BUILDING INTEGRATED PHOTOVOLTAIC (BIPV) RESEARCH STUDY

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Improving the Built Environment Since 1972

NYC School Construction Authority

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STUDY GOAL

In order to maximize the total renewable energy generation of the New York City (NYC) School Construction Authority (SCA) projects, the NYC SCA will consider the application of Building Integrated Photovoltaic (BIPV) components and kinetic energy technologies at SCA buildings of 3 to 6 stories tall.

SCA has requested technical research be conducted to determine the feasibility of applying BIPV components and kinetic energy technologies on new building projects as well as on existing buildings undergoing recladding and envelope improvements as part of deep carbon retrofit projects.

The goal of this research is to determine if and in what specific ways BIPV components and kinetic energy technologies could feasibly be applied on SCA projects to help those buildings meet energy performance and greenhouse gas (GHG) emissions reduction mandates and support the City's goals for mitigating climate change, which include the following:

- Local Law 24/2016, requiring municipal buildings to install at least 100 MW of solar photovoltaic (PV) generation on municipal buildings by 2025.
- Local Law 51/2023, requiring feasibility studies of renewable energy generation or net zero energy use for municipal buildings that are subject to low energy use intensity limits.

As a potential strategy for maximizing the utilization of a building envelope's surface area for solar PV generation by replacing existing essential building functions with solar power-generating components, the application of BIPV products on SCA projects, if feasible, could constitute a significant contribution toward meeting these goals.

RESEARCH OBJECTIVES

The primary goal of this Research Project (the "Project") is to determine the feasibility of effectively applying BIPV components and kinetic energy technologies on suitable SCA projects. Related tasks include:

- Review current state of industry for BIPV components; identify and evaluate available BIPV products;
- Calculate potential energy generation benefits of BIPV components and kinetic technologies;
- Analyze regulatory, design, constructability, and cost implications of applying BIPV components and kinetic technologies;
- Assess feasibility of implementing BIPV components on SCA projects, considering factors including cost, energy efficiency and output, aesthetics, impact on building energy performance, impact on building envelope performance, reliability, durability, structural impact, architectural design coordination, constructability, impact on construction schedule, and regulatory constraints;
- Describe best practices, model standards, and design considerations for effective and successful application of BIPV components on SCA projects;

- Review current state of industry for kinetic energy technologies; identify and evaluate available kinetic energy products.

RESEARCH APPROACH

The following tasks were performed during this research project:

- Review the current state and conditions of the BIPV industry and conduct a literature review to determine current BIPV product availability and capabilities.
- Coordinate with selected primary BIPV manufacturers to evaluate currently available products.
- Conduct feasibility assessments of applying selected currently available BIPV products to SCA case study projects.
- Perform insolation analysis of SCA case study projects to determine potential for solar energy generation.
- Perform energy model analysis of SCA case study projects to determine potential impact of installed BIPV products on building energy performance.
- Perform thermal envelope analysis to determine potential impact of selected currently available BIPV products on thermal performance of exterior building wall.
- Perform cost estimation analysis to determine full project cost of applying BIPV products.

SUMMARY OF FINDINGS

BIPV

This study found that it would be feasible to integrate BIPV components on SCA projects for the following applications: **rainscreen panels, window glazing, roof pavers, play yard canopies/shading structures, covered bicycle parking**. This assessment is based on the following findings:

- Availability
  - The study found that viable BIPV component products from multiple manufacturers are currently available within the relevant market, including:
    - BIPV rainscreen panels
    - PV window and skylight glazing
    - BIPV rooftop pavers*
    - BIPV canopies†
    - BIPV roof security railings
  - BIPV technology is rapidly evolving, and new manufacturers are introducing products to the market regularly. While conducting this study, multiple new products were introduced that were not evaluated.
- PV energy generation potential
    - The study found that BIPV rainscreen panels could generate approximately 13 to 15 watts per square foot and approximately 8 to 10 kilowatt hours per square foot per year.

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* Only one viable product found in U.S. market research. Multiple products available internationally.
† Only one viable product considered for the purposes of this study. Multiple products available.

