New York City
Guide to Solar on Existing School Buildings




Contents

Solar Technologies

Solar energy systems consist of technologies that use the sun's natural energy to produce electrical energy, heat, hot water, and even cooling for residential, commercial, or industrial buildings. Although there are many solar energy technologies, all solar energy systems are built to convert the sun's solar radiation into useful forms of energy, such as heat or electricity.

Solar energy technologies fall into two categories: passive and active. Passive solar technology takes advantage of the sun's natural position and availability using a building's special location, design, and building materials to provide direct heating or lighting. Active solar technology converts the sun's energy into either heat or electricity. Solar Photovoltaic (PV) technology produces electricity, while Solar Thermal (ST) technology produces heat. This guide will focus on active technologies.

All types of solar systems are designed to offset energy generation by other sources, such as fossil fuels. PV systems can offset electricity generation from coal, natural gas, nuclear, petroleum fuels, and other resources. ST systems will typically offset heating fuels such as natural gas, coal, and petroleum.

Solar Photovoltaic (PV)

PV technology uses the electrical properties of materials called semiconductors to produce electricity. When hit by sunlight, a semiconductor material creates an electrical charge, which can then be transferred through a circuit to anything that uses electricity. In a PV system, these semiconductors are manufactured in the form of cells, which are then assembled into a structural panel. Panels can then be assembled into larger groups, or arrays, to produce increasing amounts of electricity, depending on the amount of energy needed.

Solar Thermal (ST)

Unlike solar PV systems, ST systems turn the sun's radiation into heat and then transfer the heat produced to air or water. They do not produce electricity. These systems can be mounted to a roof or wall to provide solar water heating or space heating for buildings.

Educational Opportunities

Solar systems present educational opportunities for students, but proper safety precautions must be taken. Solar systems that generate electricity are considered static energy generation systems. Although there is no mechanical motion in the system, the electricity flowing out of the modules can be dangerous if safety precautions are not followed or if untrained individuals access the system. Solar thermal systems that are designed to heat a fluid have functional pumps and scalding-hot liquid flowing through them, so only professionally trained individuals should access the system. Furthermore, many solar systems are mounted on rooftops and therefore cannot be accessed except by trained professionals with special equipment. In order to make a rooftop solar system accessible to students, special design considerations need to be met that could increase the cost of installation. These considerations are described below in the Planning Requirements and Considerations section.

An educational lesson could involve going to the site and seeing the solar system, but there are also many ways to educate students without visiting the site in person. Without requiring a trip to the solar system, students could investigate how a solar system works, how much energy it generates, how it benefits the environment, how to design engineering plans, and how it is mounted to the building. There are many different courses that could utilize system specification sheets, system design/schematics, actual electricity output data, and system flow diagrams. Mock roofs are common for professional solar installer training courses. They can easily be created to teach solar installation and wiring to students.

Courses such as Chemistry, Physics, Mathematics, Engineering, and Computer Programing and Software can all utilize an on-site solar system safely for classroom education. Some examples include:

> **Chemistry:** PV cells operate because of the flow of electrons. PV modules are made of different elements to take advantage of their varying abilities to release electrons. The heat transfer of fluids in solar thermal relates to chemistry.
>
> **Physics**: The flow of electricity is a physical phenomenon. Different systems will operate at different voltages and amperages. They also have to meet different frequencies depending on the local electric grid to which they are connected.
>
> **Mathematics:** The design of a solar system involves a great deal of mathematics. Some of the necessary equations can be considered discipline specific. These specific equations will be addressed in the General Engineering section, but they could easily be integrated into many basic mathematics classes as real-world examples.
>
> **Geometry:** When designing a solar system, the path of the sun and the local latitude of the system are all considered to determine the optimum module angle or tilt above the horizon, while also placing the modules in such a position that they do not shade each other in a given space.
>
> **General Engineering:** All engineering disciplines require specific calculations for solar system components, and each discipline is required to develop system schematics for the system design.
>
> **Mechanical Engineering:** Determining loads on the roof resulting from solar system installation, and selecting materials for module manufacturing and mounting materials.

Electrical Engineering: Determining wire sizes, voltages, amperage, predicted wire losses, and outputs. System designs require single- or three-line electrical diagrams for building department and utility approval.

Civil/Environmental Engineering and Architecture: Structural loads on mounting systems, ground penetration considerations, ground bearing loads, and wind loads.

