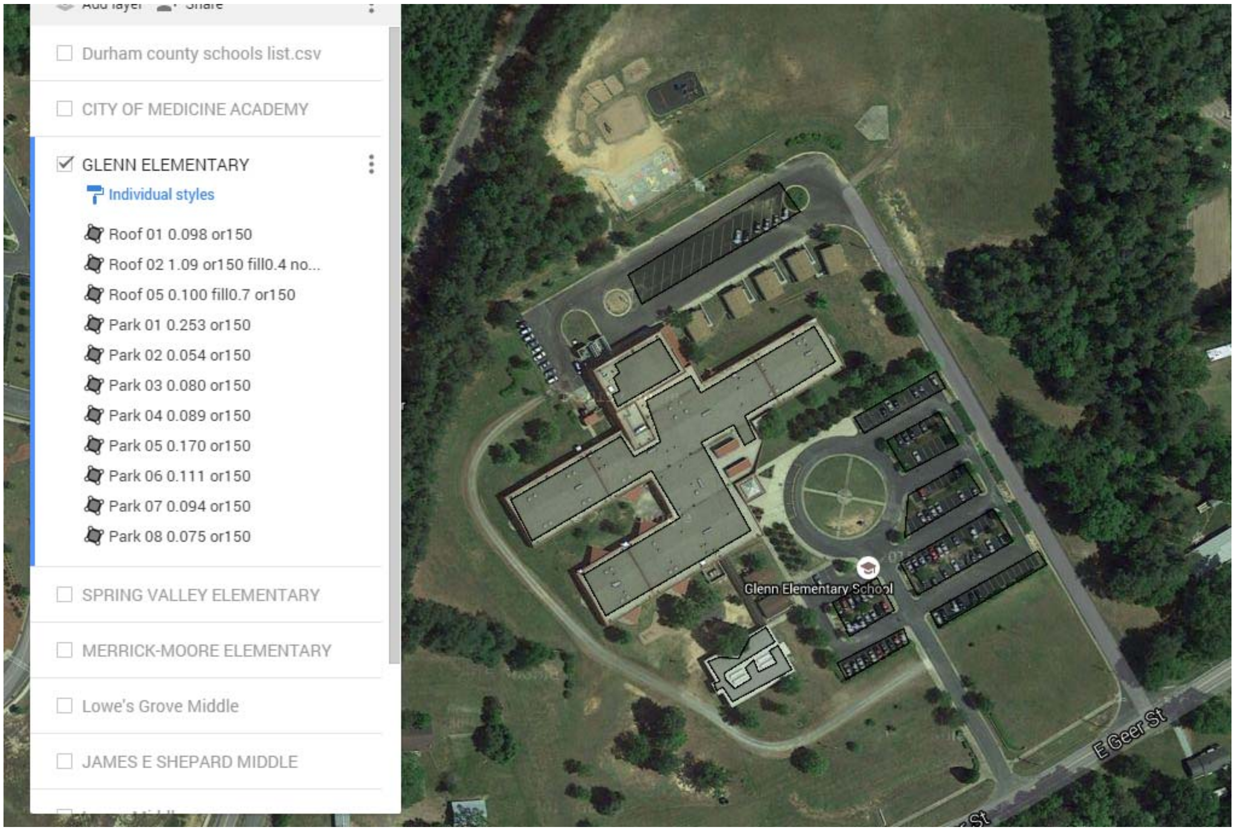
SPRING VALLEY ELEMENTARY
MERRICK-MOORE ELEMENTARY
Lowe's Grove Middle
Crutchfield St
City of Medicine Academy