    - The study found that BIPV glass could generate approximately 5 to 7 watts per square foot and approximately 3.5 kilowatt hours per square foot per year.
    - The study found that BIPV rooftop pavers could generate approximately 13 watts per square foot and approximately 16 kilowatt hours per square foot per year.
    - The study found that BIPV canopies could generate approximately 5.5 watts per square foot and approximately 7 kilowatt hours per square foot per year.
- Impact on building thermal envelope performance
  - The study found that there are available BIPV facade components (rainscreen panels) that can provide the minimum exterior wall insulation value specified by SCA design requirements.
- Benefit to building energy performance
  - The study found that the application of select BIPV components (rainscreen panels) could achieve a 15-25% reduction in overall building energy use.
- Cost
  - The study found that the cost of installing BIPV components can be comparable to the current SCA budgeted cost for traditional building components (rainscreen panels, windows/glazing, roof pavers, canopies).
  - Additional cost benefits, including tax credits may be applicable despite the SCA not traditionally being eligible to claim such benefits.
  - BIPV is an emergent and evolving technology and therefore it is important to periodically reevaluate market availability, pricing, and suppliers. As this market continues to mature, cost competitiveness may continue to evolve and become more favorable.
- Absence of definitive barriers related to constructability
- Absence of definitive regulatory constraints

This study found that the feasibility of integrating BIPV components on SCA projects is dependent on the following:

- The implementation of appropriate analysis procedures and coordination during the architectural design process to ensure that BIPV products are cost-effectively applied.
- Use of OTCR process to gain pre-approval for specific desired BIPV products.

This study identified the following **potential issues** related to the application of BIPV products on SCA projects:

- The North American BIPV market is still nascent but steadily evolving. There are currently a limited number of reputable manufacturers providing BIPV products, and there are yet few completed BIPV projects in North America that can be offered as case studies. However, it is anticipated that this situation will change as awareness of and interest in the technology appears to be rapidly increasing, giving existing manufacturers and their products ever more exposure. It's anticipated that this continued increasing interest will motivate a greater number of manufacturers to develop BIPV products and accelerate the further development of the technology.

- The typical lifetime of available BIPV products is approximately 25 years. This is compared to the minimum 50-year lifetime of buildings.
- Based on current testing standards, there is the potential for extended permitting and approvals process for new BIPV technologies.
- BIPV products, as with all solar PV products, have a high embodied carbon impact. This study did not find that strategies for embodied carbon reduction of BIPV production (circular economy practices, etc.) are currently being implemented within the industry.

Kinetic Energy

This study found that kinetic energy technologies would not be feasible for integration on SCA projects, based on the current limited range and availability of kinetic energy products, and the limited energy output capabilities of those available products. Additionally, there is minimal information available on the cost and frequency of maintenance of kinetic energy products, which can add to the overall operations expenditure of the projects. Although these products have a potential to contribute to the energy savings of the SCA buildings, it is recommended that this technology be considered in the future when technological advancements and research can improve the efficiency and applicability of the energy systems which is not the case currently.

DESCRIPTION OF RESEARCH TASKS AND APPROACH

BIPV and Kinetic Energy Research Approach

For the initial task of general BIPV and Kinetic Energy Research, SWA studied the BIPV and Kinetic Energy products and their manufacturers in the market. It included review of the products with the SCA team and consultation with manufacturers with primary focus on the feasibility of integrating these products in the SCA projects. This research also focuses on the regulatory review of this technology with respect to the relevant local, national and regional building codes with particular consideration to potential changes to the code language related to BIPV.

In this report, this task has been summarized into a summary of product data using BIPV and Kinetic energy, best practices and design considerations for integration at SCA projects. It includes the following:

1. BIPV
    a. Identification of major manufacturers of BIPV products and services available in in New York City.
    b. Evaluation of technological impacts and constraints of BIPV to understand the potential risks and challenges associated with BIPV technology, as well as the opportunities for innovation, such as its durability, efficiency, cost, and contribution to carbon reductions.
    c. Assessment of services provided by BIPV product manufacturers to understand the level of support that is available from fabricators, as well as the types of services that they can provide including but not limited to product design and engineering, installation, and maintenance and repair.
    d. Technical design consideration of the BIPV in NYC, such as the climate, the availability of sunlight, and the regulatory environment.
    e. Analysis of benefits and/or limitations specifically affecting the application of BIPV in SCA's construction work and understanding the specific challenges and opportunities that SCA will face in incorporating this technology into their construction projects.