Computer Programing/Software: Programing from AC/DC inverter to system display panel that shows electrical output of system, voltage, frequency, and amperage regulation, as well as overall system performance. System designs can be completed in AutoCad, Google SketchUp, and other computer design programs.

Planning Requirements and Considerations

Planning a solar project is similar to planning for other capital projects, such as heating ventilation and air conditioning (HVAC) upgrades, roof repair/upgrade, and electronic upgrades. The following is a list of considerations and requirements that should be followed when pursuing a solar project. Note: a solar project can only be installed on NYC Department of Education-owned buildings (not leased buildings). Many of the following items will be addressed by a professional solar installation company prior to any agreement to perform an installation. While it is beneficial to be aware of these considerations and requirements, it is best to let a professional installer or engineer make the final decisions on whether or not something is acceptable or unacceptable for a solar installation.

Upfront Costs - Building Retrofits and Initial Installation

Depending on how ambitious the system size and design are and the conditions of the existing school building, the solar project may be a significant capital expense. It is important to determine if the school will have funds to support the effort from start to finish. Part of the process to assess initial costs will include conducting a Solar Project Feasibility Study, which must consider crucial issues including, but not limited to, amount of solar light hitting the roof, structural capacity of the roof, the condition and age of the existing roofing, status of the roof’s warranty, available environmental studies (hazardous materials), access to the roof, American Disability Act requirements, egress, approved roof occupancy, landmark status, and safety requirements for having an occupied instructional space on the roof. A solar project can also trigger compliance with new building code requirements that may otherwise have been “grandfathered”, increasing the cost of the project.

Upfront costs may include replacement of the existing roof if it is not in good condition, added egress stairs to meet code requirements, a new lift or elevator for accessibility, and a perimeter fence around the solar array for safety.

The school must work with a solar contractor and/or engineer in advance to identify the scope of work required for the project, as well as cost estimates for design/engineering, construction, and installation. Note that in addition to the construction and installation, the cost of all studies, evaluations, and investigations must be funded by the school. Solar contractors typically work with their own NYS Registered Architect (RA) or Professional Engineer (PE). In NYC, the Department of Buildings requires this person to submit all construction permit applications. A NYC Licensed Electrician submits the electrical permit to the NYC Department of Buildings. The electrician is typically hired by or a part of the solar contractor's staff.

The school, PTA, or other funding source must be identified before any planning or design for the solar project begins. Grants may be available for different phases of the solar project from sources such as the City Council or a Borough President's Major Capital Improvement Fund. There may also be funding available from the New York State Energy Research and Development Authority (NYSERDA), which the solar contractor would be aware of and facilitate.

Viable Roof and Schoolyard Space

For a PV array to be cost effective there should be sufficient roof space as well as available space on the school grounds if needed. The roof should not be blocked by trees or buildings that will shade sections of the roof where solar would be installed. The roof should have sufficient space to hold the inverter. If the inverter does not fit or would compromise the integrity of the roof, a suitable space on school grounds will need to be designated. Material holding areas, storage containers, and waste containers will need to be located on school grounds during construction. These areas should be identified and discussed with school staff in advance. For example, if a parking lot will be needed, staff should know that they will lose parking spaces until the project is completed.

Existing Roof Condition

The existing roof will need to be in good condition and not be too old. Generally, a relatively new roof (up to perhaps 5-7 years old) would be a suitable candidate, depending on warranty provisions for solar projects. Otherwise, it will need to be replaced before the project begins. Once the solar array is installed, making repairs to a failing roof below is difficult and disruptive. Therefore, an evaluation of the existing roof must be made by a Department of Education (DOE) or School Construction Authority (SCA) qualified tradesperson or professional architect or engineer, and it will need to be reviewed for approval by DOE and SCA. The evaluation must include an assessment of the condition of the roof membrane, flashing, masonry parapets, and roof penetrations, and the existing roof drains and drainage system. The current SCA estimate for a new roof is approximately $40 per square foot.

If the roof is less than 10 years old, determine if the roof is still under warranty by the installer or manufacturer. Obtain a copy of the existing roof warranty from DSF or SCA. The warranty company must review and approve the design for the solar array.

If the existing roof requires replacement, the cost of the replacement combined with the solar installation can range from $30 to $50 per sq. ft. (based on 2012 costs.) These costs depend on the roofing system and whether or not asbestos abatement will be required. If the roof replacement involves work on the masonry parapet, skylights, HVAC equipment, the roof drains, or any other repairs, the cost will increase further. It is, therefore, important to have a cost estimate developed along with the existing roof evaluation.