Durham county schools list.csv
CITY OF MEDICINE ACADEMY
GLENN ELEMENTARY
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Roof 02 1.09 or150 fill0.4 no...
Roof 05 0.100 fill0.7 or150
Park 01 0.253 or150
Park 02 0.054 or150
Park 03 0.080 or150
Park 04 0.089 or150
Park 05 0.170 or150
Park 06 0.111 or150
Park 07 0.094 or150
Park 08 0.075 or150
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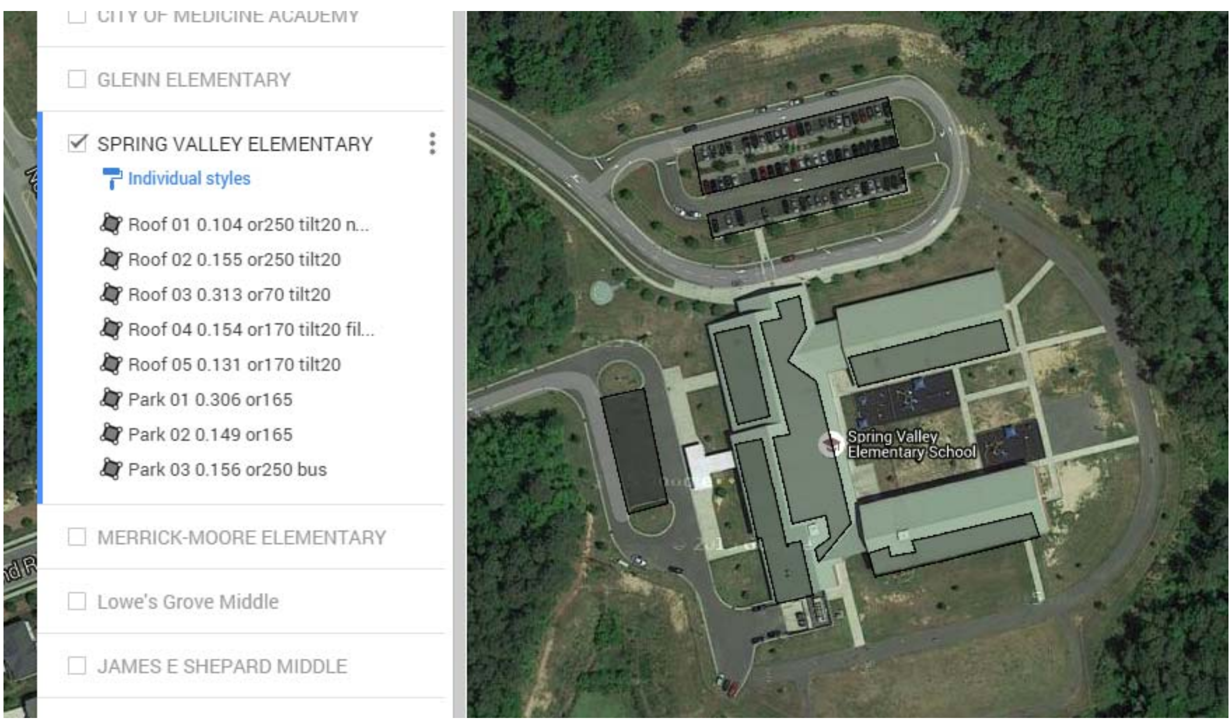
MERRICK-MOORE ELEMENTARY
Lowe's Grove Middle
JAMES E SHEPARD MIDDLE
Glenn Elementary School
E Geer St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GLENN ELEMENTARY
SPRING VALLEY ELEMENTARY
Individual styles
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Roof 02 0.155 or250 tilt20
Roof 03 0.313 or70 tilt20
Roof 04 0.154 or170 tilt20 fil...
Roof 05 0.131 or170 tilt20
Park 01 0.306 or165
Park 02 0.149 or165
Park 03 0.156 or250 bus
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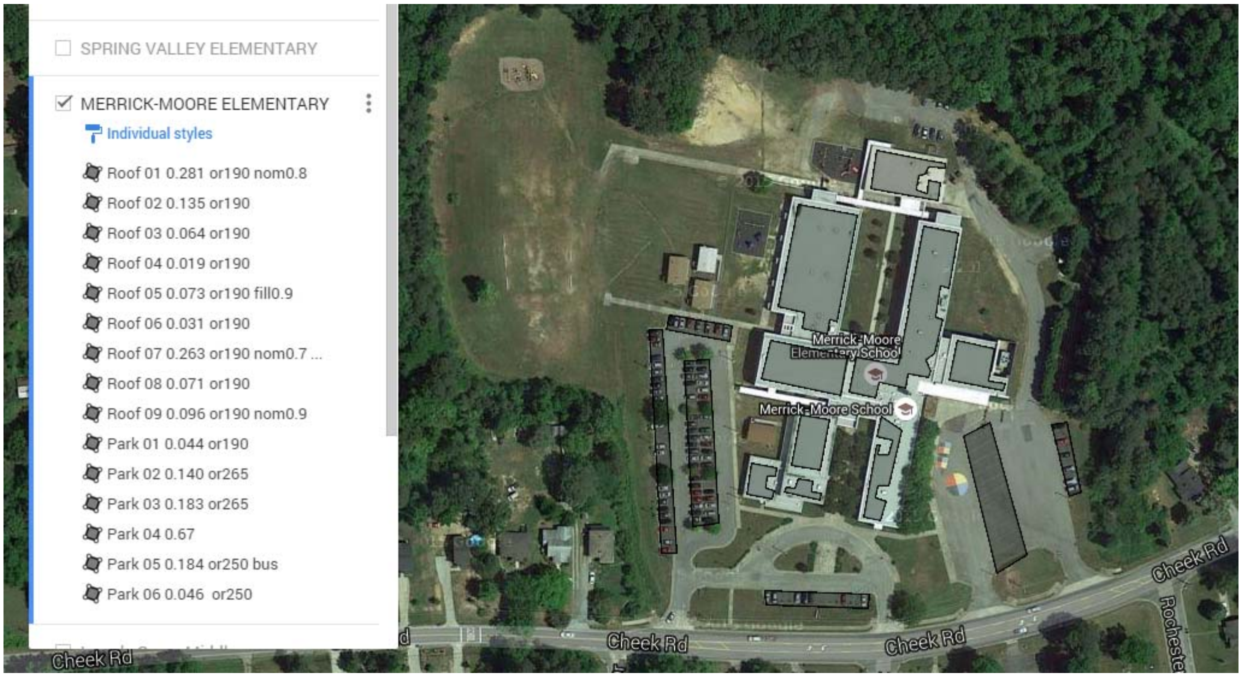
Lowe's Grove Middle
JAMES E SHEPARD MIDDLE
Spring Valley Elementary School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MERRICK-MOORE ELEMENTARY
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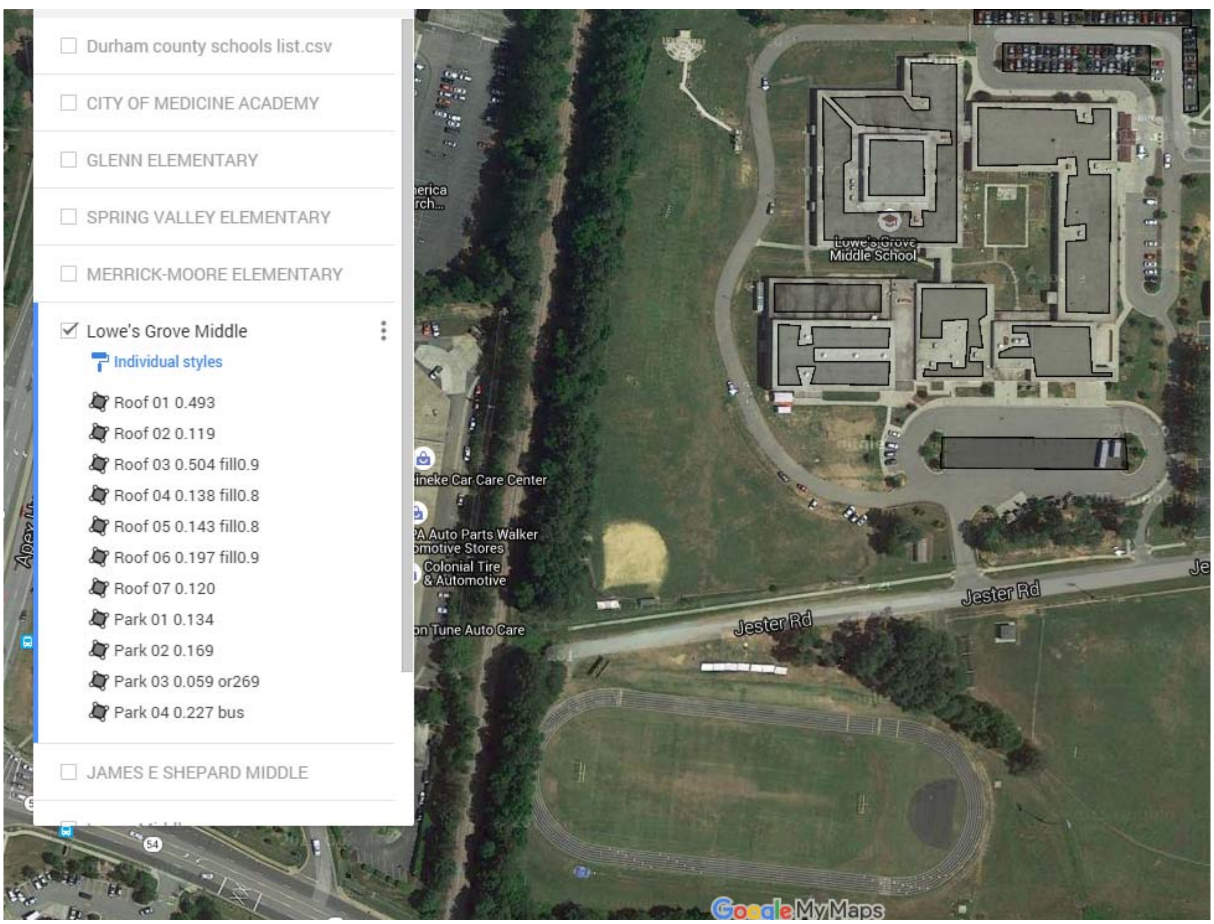
Roof 04 0.019 or190
Roof 05 0.073 or190 fill0.9
Roof 06 0.031 or190
Roof 07 0.263 or190 nom0.7 ...
Roof 08 0.071 or190
Roof 09 0.096 or190 nom0.9
Park 01 0.044 or190
Park 02 0.140 or265
Park 03 0.183 or265
Park 04 0.67
Park 05 0.184 or250 bus
Park 06 0.046 or250
Merrick-Moore Elementary School
Merrick-Moore School
Cheek Rd
Cheek Rd
Cheek Rd
Cheek Rd
Rochester