2. Kinetic Energy
    - Overview of different types of Kinetic Energy technology adopted in the buildings, and identification of systems feasible in the New York City region.
    - Comparison of different Kinetic Energy systems such as floor tiles, pedal bikes, etc.

Case Study Review Approach

SWA applied the summary findings from the initial BIPV Research task to conduct a Case Study Review of two SCA school projects. Full case studies are included in a later section of this report. The following tasks were conducted for this case study review:

- Identification of site-specific conditions that may impact the production and distribution of energy from BIPV systems, such as shading from site neighboring structures, landscape elements such as trees, building's location, and evaluation of the building façade to determine the optimal design for the BIPV system.

- Assessment of advantages and disadvantages of each BIPV system type, considering factors such as energy generation capacity, aesthetic appeal, durability, and maintenance requirements.
- Estimated PV generation based on the design layouts of the school buildings using Rhino with Grasshopper plug in.
- Evaluation of the thermal performance of the BIPV-integrated designs by comparison of u-values with those to typical SCA designs to analyze the potential energy savings achieved through BIPV integration.
- Energy analysis of each case study building based on variables such as BIPV type and orientation, and assessment of the energy generation potential of BIPV technology in the specific context of SCA projects.
- Inclusion of cost estimates associated with procurement, installation and maintenance of BIPV systems in SCA schools after collaboration with third party consultants to provide a comprehensive summary of the financial implications of integration this technology.

Envelope Performance Analysis

SWA evaluated the thermal performance of the façade anchor systems for proprietary BIPV systems from two manufacturers: Mitrex and Elemex. The goals of this thermal analysis were to:

- Quantify the true thermal performance of a typical SCA wall assembly with each BIPV system
- Evaluate what design modifications, if any, would be needed to meet SCA's standard of R-30 walls.

SWA performed all thermal modeling in Heat3, a 3-dimensional steady state conductive heat flow modeling software commonly used to evaluate the performance of building envelope systems. The BIPV façade anchors were modeled according to manufacturer's specific details to their respective systems as well as additional clarifications provided directly from each manufacturer.

SWA used the results of this modeling in supplemental calculations to determine the true R-values of the modeled wall assemblies.

TECHNOLOGY DESCRIPTION AND APPLICATIONS

This study evaluates the feasibility of applying Building Integrated Photovoltaic (BIPV) components and kinetic energy technologies at SCA projects.

The study investigates the following specific products:

- Photovoltaic rainscreen panels
- Photovoltaic window glass
- Photovoltaic rooftop walkable pavers
- Photovoltaic solar canopies
- Piezoelectric Systems
- Kinetic Energy Recovery Systems (KERS)
- Kinetic energy - harvesting equipment

BUILDING INTEGRATED PHOTOVOLTAIC (BIPV)

Overview

It is critical for SCA projects to maximize on-site renewable energy generation in order to comply with both Local Law 51 of 2023, requiring these projects to achieve a source energy use intensity (EUI) of no more than 70 kBtu/sf/year, and Local Law 97 of 2019, which requires SCA to help the City reduce GHG emissions from City government operations 50% by 2030.

One component of this study has been the evaluation of the feasibility of implementing various types of building-integrated photovoltaic (BIPV) technology on SCA projects as one potential strategy for maximizing on-site renewable energy production.

BIPV Definition

For the purposes of this study, BIPV technology is defined as *a photovoltaic (PV) energy-generating technology, applied to a building in such a way that it performs at least one (1) additional function in addition to solar energy generation.*

BIPV systems, by simultaneously serving as a building envelope material or exterior building application, as well as a power generator, should provide savings in the quantity and cost of building materials, reduce the building's electricity costs, reduce the building's operational carbon emissions, and may also add architectural interest to the building design.