Alternatives to installing solar on rooftops are solar carports or shade structures. If the school owns a parking lot or other open space, a contractor may be able to build a structure to mount the solar panels above the parking lot. Generally, roof-mounted systems are less expensive than building a new structure. However, it is an option if roof age or space is a constraint for your school.

Structural Loading Capacity

The solar array will add weight to the existing roof structure. A licensed Professional Structural Engineer (P.E.) or Architect must establish the roof's existing structural capacity to determine whether or not adding the weight of the solar components is allowable. The engineer and/or architect must be SCA-approved[1]. Additional load, such as people, furniture, planters, pathways, HVAC equipment, etc., must be factored into the capacity.

There are many roofs where a quick determination can be made that the existing building, as designed, is not suitable for a solar array. Where such a determination is less clear cut, the proposing entity must be able to fund the feasibility investigation of whether or not the structure can be reinforced for the additional load. DOE and SCA can often provide plans for the existing roof, and may have other related information as well.

Wind Load Analysis

The wind load on a structure depends on many factors, including the wind speed, the wind characteristics (turbulence and velocity profile), the geometry of the structure, the effect of surrounding objects and the height above the ground. A structural engineer must calculate wind forces or loads to ensure that a structure can resist wind conditions at a particular location.

Equipment Maintenance and Fire Department Access Paths

The planning for a solar array must include walkways (typically pavers) for access to existing rooftop equipment and parapets. A clear path for circulation must also be provided for maintenance staff to the roof so that the solar system and other roof-sited building equipment

[1] SCA Approved list, http://www.nycsca.org/Business/Pages/default.aspx.

can be maintained to its full productive benefit. In addition, clear paths must be provided in accordance with NYC Fire Code to allow for Fire Department access from the front to the back of the roof and around the perimeter. When laying out the plan, the designer will need to consider how the roof is used by the maintenance staff. The paver path must be configured to permit access to all of the equipment, and must be wide enough to allow for the use of service equipment such as ladders. The plan will be reviewed by the NYC Department of Buildings for these access pathways.

Egress from the Roof

If the solar array is used as a “working classroom,” proper code-mandated egress—typically two stairs that open onto the roof area—would need to be provided if the project anticipates visitors to the roof. The area available for visitors on the roof should be limited so as not to invoke “Public Assembly” requirements of the NYC Building Code. An Architect or Engineer must review the existing conditions and develop the plan to ensure compliance with all relevant NYC Building Codes.

Americans with Disabilities Act (ADA) Requirements

If the project anticipates bringing students and staff to the roof for instructional activities, it must comply with NYC Local Law 58, which enforces the ADA requirements. This will ensure that the roof will be accessible to everyone in the school community. As part of plan examination objections by the Department of Buildings (covered in Local Law 58/87), the school could apply to the Mayor’s Office for People with Disabilities (MOPD) for a handicap accessibility waiver. Prior to the issuance of this waiver, the MOPD should be consulted and will issue a recommendation to the Department of Buildings on interpretation of code requirements.

Using Roof as a Working Classroom

If the school envisions using the roof as a classroom, to be programmed regularly as other classrooms are, then it will be considered a "new use", and therefore the Certificate of Occupancy for the building will need to be amended. The amendments include the new use and occupancy for the roof, and handicapped accessibility (Local Law 58 compliance) would need to be provided as well as other safety features that the NYC Building Code requires for an "occupied classroom". In this case, an Architect must be engaged to define the scope of work necessary to provide an “accessible route” that would allow a non-ambulatory person to travel from the sidewalk outside the school up to the roof.

Student Safety on the Roof

If students and staff are anticipated to come to the roof for observation, measurement and recording activities, a tall, fence-type protective barrier will need to be provided at the perimeter of the roof area as a safety measure. This installation will need to be planned by the Architect or Engineer to ensure that it doesn't negatively impact the waterproof envelope of the building, and that it doesn't trigger other agency requirements, such as State Historic Preservation, NYC Landmarks, or NYC Public Design Commission.

Costs

The average cost of a PV solar system in NYC is between $4.00-6.00 per DC Watt. Often, the larger the system the lower the cost due to economies of scale and many fixed costs for solar installations. Smaller systems will be on the higher end and large systems will be on the lower end. Many other factors, such as those described above, can also add to system costs. This cost per Watt equates roughly to $30-$90 per square foot, depending on the slope of the roof, panel cost, and panel efficiency (see Roof Space section below).