Durham county schools list.csv
CITY OF MEDICINE ACADEMY
GLENN ELEMENTARY
SPRING VALLEY ELEMENTARY
MERRICK-MOORE ELEMENTARY
Lowe's Grove Middle
Individual styles
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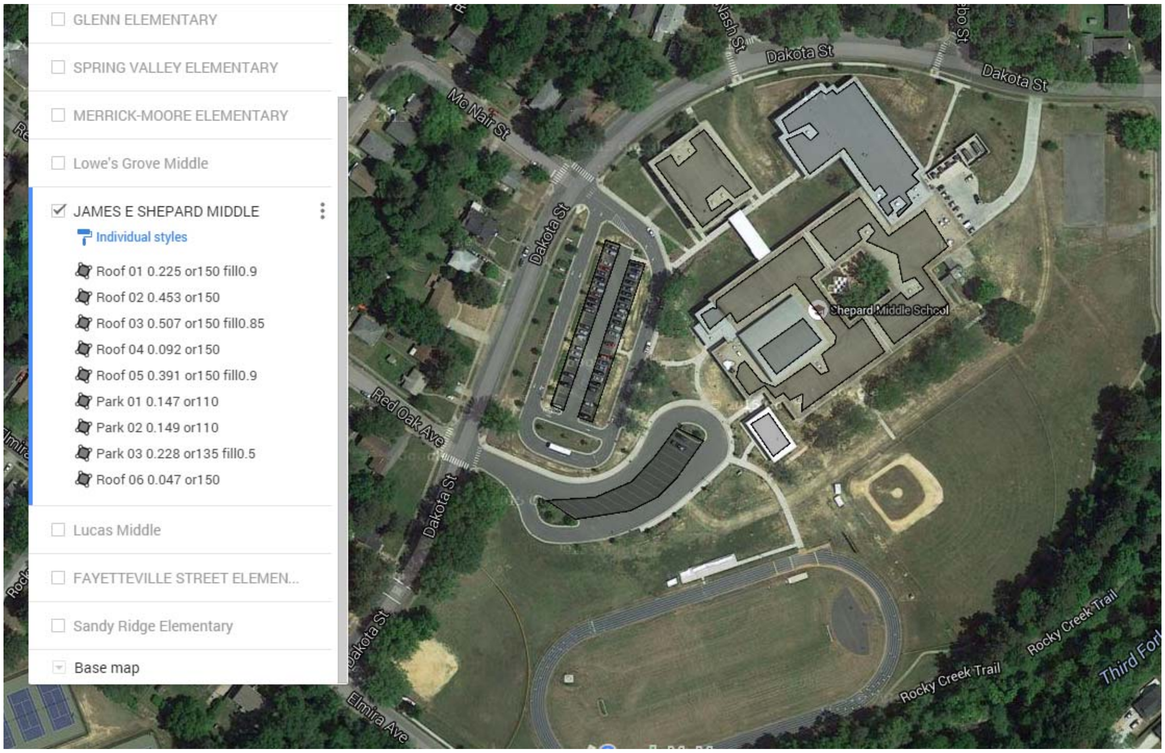
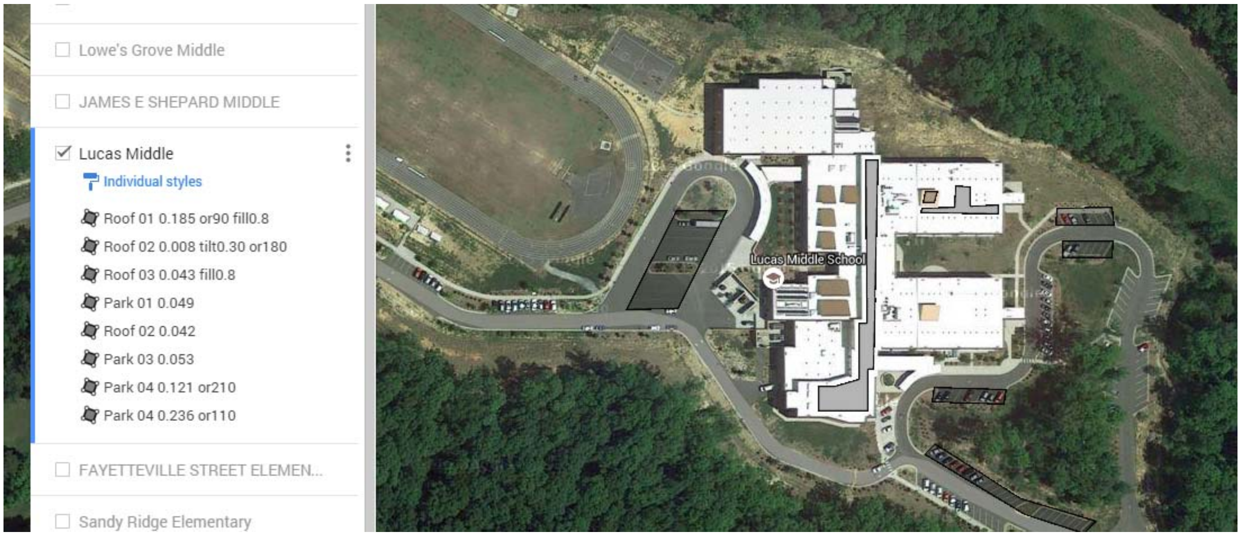
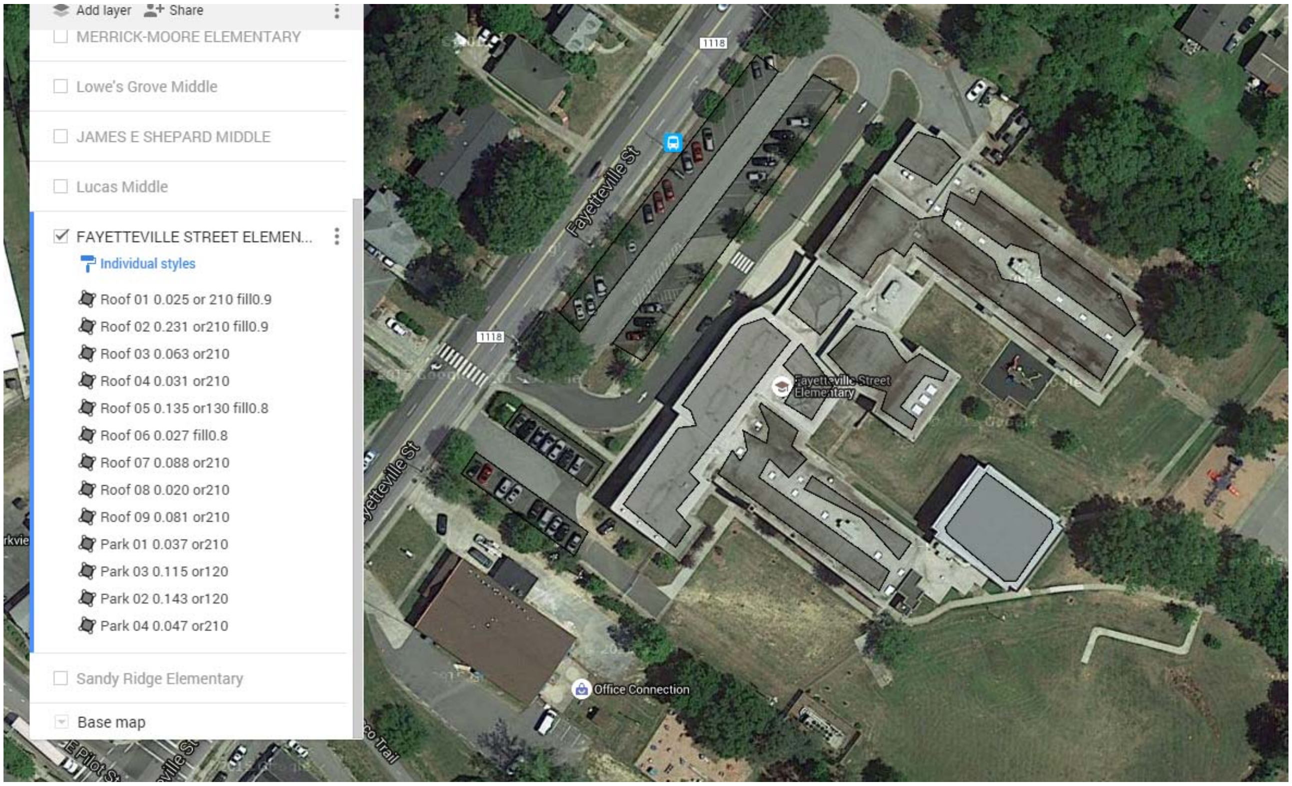
Roof 02 0.119
Roof 03 0.504 fill0.9
Roof 04 0.138 fill0.8
Roof 05 0.143 fill0.8
Roof 06 0.197 fill0.9
Roof 07 0.120
Park 01 0.134
Park 02 0.169
Park 03 0.059 or269
Park 04 0.227 bus
JAMES E SHEPARD MIDDLE
Lowe's Grove Middle School
Colonial Tire & Automotive
Jester Rd
Jester Rd
Google My Maps