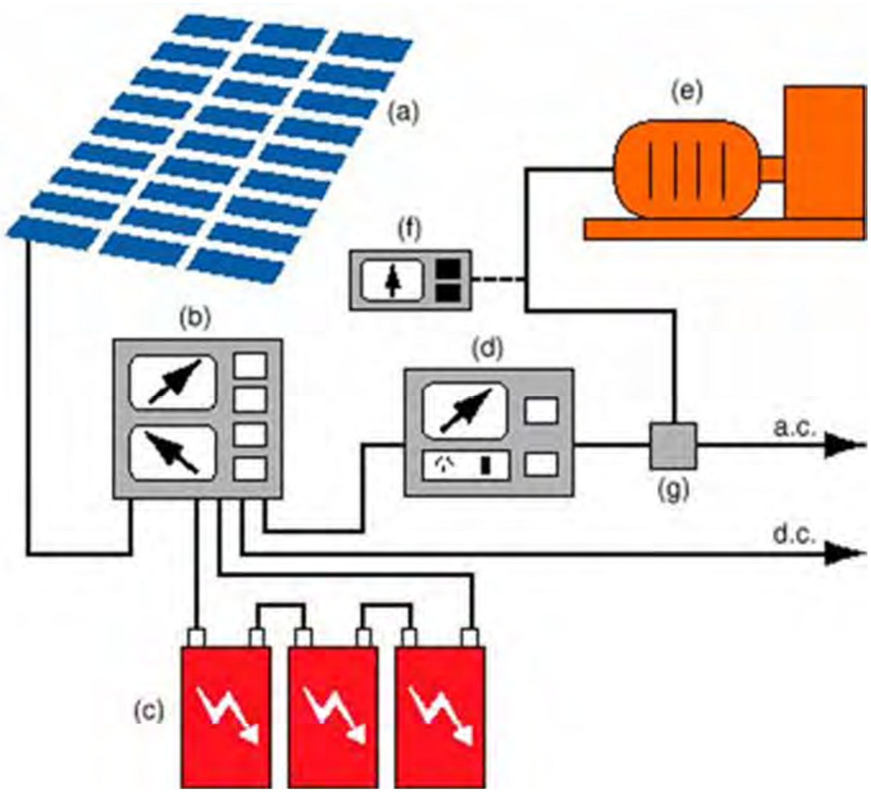
Per the *National Institute of Building Sciences' Whole Building Design Guide*, a complete BIPV system includes the following components (Source: https://www.wbdg.org/resources/building-integrated-photovoltaics-bipv):

a. PV modules, thin-film or crystalline;
    - **Thin-film PV products** typically incorporate thin layers of photovoltaic material placed on a glass superstrate or a metal substrate using vacuum-deposition manufacturing techniques similar to those methods used in the coating of architectural glass. Currently, commercial thin-film materials can deliver about **4-5 watts per ft² of PV array area** (under full sun conditions). Thin-film products will typically have a lower cost compared to crystalline products as there are reduced requirements for active materials and energy in the production process.

- **Crystalline PV products, or thick crystal PV products,** include solar cells that are made from crystalline silicon either as single or poly-crystalline wafers. These products can deliver about **10-12 watts per ft² of PV array** (under full sun conditions). Crystalline cells fall into two categories: monocrystalline, the highest efficiency, and polycrystalline, generally slightly less efficient. Crystalline products can be manufactured to be transparent, semi-transparent, or opaque.

b. Charge controller to regulate power in and out of the power storage system (in stand-alone PV systems);
c. power storage system, which is comprised of the utility grid in utility-interactive systems, or on-site batteries in stand-alone systems;
d. power conversion equipment including an inverter to convert the PV modules' DC power output to AC power that is compatible with the utility grid;
e. optional backup power supplies such as a diesel generator; and
f. required support and mounting hardware, wiring, and safety disconnects.