The following is an example cost and size of a 10kW solar system. A 10kW solar system at $5.00 per DC Watt will cost $50,000 before incentives from NYSERDA and other government agencies. NYSERDA incentives reduce the cost by 20-30 percent. There are also federal tax credits available for solar PV, which can be monetized by a third-party financier in some cases. To provide an idea of the size of a 10kW solar system, a typical solar panel is 270 Watts. A 10kW system would thus require about 37 panels. Solar panel wattages currently range between 230 Watts to 345 Watts, but efficiency is always improving. Depending on the orientation of the array and any shading concerns, the solar array will likely produce approximately 12,000 kilowatt-hours per year.

Ancillary Construction Costs

The actual construction of the project should be discussed with all relevant parties up front, including DSF staff, the school's Custodian Engineer, and school principals. The school schedule should be reviewed to determine what work, if any, can occur during normal school hours. Some, if not all, work may have to happen after hours, on weekends, and over holidays. For example, the rigging of materials should be conducted when no staff or students are on site, which usually occurs during school holidays. After hours work will require DOE permits and will add to the overall cost of the project.

Ongoing Costs – Maintenance

The additional maintenance and operational cost for solar arrays, which are "ancillary" to the instructional program, is expected to be minimal but will depend on the system design and location of the system. The actual cost will be determined by the installation company. Where the roof is used as a full teaching environment, the cost of maintaining the equipment needed to access the roof and regular cleaning of the instructional space will add to the cost above.

There also may be ongoing costs to provide access to the website that houses the solar productivity data. These costs need to be addressed and included in any request for a solar project.

The Division of School Facilities (DSF) managers should be involved upfront in the planning process – the principal will need their support for the project from beginning to end. For costly projects involving capital construction work (roof replacement, and other major work in the building), the School Construction Authority should be involved at the early planning stage, and throughout design and construction.

Warranties

Solar panels typically have a 25-year warranty, but they are expected to last longer. However, electricity production decreases slightly over the lifetime of the solar system. Inverter warranties often last 10 or 25 years depending on the equipment and manufacturer. If it fails within the warranty period, the equipment will be replaced for free. The National Renewable Energy Lab (NREL) estimates inverter replacements to cost $0.50/Watt, but this will likely be reduced over time as equipment costs are declining as the technology improves. Contractor warranties for the labor are typically for 5 to 10 years. If a Power Purchase Agreement or lease option is used for financing, the third party owner of the solar system often provides the warranty for the lifetime of the 20-25 year agreement. More on these financing methods is described below.

Roof Space

If the average slope within a building's usable roof area for solar is less than 10 degrees, a conservative estimate of power density is 8 Watts-DC per square foot. Slopes greater than or equal to 10 degrees can be conservatively estimated as 11 Watts-DC per square foot. If higher efficiency panels are used for the project, the power density will be higher. Taking the example of a 10kW solar system on a flat roof, a conservative estimate roof space utilized for the panels would be 1,250 square feet. This estimate does not include space required for using the roof as a working classroom or Fire Code access requirements.

Funding

Schools should consider multiple financing models and weigh the cost and benefits of purchasing the solar system versus a third-party ownership model (leasing or a Power Purchase Agreement). Multiple financing proposals should also be sought prior to installation. By weighing the long- and short-term benefits of each financing mechanism, an informed decision can be made. Third-party ownership, mostly in the form of Power Purchase Agreements (PPAs) and leasing, has become increasingly common for solar systems in recent years. The main difference between the two third-party ownership models is that in a PPA requires the end user to purchase the solar energy at a set rate while a lease allows the end user to use the solar system's energy while a regular lease payment is made for the equipment. While the PPA requires a payment per unit energy and the lease requires a payment per unit of time, the two models are often discussed interchangeably. Different companies will manipulate these two models into varying arrangements. The following definitions are meant to provide a general, high-level overview.

Paying Outright

When paying outright with cash for a solar system, the cost of the installation is typically paid during construction milestones specified in the contract as the project is completed or near completion. When owning outright, the owner receives all of the solar energy, which offsets energy consumption from the utility, as well as net-metering credits for excess generation beyond what is used on site during times of low energy consumption and high energy generation. Net-metering credits are provided on the utility bill and can offset future consumption. The savings accrued from the solar energy offsetting energy from the utility and net-metering credits will eventually pay back the investment. After the payback of a system, which can range from 5 to 50 years, the solar system will essentially generate free electricity, resulting in significant savings over the life of the system. A school should determine the length of an acceptable payback period based on an examination of its capital budget, the internal rate of return of the project, and other metrics, such as the net present value of the investment.