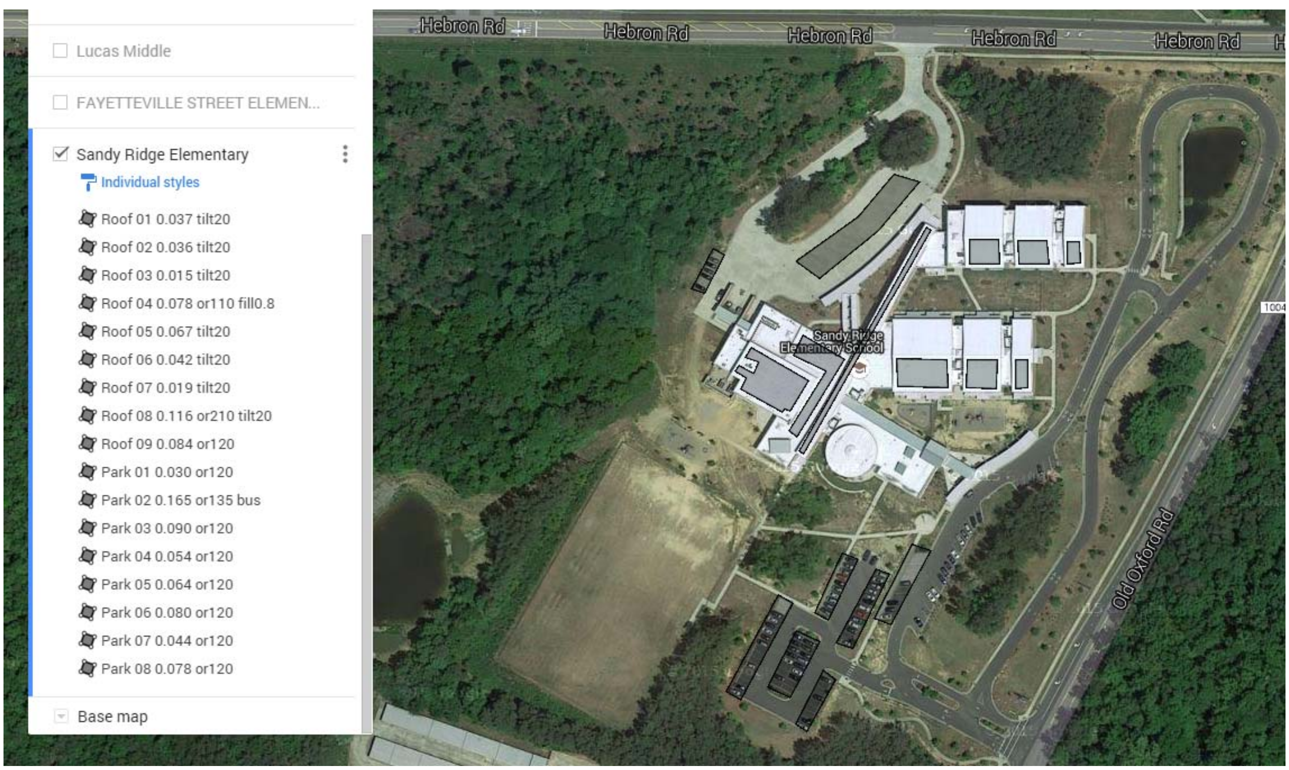
GLENN ELEMENTARY
SPRING VALLEY ELEMENTARY
MERRICK-MOORE ELEMENTARY
Lowe's Grove Middle
JAMES E SHEPARD MIDDLE
Individual styles
Roof 01 0.225 or150 fill0.9
Roof 02 0.453 or150
Roof 03 0.507 or150 fill0.85
Roof 04 0.092 or150
Roof 05 0.391 or150 fill0.9
Park 01 0.147 or110
Park 02 0.149 or110
Park 03 0.228 or135 fill0.5
Roof 06 0.047 or150
Lucas Middle
FAYETTEVILLE STREET ELEMEN...
Sandy Ridge Elementary
Base map
Dakota St
McNair St
Red Oak Ave
Elmira Ave
Shepard Middle School
Rocky Creek Trail



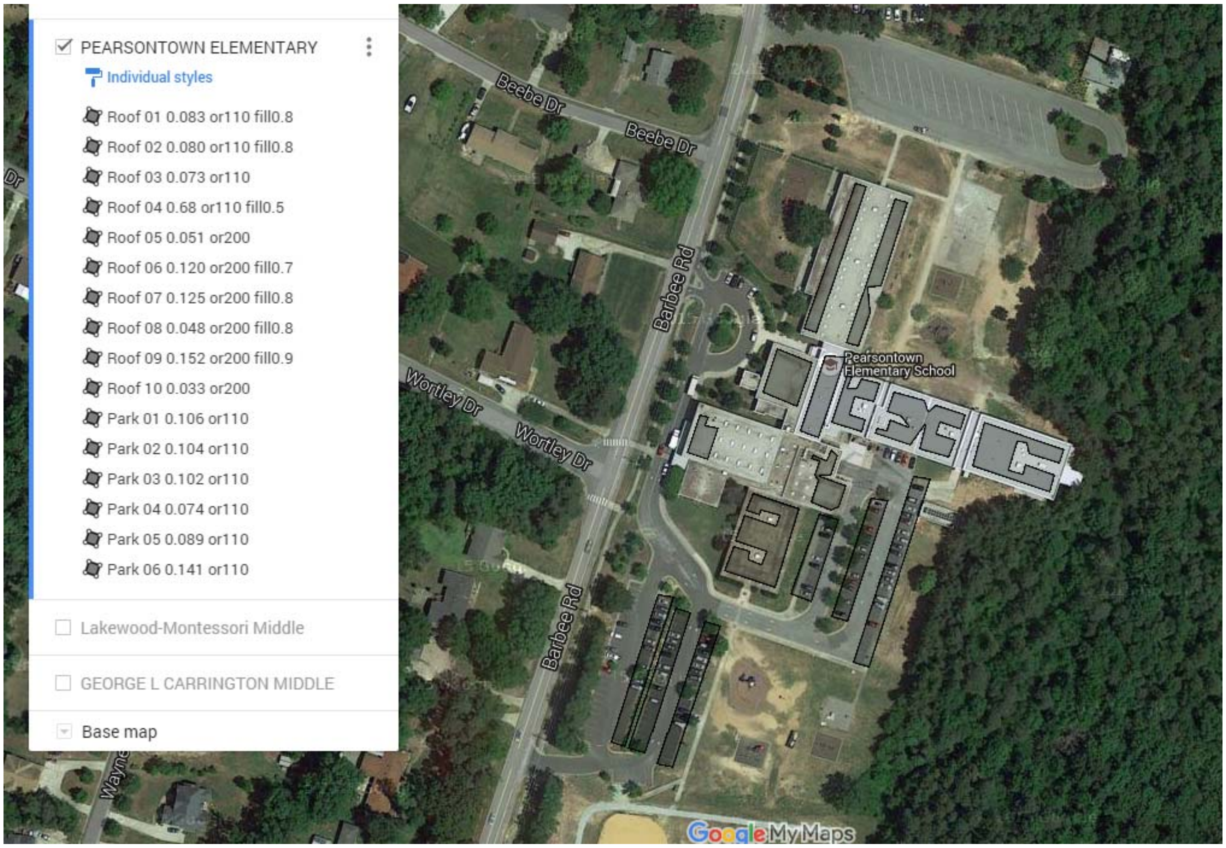
Lowe's Grove Middle
JAMES E SHEPARD MIDDLE
Lucas Middle
Individual styles
Roof 01 0.185 or90 fill0.8
Roof 02 0.008 tilt0.30 or180
Roof 03 0.043 fill0.8
Park 01 0.049
Roof 02 0.042
Park 03 0.053
Park 04 0.121 or210
Park 04 0.236 or110
FAYETTEVILLE STREET ELEMEN...
Sandy Ridge Elementary
Lucas Middle School