Figure 1: BIPV System Diagram (Source: Murdoch University Energy Research and Innovation Group)



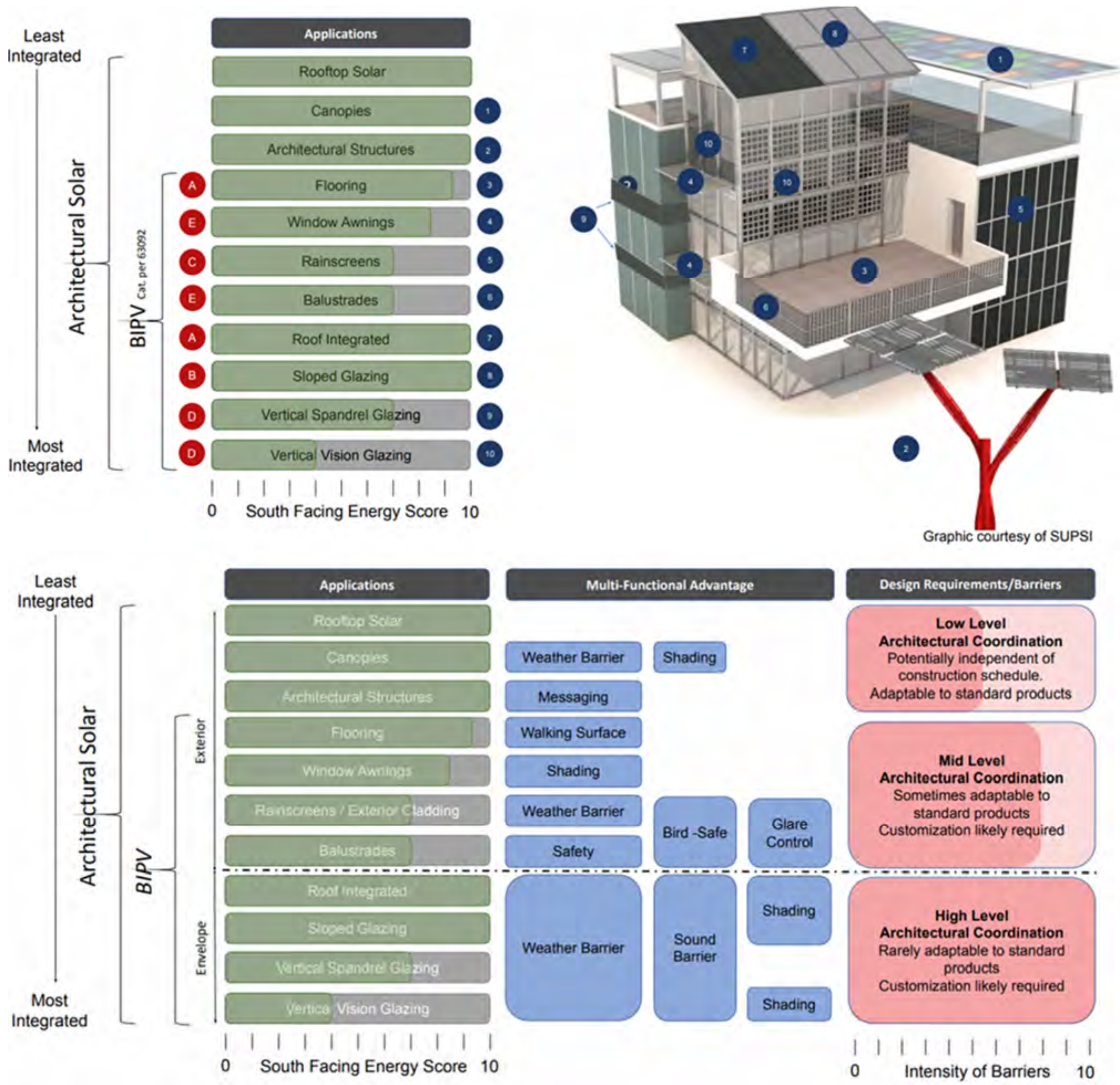
Per standard EN 50583 / IEC 63092 / IEC 61730, photovoltaic modules are considered to be building-integrated if the PV modules form a building component providing one of the following additional building functions:

- Mechanical rigidity or structural integrity
- Primary weather impact protection (rain, snow, wind, hail)

- Energy economy (such as shading, daylighting, thermal insulation)
- Fire protection
- Noise protection
- Separation between indoor and outdoor environments
- Security, shelter or safety

Under this definition, the application of building-applied PV (BAPV), or conventional solar panels that serve an additional building function would qualify as BIPV.