It is important to note that a non-profit organization, such as a school, making a direct purchase of a solar system may not be able to take advantage of the tax credit incentives that would be available to a third-party financing company. These tax incentives account for 50 percent or more of the installed cost for businesses and residences. This will likely cause the school to see a longer payback period than other building owners if purchasing with cash.

Power Purchase Agreements (PPA) and Solar Leases

A solar power purchase agreement (PPA) is a financial agreement where the end user (a school) pays for a set rate of electricity over a given period of time. The electric rate offered by the PPA is often lower than the utility rate, allowing for immediate savings in some cases with minimal up-front cost. The solar system is owned by a solar developer or third-party financier. The end user will not own the system unless the contract terms allow for the end user to buy the system from the solar developer or third party financer at a certain point of the contract period.

In a solar lease agreement, an end user will lease the solar equipment for a negotiated time similar to that of a car lease (often 20-25 years). Financial benefits can be seen in different methods, depending on lease terms. In one method the end user will receive all net-metering benefits, which are credits for excess generation during times of low energy consumption and high energy generation, thus decreasing the overall energy bill. For the other methods, which are more common, the end user agrees to buy power from the solar system at a rate lower than that obtained from the utility grid. Leases often allow for immediate savings relative to the cost of utility power for no money down.

NYC DOE is not eligible at the school level to sign a PPA or lease. The NYC Department of Citywide Administrative Services (DCAS) manages the school's electric bills and is currently looking into PPAs for school buildings that are a good fit for the City.

Financing

One method of deferring the upfront capital costs of a solar system is to obtain a loan similar to that of a bank loan or a mortgage. This financing option is becoming more available as organizations such as NYSERDA and the NYS Green Bank have engaged the commercial lending sector to offer special financing and support for solar projects.

Next Steps

If you have considered all requirements and considerations above and would like to move forward with a feasibility study for a solar project, we have provided a checklist for you to follow. The checklist is guidance for whom to involve in the process and at a minimum what should be included in the feasibility study. Because of the technical nature of solar projects, the first step would be to consult with a solar installation company who would survey the site and determine site benefits and constraints, as well as cost estimates and output potential. The second step would be to engage the school's custodian and examine the following feasibility study checklist together. It is always recommended to receive multiple quotes from solar contractors, if you decide to move forward with the installation.

Contact DOE Sustainability Office for more information, sustainability@schools.nyc.gov.

Additional Resources

Sustainable CUNY: http://www.cuny.edu/about/resources/sustainability/solar-america.html

NYC Solar Map: http://nycsolarmap.com/

Community Solar Report: http://www.cuny.edu/about/resources/sustainability/solar-america/nyc-communitysolar/CommunitySolarReportFINAL.pdf

Installing Solar: http://www.cuny.edu/about/resources/sustainability/solar-america/installingsolar.html

NYSERDA: http://www.nyserda.ny.gov/

US DOE: http://energy.gov/science-innovation/energy-sources/renewable-energy/solar

NYS DEC: http://www.dec.ny.gov/energy/43231.html

NY-Sun Initiative: http://ny-sun.ny.gov/

DSIRE Incentive Database:
http://www.dsireusa.org/incentives/index.cfm?re=0&ee=0&spv=0&st=0&srp=1&state=NY

K-Solar: http://www.nypa.gov/K-Solar/default.html

Solar Project Feasibility Study Checklist

- Who to involve in the feasibility study
  - Custodial Staff
  - Deputy Director of Facilities for your school
  - Solar Contractor
  - Architect and/or Engineer
  - School Construction Authority
  - School Administrative Staff
- Scope of Project
  - Definition of Project
  - Solar Study – viability of space and solar capacity
  - How much of roof to be occupied by the solar array (square footage)
  - Types of installation
- Planning Requirements and Considerations
  - Existing roof condition
  - Structural load capacity
  - Access to roof
  - Fire egress
  - ADA requirements
  - Safety requirements
  - Equipment maintenance paths
- Cost estimates
  - Design
  - Engineering
  - Construction/Installation

Developed by the NYC Department of Education Office of Sustainability, School Construction Authority, NYC Citywide Administrative Services, and Sustainable CUNY

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