Add layer
Share
MERRICK-MOORE ELEMENTARY
Lowe's Grove Middle
JAMES E SHEPARD MIDDLE
Lucas Middle
FAYETTEVILLE STREET ELEMEN...
Individual styles
Roof 01 0.025 or 210 fill0.9
Roof 02 0.231 or210 fill0.9
Roof 03 0.063 or210
Roof 04 0.031 or210
Roof 05 0.135 or130 fill0.8
Roof 06 0.027 fill0.8
Roof 07 0.088 or210
Roof 08 0.020 or210
Roof 09 0.081 or210
Park 01 0.037 or210
Park 03 0.115 or120
Park 02 0.143 or120
Park 04 0.047 or210
Sandy Ridge Elementary
Base map
Fayetteville St
Fayetteville Street Elementary
Office Connection



Lucas Middle
FAYETTEVILLE STREET ELEMEN...
Sandy Ridge Elementary
Individual styles
Roof 01 0.037 tilt20
Roof 02 0.036 tilt20
Roof 03 0.015 tilt20
Roof 04 0.078 or110 fill0.8
Roof 05 0.067 tilt20
Roof 06 0.042 tilt20
Roof 07 0.019 tilt20
Roof 08 0.116 or210 tilt20
Roof 09 0.084 or120
Park 01 0.030 or120
Park 02 0.165 or135 bus
Park 03 0.090 or120
Park 04 0.054 or120
Park 05 0.064 or120
Park 06 0.080 or120
Park 07 0.044 or120
Park 08 0.078 or120
Base map
Hebron Rd
Sandy Ridge Elementary School
Old Oxford Rd


PEARSONTOWN ELEMENTARY
Individual styles
Roof 01 0.083 or110 fill0.8
Roof 02 0.080 or110 fill0.8
Roof 03 0.073 or110
Roof 04 0.68 or110 fill0.5
Roof 05 0.051 or200
Roof 06 0.120 or200 fill0.7
Roof 07 0.125 or200 fill0.8
Roof 08 0.048 or200 fill0.8
Roof 09 0.152 or200 fill0.9
Roof 10 0.033 or200
Park 01 0.106 or110
Park 02 0.104 or110
Park 03 0.102 or110
Park 04 0.074 or110
Park 05 0.089 or110
Park 06 0.141 or110
Lakewood-Montessori Middle
GEORGE L CARRINGTON MIDDLE
Base map
Beebe Dr
Beebe Dr
Barbee Rd
Pearsontown Elementary School
Wortley Dr
Wortley Dr
Barbee Rd
Google My Maps


Lakewood-Montessori Middle
GEORGE L CARRINGTON MIDDLE
Individual styles
Roof 01 0.328 fill0.8
Roof 02 0.054 fill0.9
Roof 03 0.203 fill0.8
Roof 04 0.021
Roof 05 0.122 fill0.7
Roof 06 0.248 fill0.6
Roof 07 0.029 fill0.8
Roof 08 0.093 fill0.8
Roof 09 0.110
Roof 10 0.158 fill0.6
Park 01 0.053 or170
Park 02 0.048 or90
Park 03 0.062 or90
Park 04 0.065 or90
Park 05 0.086 or120 shade0....
Park 06 0.084 or120
Park 07 0.084 or90
Park 08 0.074 or90
Park 09 0.071 or110
Park 10 0.052 or110
Base map
G Carrington Middle School

APPENDIX E: ON-SITE TECHNICAL ANALYSIS RESULTS FOR ALL SCHOOLS

Total Students: approximate number of current students at the school, from a variety of data sources

Conservative Roof PV Capacity (kW_{DC}): calculated as described in Appendix B: PV Capacity and Production Methodology Details for the first 20 schools in the list (the sampled schools), and calculated by multiplying the average $W_{rooftop}$/(square foot of roof space) by the school's total roof square footage for the non-sampled 29 remaining schools.

Standard Roof PV Capacity (kW_{DC}): same process as Conservative Roof PV Capacity, see Appendix B: PV Capacity and Production Methodology Details

Aggressive Roof PV Capacity (kW_{DC}): same process as Conservative Roof PV Capacity, see Appendix B: PV Capacity and Production Methodology Details

Conservative Parking Lot PV Capacity (kW_{DC}): calculated as described in Appendix B for the first 20 schools, and calculated by subtracting the estimated roof PV capacity from the estimated total PV capacity for each of the remaining 29 non-sampled schools

Standard Parking Lot PV Capacity (kW_{DC}): same process as Conservative Parking Lot PV Capacity

Aggressive Parking Lot PV Capacity (kW_{DC}): same process as Conservative Parking Lot PV Capacity

2014-2015 Total Electricity Usage (kWh): calculated from data provided by DPS

Electricity Usage after 25% Savings (Post-EE) (kWh): calculated from data provided by DPS

Sell-all Standard rooftop system to achieve 100% post-EE (kW_{DC}): If the standard rooftop system is large enough to meet 100% post-EE energy needs then this is the system capacity required to meet 100%, if the standard system is not large enough to meet 100% then this is the full standard rooftop PV potential capacity

Sell-all Standard parking lot system to achieve 100% post-EE (kW_{DC}): If the standard rooftop capacity is not large enough to meet 100% post-EE electricity usage then this is the parking lot capacity needed to accompany the rooftop capacity to together achieve 100% post-EE. If combined, the standard systems are not able to meet or exceed 100% post-EE, this value equals the full standard parking lot potential capacity.

Average cost of sell-all system for up to 100% post-EE (\$/W_{DC}): The average cost per DC Watt for the combined rooftop and parking lot system with the capacities listed in the previous two columns

Percent of post-EE met with this sell-all system: 100% if together the standard rooftop and parking lot capacities are adequate to meet 100% of post-EE annual electricity needs, if less than 100% this is the amount of post-EE electricity needs that the full standard rooftop and parking lots systems can supply

Cost of a sell-all system to meet 100% post-EE: calculated using the average cost of the combination of the rooftop and parking lot systems described in previous few columns

Cost of sell-all system to meet 100% post-EE Energy per student: as the name describes

Annual cost per student (not considering savings) of 2.88% 25-year CREBs bond: as described, calculated solely from the turnkey retail cost of the full system, i.e. not accounting for the many values provided by the PV system, such as electricity cost savings.