Figure 2: BIPV Applications (Source: The Institute for Applied Sustainability to the Built Environment, The University of Applied Sciences and Arts of Southern Switzerland (SUPSI))



BIPV Applications

Per the definition of BIPV given, the technology can be applied to buildings in the following ways:

Envelope & Exterior Applications

- **Wall Integrated Panels**
  - Additional building function(s): weather barrier, sound barrier
- **Roof-Integrated Panels & Solar Shingles**
  - Additional building function(s): weather barrier, sound barrier
- **Glazing (Sloped, Vertical Spandrel, Vertical Vision)**
  - Additional building function(s): weather barrier, sound barrier, shading
- **Rainscreens & Exterior Cladding**
  - Additional building function(s): weather barrier, bird-safe, glare control
- **Window Awnings and Shading Devices**
  - Additional building function(s): shading
- **Flooring / Pavers**
  - Additional building function(s): walking surface
- **Balustrades & Railings**
  - Additional building function(s): safety, bird-safe, glare control
- **Canopies & Architectural Structures**
  - Additional building function(s): weather barrier, shading
- **Rooftop Mechanical Equipment Screening**
  - Additional building function(s): visual screening
  - Per NYC Zoning Resolution 134-32 - 1510.10 BIPV is a potential application for Rooftop Mechanical Equipment Screening

SWA has evaluated specific market-available products in the multiple BIPV application categories, found in the chart below. These BIPV applications were selected for evaluation based on the understanding that they would have the highest impact in terms of replacing existing essential building functions with solar power-generating components. These components comprise a significant portion of available building surface area that is not likely to be allocated for other production or active occupancy functions (ex. rooftop solar, green roofs, etc.).

Based on SWA's research of the current state of the BIPV market, these following categories are also the BIPV technologies that are most developed, and most readily available in the relevant market. Additionally, according to the US Department of Energy, these product types fall within the BIPV market segments that are currently being actively pursued.

Product Categories

Figure 3: Product Categories

Type	**Description**	**Market Availability**
Envelope Applications		
Roof-Integrated	• Use of photovoltaic roof panels and shingles in place of conventional roofing materials. • Use of PV in roofing systems replace batten and seam metal roofing and traditional 3-tab asphalt shingles. • Horizontal applications increase solar access compared to vertical applications, resulting in increased power generation.	• Tesla, Solar Roof • Timberline Solar by GAF Energy • Certainteed, Solstice Shingle • SunTegra, Solar Tiles; Solar Shingles • LUMA Solar, Solar Roof • Onyx, Photovoltaic Roof Tiles
Wall-Integrated	• Use of pre-fabricated exterior wall panels with integrated photovoltaic panels. • Installation on the building's vertical faces reduces solar access compared to horizontal surfaces, but the large surface area of the building's exterior walls would in some cases compensate for the reduced power generation.	• Mitrex - Prefab Wall Panel (Cladify) • Helios Façade
Glazing	• Use of photovoltaic glass as a replacement for conventional window glass. • Installation on the building's vertical glazing areas reduces solar access compared to horizontal areas, but on buildings with a larger total available window area, this would in some cases compensate for the reduced power generation.	• Mitrex - Solar Glass • Onyx Solar - Photovoltaic Glass (Skylight, Curtain Wall, Spandrel Glass) • Helios Façade
Exterior Applications		
Rainscreen Cladding Panels	• Replacing "inactive" conventional rainscreen cladding panels with "active" panels with integrated photovoltaic technology. • Installation on the building's vertical faces reduces solar access, but the large surface area of the building's exterior walls would in some cases compensate for the reduced power generation.	• Mitrex - Solar Façade (Cladify) • Elemex - Solstex Solar Façade • Helios Façade
Rooftop Paver	• Replacing conventional rooftop pavers with "walkable" photovoltaic pavers. • Horizontal applications increase solar access compared to vertical	• Onyx - Photovoltaic Floor • Platio - Solar Pavement