School Name	Total Students	Conservative Roof PV Capacity (kW_DC)	Nominal Roof PV Capacity (kW_DC)	Aggressive Roof PV Capacity (kW_DC)	Conservative Parking Lot PV Capacity (kW_DC)	Nominal Parking Lot PV Capacity (kW_DC)	Aggressive Parking Lot PV Capacity (kW_DC)	2014-2015 Total Electricity Usage (kWh)	Electricity Usage after 25% Savings (Post-EE) (kWh)	Sell-all Nominal rooftop system to achieve 100% post-EE (kW)	Sell-all Nominal parking lot system to achieve 100% post-EE (kW)	Average cost of sell all system for up to 100% post-EE ($/W)	Percent of post-EE met with this sell-all system	Cost of a sell-all system to meet 100% post-EE	Cost of sell-all system to meet 100% post-EE Energy per student	Annual Debt Service per student (CREBs 2.88% 25-year bond)
OAK GROVE ELEMENTARY	553	293	523	944	488	651	916	1,279,933	959,950	523	164	$ 2.23	100%	$ 1,528,963	$ 2,765	$ 157
C C SPAULDING ELEMENTARY	253	165	246	389	136	181	255	1,075,960	806,970	246	181	$ 2.40	70%	$ 1,026,420	$ 4,057	$ 230
LAKEVIEW SCHOOL	115	270	408	645	146	195	275	365,920	274,440	211	0	$ 2.00	100%	$ 422,286	$ 3,672	$ 208
MANGUM ELEMENTARY	505	250	345	515	102	136	191	664,823	498,617	345	15	$ 2.04	100%	$ 734,351	$ 1,454	$ 82
GEORGE WATTS ELEMENTARY	391	183	271	421	42	63	88	1,061,447	796,085	271	63	$ 2.18	52%	$ 728,351	$ 1,863	$ 106
LAKEWOOD-MONTESSORI MIDDLE	500	88	137	221	152	203	286	913,614	685,211	137	203	$ 2.57	68%	$ 871,738	$ 1,743	$ 99
HOLT ELEMENTARY	612	417	650	1,149	294	392	552	789,144	591,858	426	0	$ 2.00	100%	$ 852,315	$ 1,393	$ 79
SOUTHWEST ELEMENTARY	695	225	463	905	455	607	854	783,133	587,350	413	0	$ 2.00	100%	$ 826,143	$ 1,189	$ 67
EASLEY ELEMENTARY	640	193	409	812	382	509	717	665,228	498,921	355	0	$ 2.00	100%	$ 709,637	$ 1,109	$ 63
CITY OF MEDICINE ACADEMY	215	107	157	245	95	126	178	531,977	398,983	157	126	$ 2.42	100%	$ 687,303	$ 3,197	$ 181
GLENN ELEMENTARY	699	195	379	826	409	545	767	1,139,207	854,405	379	230	$ 2.36	100%	$ 1,436,787	$ 2,055	$ 116
SPRING VALLEY ELEMENTARY	632	411	480	743	270	359	506	1,486,032	1,114,524	480	359	$ 2.41	99%	$ 2,020,388	$ 3,197	$ 181
MERRICK-MOORE ELEMENTARY	676	289	396	663	559	745	1,049	1,074,276	805,707	396	179	$ 2.30	100%	$ 1,321,016	$ 1,954	$ 111
LOWE'S GROVE MIDDLE	629	505	727	1,099	260	347	488	1,253,808	940,356	660	0	$ 2.00	100%	$ 1,319,798	$ 2,098	$ 119
JAMES E SHEPARD MIDDLE	412	504	727	1,100	184	276	389	1,343,931	1,007,948	714	0	$ 2.00	100%	$ 1,427,937	$ 3,466	$ 196
LUCAS MIDDLE	500	75	113	178	203	270	380	1,451,242	1,088,432	113	270	$ 2.67	48%	$ 1,022,514	$ 2,045	$ 116
FAYETTEVILLE STREET ELEMENTARY	262	205	296	450	151	201	283	664,425	498,319	296	60	$ 2.16	100%	$ 769,572	$ 2,937	$ 166
SANDY RIDGE ELEMENTARY	500	220	272	392	267	356	501	1,010,484	757,863	272	277	$ 2.48	100%	$ 1,363,331	$ 2,727	$ 155
PEARSONTOWN ELEMENTARY	899	319	538	927	272	362	510	1,252,301	939,226	538	151	$ 2.21	100%	$ 1,519,764	$ 1,691	$ 96
GEORGE L CARRINGTON MIDDLE	1,110	334	531	876	300	399	562	1,767,904	1,325,928	531	399	$ 2.41	97%	$ 2,240,470	$ 2,018	$ 114
EASTWAY ELEMENTARY	565	245	376	626	237	318	447	1,061,241	795,931	376	205	$ 2.34	100%	$ 1,356,031	$ 2,400	$ 136
NORTHERN HIGH	1,625	813	1,246	2,077	786	1,054	1,482	2,631,752	1,973,814	1246	182	$ 2.12	100%	$ 3,028,552	$ 1,864	$ 106
W G PEARSON ELEMENTARY	621	259	397	662	251	336	472	1,006,176	754,632	397	152	$ 2.26	100%	$ 1,242,005	$ 2,000	$ 113
PARKWOOD ELEMENTARY	604	249	381	635	240	322	453	1,062,663	796,997	381	200	$ 2.33	100%	$ 1,352,936	$ 2,240	$ 127
ROGERS-HERR MIDDLE	643	528	809	1,348	510	684	962	1,563,351	1,172,513	809	37	$ 2.04	100%	$ 1,726,045	$ 2,684	$ 152
Y E SMITH ELEMENTARY	346	146	223	372	141	189	265	900,224	675,168	223	189	$ 2.44	83%	$ 1,002,852	$ 2,898	$ 164
HILLSIDE HIGH	1,261	943	1,445	2,409	912	1,222	1,718	4,523,323	3,392,492	1445	1036	$ 2.40	100%	$ 5,946,424	$ 4,716	$ 267
SOUTHERN HIGH	1,101	893	1,368	2,281	863	1,157	1,627	3,032,163	2,274,122	1368	279	$ 2.16	100%	$ 3,561,140	$ 3,234	$ 183
BETHESDA ELEMENTARY	631	269	412	686	260	348	489	1,312,324	984,243	412	308	$ 2.41	100%	$ 1,733,340	$ 2,747	$ 156
MOREHEAD MONTESSORI	234	129	197	328	124	166	234	359,820	269,865	194	0	$ 2.00	100%	$ 388,642	$ 1,661	$ 94
SHERWOOD GITHENS MIDDLE	893	421	645	1,075	407	545	767	1,419,189	1,064,392	645	126	$ 2.16	100%	$ 1,661,987	$ 1,861	$ 105
CHEWNING MIDDLE	482	391	599	998	378	506	712	1,244,810	933,608	599	76	$ 2.11	100%	$ 1,422,733	$ 2,952	$ 167
ENO VALLEY ELEMENTARY	639	278	427	711	269	361	507	848,350	636,263	427	33	$ 2.07	100%	$ 949,763	$ 1,486	$ 84
FOREST VIEW ELEMENTARY	618	270	414	690	261	350	492	1,229,045	921,784	414	259	$ 2.37	100%	$ 1,593,216	$ 2,578	$ 146
R N HARRIS ELEMENTARY	402	221	339	565	214	287	403	844,461	633,346	339	122	$ 2.25	100%	$ 1,036,626	$ 2,579	$ 146
CREEKSIDE ELEMENTARY	865	298	456	760	288	386	542	1,134,592	850,944	456	163	$ 2.25	100%	$ 1,391,947	$ 1,609	$ 91
LAKEWOOD ELEMENTARY	421	190	290	484	183	245	345	749,946	562,460	290	119	$ 2.28	100%	$ 931,907	$ 2,214	$ 125
HILLANDALE ELEMENTARY	621	270	414	690	261	350	492	1,044,476	783,357	414	156	$ 2.26	100%	$ 1,287,865	$ 2,074	$ 118
BROGDEN MIDDLE	759	492	754	1,256	475	637	896	1,410,141	1,057,606	754	8	$ 2.01	100%	$ 1,531,616	$ 2,018	$ 114
RIVERSIDE HIGH	1,910	890	1,363	2,271	860	1,152	1,620	3,554,643	2,665,982	1363	578	$ 2.28	100%	$ 4,431,451	$ 2,320	$ 131
NEAL MIDDLE	628	407	624	1,039	393	527	741	1,672,022	1,254,017	624	290	$ 2.30	100%	$ 2,103,108	$ 3,349	$ 190
LITTLE RIVER ELEMENTARY	657	263	403	672	254	341	479	856,809	642,607	403	62	$ 2.13	100%	$ 989,020	$ 1,505	$ 85
C E JORDAN HIGH	1,890	838	1,284	2,140	810	1,086	1,527	2,232,192	1,674,144	1205	0	$ 2.00	100%	$ 2,410,996	$ 1,276	$ 72
CLUB BOULEVARD ELEMENTARY	504	142	217	362	137	184	258	790,224	592,668	217	184	$ 2.44	92%	$ 976,607	$ 1,938	$ 110
W.G. PEARSON MAGNET MIDDLE	322	172	263	438	166	222	313	615,132	461,349	263	72	$ 2.20	100%	$ 737,899	$ 2,292	$ 130
DURHAM SCH OF THE ARTS	1,403	1,108	1,697	2,829	1,071	1,435	2,018	4,070,045	3,052,534	1697	520	$ 2.22	100%	$ 4,928,400	$ 3,513	$ 199
E K POWE ELEMENTARY	419	313	479	798	302	405	569	1,085,613	814,210	479	112	$ 2.18	100%	$ 1,286,776	$ 3,071	$ 174
HOPE VALLEY ELEMENTARY	702	249	382	636	241	323	454	916,707	687,530	382	118	$ 2.22	100%	$ 1,110,621	$ 1,582	$ 90
BURTON ELEMENTARY	325	224	344	573	217	291	409	1,205,240	903,930	344	291	$ 2.44	96%	$ 1,545,282	$ 4,755	$ 269
AVERAGE	**671**	**350**	**537**	**896**	**340**	**456**	**642**	**1,325,540**	**994,155**	**523**	**175**	**$ 2.23**	**96%**	**$ 1,561,120**	**$ 2,409**	**$ 137**

APPENDIX F: EXAMPLE HELIOSCOPE REPORT

HelioScope Annual Production Report produced by Tommy Cleveland

Design 1 Oak Grove Elementary, 35.980137, -78.819560

Report

Project Name	Oak Grove Elementary
Project Address	35.980137, -78.819560
Prepared By	Tommy Cleveland thclevel@ncsu.edu

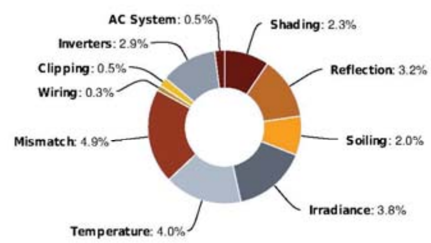
System Metrics

Design	Design 1
Module DC Nameplate	483.0 kW
Inverter AC Nameplate	400.0 kW Load Ratio: 1.21
Annual Production	663.5 MWh
Performance Ratio	78.3%
kWh/kWp	1,373.6
Weather Dataset	TMY, 10km Grid (35.95,-78.85), NREL (prospector)
Simulator Version	153 (443094f0ad-ea93f843ef-fce6caf820-00aa14f623)

Field Segments

Monthly Production

Sources of System Loss



Annual Production

	Description	Output	% Delta
Irradiance (kWh/m²)	Annual Global Horizontal Irradiance	1,630.7	
	POA Irradiance	1,754.8	7.6%
	Shaded Irradiance	1,714.7	-2.3%
	Irradiance after Reflection	1,659.8	-3.2%
	Irradiance after Soiling	1,626.6	-2.0%
	Total Collector Irradiance	**1,626.6**	**0.0%**
Energy (kWh)	Nameplate	786,516.3	
	Output at Irradiance Levels	756,836.1	-3.8%
	Output at Cell Temperature Derate	726,865.4	-4.0%
	Output After Mismatch	691,560.6	-4.9%
	Optimal DC Output	689,740.5	-0.3%
	Constrained DC Output	686,557.6	-0.5%
	Inverter Output	666,788.0	-2.9%
	Energy to Grid	**663,454.0**	**-0.5%**
Temperature Metrics			
	Avg. Operating Ambient Temp		17.8 °C
	Avg. Operating Cell Temp		26.1 °C
Simulation Metrics			
		Operating Hours	4671
		Solved Hours	4671

Condition Set

Description	Condition Set 1
Weather Dataset	TMY, 10km Grid (35.95,-78.85), NREL (prospector)
Solar Angle Location	Meteo Lat/Lng
Transposition Model	Perez Model
Temperature Model	Sandia Model

Temperature Model Parameters

Rack Type	a	b	Temperature Delta
Fixed Tilt	-3.56	-0.075	3°C
Flush Mount	-2.81	-0.0455	0°C

Soiling (%)

J	F	M	A	M	J	J	A	S	O	N	D
2	2	2	2	2	2	2	2	2	2	2	2

Irradiation Variance	5%
Cell Temperature Spread	4° C
Module Binning Range	-2.5% to 2.5%
AC System Derate	0.50%

Module Characterizations

Module	Characterization
TSM-250PDG5 (Trina Solar)	Default Characterization, PAN

Component Characterizations

Device	Characterization
TRIO-20.0-TL-OUTD-S1-US-480-A (ABB)	CEC Efficiency Curves, May-15

 1/2 September 01, 2015

Components

Component	Name	Count
Inverter	TRIO-20.0-TL-OUTD-S1-US-480-A (ABB)	20 (400.0 kW)
Combiner	1 pole Combiner	20
Combiner	4 pole Combiner	8
Combiner	5 pole Combiner	12
Strings	10 AWG (Copper)	92 (10,929.4 ft)
Module	TSM-250PDG5 (Trina Solar)	1,932

Wiring Zones

Description	Combiner Poles	String Size	Stringing Strategy
Wiring Zone	12	21	Along Racking

Field Segments

Description	Racking	Orientation	Tilt	Azimuth	Intrarow Spacing	Frame Size	Frames	Modules
Field Segment 1	Fixed Tilt	Horizontal (Landscape)	10°	196.078°	1.7 ft	1x1	205	205
Field Segment 2	Fixed Tilt	Horizontal (Landscape)	10°	196.078°	1.7 ft	1x1	130	130
Field Segment 3	Fixed Tilt	Horizontal (Landscape)	10°	196.078°	1.7 ft	1x1	533	533
Field Segment 4	Fixed Tilt	Horizontal (Landscape)	10°	196.078°	1.7 ft	1x1	124	124
Field Segment 5	Fixed Tilt	Horizontal (Landscape)	10°	196.078°	1.7 ft	1x1	196	196
Field Segment 6	Fixed Tilt	Horizontal (Landscape)	10°	196.078°	1.7 ft	1x1	131	131
Field Segment 7	Fixed Tilt	Horizontal (Landscape)	10°	196.078°	1.7 ft	1x1	181	181
Field Segment 8	Fixed Tilt	Horizontal (Landscape)	10°	196.078°	1.7 ft	1x1	432	432

Detailed Layout

APPENDIX G: SIMPLE PAYBACK PERIOD

One of the simplest measures of the financial attractiveness of a capital investment is simple payback period, which is the total cost of the project divided by the annual cash inflows that equal the total cost of the project. The result is the number of years of project revenue required to equal the initial cost of the project. Projects with shorter payback periods are preferred, but this measure of attractiveness has several shortcomings. First, it does not consider the time value of money and thus the impact of varying cost of capital as considered in the Levelized Cost of Electricity or Nominal Savings analyses. Second, it ignores any benefits that occur after the payback period and ignores any operating costs. The nature of this type of analysis requires it to be performed from the point of the view of the project, rather than from the point of view of the school. Thus, the Direct Ownership model is the only system type where the point of view of the PV project and the school are one and the same.

						$2.25/W	$1.50/W
System Name	System Location	Billing Inter-connection	ITC	RECs Available	Current Availability	Simple PayBack Period** (Years)	Simple PayBack Period** (Years)
Direct Ownership, Net Meter	On-site	Net-Meter	no	NO*	YES, uses CREBs	21.2	15.2
	On-site	Net-Meter, no standby	no	YES	NO, requires no standby charges and no less of RECs	18.8	13.4
PPA, Net Meter	On-site	Net-Meter (PPA between 3rd Party owner and school)	30%	NO*	NO, requires 3rd Party Sales, uses 30% ITC	10.3	7.3
	On-site	Net-Meter (PPA between 3rd Party owner and school)	10%	NO*	NO, requires 3rd Party Sales	13.7	9.8
	On-site	Net-Meter, no standby (PPA between 3rd Party owner and school)	30%	Yes, buy RECs in PPA	NO, requires 3rd Party Sales and no standby charges or less of RECs. Uses 30% ITC	9.0	6.3
	On-site	Net-Meter, no standby (PPA between 3rd Party owner and school)	10%	Yes, buy RECs in PPA	NO, requires 3rd Party Sales and no standby charges or less of RECs. Uses 30% ITC	12.0	8.5
Direct Ownership, Sell All	On-site	Sell-All to Utility (@$0.65/kWh)	no	YES	YES, uses CREBs	25.0	17.1
PPA, Sell All	On-site	PPA to School, then Sell-All to Utility (@$0.65/kWh)	30%	Yes, buy RECs in PPA	NO, requires 3rd Party Sales, uses 30% ITC	10.7	7.2
	On-site	PPA to School, then Sell-All to Utility (@$0.65/kWh)	10%	Yes, buy RECs in PPA	NO, requires 3rd Party Sales	15.0	10.0

* Demand-TOU rate is not financially feasible ** Assumes a utility escalation rate of 3%

Shading Key: Green = shortest payback period Orange/Red = longest payback period

Table 18: Results of Comparative Simple Payback Period Analysis From the Point of View of the PV Project

APPENDIX H: LCOE RESULTS FOR 10% ITC

System Type***	Case Summary	System Location	Billing Inter-connection	RECs Available	Current Availability	Other Considerations	$/W$_{DC}$ Installed Cost								
							$2.25/W			$1.88/W			$1.50/W		
							Utility Annual Escalation Rate			Utility Annual Escalation Rate			Utility Annual Escalation Rate		
							1.5%	3.0%	6.0%	1.5%	3.0%	6.0%	1.5%	3.0%	6.0%
							School's Levelized Cost of Electricity (LCOE) for Next 25 years (¢/kWh)								
Direct Ownership, Net Meter	Net metering policy as is	On-site	Net meter	NO**	YES uses CREBs	No tax benefits. Simple structure, but school responsible for operations and maintence	12.8¢	13.3¢	14.5¢	11.2¢	11.7¢	12.9¢	9.6¢	10.1¢	11.3¢
	Solar-friendly net metering policy	On-site	Net meter no standby	YES	NO requires no standby charges and no less of RECs		12.1¢	12.4¢	13.2¢	10.5¢	10.8¢	11.6¢	8.9¢	9.2¢	10.0¢
PPA, Net Meter	Netmetering policy as is, bank loan, 10% ITC	On-site	Net meter (PPA between 3rd Party owner and school)	NO**	NO requires 3rd Party Sales, uses10% ITC	Very easy for the school to implement, as simple as signing the PPA. 3rd party is responsible for operations and maintenance	10.2¢	10.6¢	11.8¢	9.0¢	9.4¢	10.6¢	7.8¢	8.2¢	9.4¢
	Solar-friendly netmetering policy, bank loan, 10% ITC	On-site or Off-site with Virtual Net Metering	Net meter, no standby (PPA between 3rd Party owner and school)	Yes buy RECs in PPA	NO requires 3rd Party Sales and no standby charges or less of RECs. Uses 10% ITC		9.5¢	9.7¢	10.5¢	8.3¢	8.6¢	9.4¢	7.1¢	7.4¢	8.2¢
Direct Ownership, Sell All	Policy as is	On-site	Sell-All to Utility (@$0.65/kWh)	YES	YES uses CREBs	No tax benefits. Simple structure, but school responsible for operations and maintence	12.6¢	13.7¢	16.6¢	11.0¢	12.1¢	15.0¢	9.4¢	10.5¢	13.4¢
PPA, Sell All	10% ITC	On-site or Off-site	PPA to School, then Sell-All to Utility (@$0.65/kWh)	Yes buy RECs in PPA	NO requires 3rd Party Sales, uses 10% ITC	Very easy for the school to implement, as simple as signing the PPA.	10.0¢	11.0¢	13.9¢	8.8¢	9.9¢	12.8¢	7.6¢	8.6¢	11.6¢
Partnership Flip (3rd Party Investor, Sell All)	CREBs and 10% ITC	On-Site or Off-site	Sell-All to Utility (@$0.65/kWh)	Yes buy RECs	YES uses CREBs and 10% ITC	Complicated and costly to setup, which will require school staff or consultant time	7.1¢	8.1¢	11.0¢	6.4¢	7.5¢	10.4¢	5.8¢	6.8¢	9.8¢
							$198,549*			$119,129*			$33,601*		
	Bank loan and 10% ITC	On-Site or Off-site	Sell-All to Utility (@$0.65/kWh)	Yes buy RECs from system	YES uses 10% ITC		8.3¢	9.3¢	12.2¢	7.5¢	8.5¢	11.4¢	6.6¢	7.7¢	10.6¢
							$314,623*			$216,876*			$113,020*		
REC Purchase	Policy as is	Off-site (NC)	Sell All to Utility	YES direct REC purchase	YES but limited market available	Simplest option to implement, but least environmental benefit and no financial returns	8.9¢	9.9¢	12.8¢	8.9¢	9.9¢	12.8¢	8.9¢	9.9¢	12.8¢
Do Nothing			-	-	-	-	5.9¢	6.9¢	9.8¢	5.9¢	6.9¢	9.8¢	5.9¢	6.9¢	9.8¢

* School cash input at project start, per 1 MW$_{DC}$. This is included in LCOE. ** Demand TOU rate is not financially feasible *** LCOE values are for solar PV, there is potential for wind in off-site cases

Shading Key: Grey = Do Nothing Cost Green = equal or less costly electricity for the school than the Do Nothing cost Yellow = slightly more costly than the Do Nothing cost Orange/Red = significantly more costly than Do Nothing cost

Table 19: Results of Comparative LCOE Analysis for 10% ITC