	applications, resulting in increased power generation.	
Balustrades / Railings	• Use of photovoltaic glass or photovoltaic panels for balustrade and railing components. • Vertical applications reduces solar access compared to horizontal applications.	• Mitrex - Solar Railing
External Solar Shading / Awnings	• Incorporation of photovoltaic glass or photovoltaic panels into external shading elements or awnings. • Horizontal applications increase solar access compared to vertical applications, resulting in increased power generation.	• Mitrex – Solar Glass • PVilion - Solar Canopies (fabric) • Onyx - Photovoltaic Canopy (glass)
Canopies / Architectural Structures	• Use of photovoltaic glass or photovoltaic fabric as the covering material. • Horizontal applications increase solar access compared to vertical applications, resulting in increased power generation.	• Mitrex – Solar Glass • PVilion - Solar Canopies (fabric) • Onyx - Photovoltaic Canopy (glass)

CURRENT SCA STANDARDS

The Consultant Team has identified the following components from SCA's Design Requirements that would impact the implementation of the studied BIPV technologies on SCA building projects.

PV Systems / Solar Generation Standard

- New SCA buildings must meet Green Schools Guide (GSG) 2019 requirements related to solar generation.
- Existing buildings must evaluate potential on existing roof (minimum 4 kw size).

SCA Design Requirements Section 8.0 – Sustainability and Resiliency includes guidelines for solar PV installations at SCA school buildings. These guidelines dictate that, beginning in the Pre-Schematic phase, project teams shall assess the potential of renewable energy as a component of the Integrative Design Process, included in the 2019 NYC Green Schools Guide.

Project teams should implement this process to identify and evaluate opportunities for synergies between building systems and meet the requirements of the *Onsite Energy Generating Building or Net Zero Building* feasibility study requirements of Local Law 51 of 2023.

Section 8.0 also includes the applicable local laws and regulations, fire code requirements, energy code commissioning and building code progress inspection, zoning, historic building and the permitting and approval processes for solar installations requirements for projects.

The Design Requirements further describe general PV implementation requirements, which include shading analysis, general design parameters, structural analysis, and power distribution features.

The **NYC Climate Resiliency Design Guidelines (v4.1)** recommend that a minimum of 50% of a project's site area be shaded, vegetated, and/or be comprised of high solar reflectance surfaces. These Guidelines propose that PV systems be used to mitigate heat risk by shading building or site areas and by reducing demand on the utility grid for increased cooling energy needs.

NYC SCA Green Schools Guide of 2019

- **E6.1P– Renewable Energy Feasibility**
    - This prerequisite requires all projects to study the feasibility of designing and constructing the project as an "onsite energy generating building", as per Local Law 51/2023, and when applicable, as a "net zero energy building" per the same law.
        - "On-site energy generating building" means that the building has been designed and constructed to produce energy on-site from renewable energy sources, in an amount equal to or greater than ten (10) percent of such building's total energy needs."
- **E6.2 – Renewable Energy Production**
    - Required, if determined to be feasible under E6.1P, for all projects.
    - As per Local Law 94/2019, a solar PV system may be selected to comply with sustainable roofing zone requirements outlined in the law. If this option is selected, then project teams must evaluate renewable energy production based on the requirements of this credit.
    - Use renewable energy systems to offset building energy costs. Calculate the percentage of renewable energy with Equation 1.

Equation 1. Percentage of Renewable Energy

$$\%\ \text{Renewable energy} = \frac{\text{Equivalent cost of annual usable energy produced by renewable energy system}}{\text{Total building annual energy cost}}$$

-
    - To qualify as an eligible on-site system, the fuel source must meet one of the following conditions:
        - Wholly contained/produced on-site;
        - If the fuel source is not fully owned, and in cases where use of a substitute non-renewable fuel is possible, projects must engage a two-year contract for purchase of the renewable fuel source, with an on-going commitment to renew, for a period of 10 years total.

Notes:

- **Local Law 51/2023**, requires that all buildings investigate the possibility of providing 10% of the building's usage for alternate energy sources. Based on the findings of that study, the SCA will then determine if the building is to incorporate solar, and to what extent.
- As per US Code Tile 26, Section 45, qualified renewable energy sources are the following: wind, biomass, geothermal (in some cases), solar energy, low impact hydropower, and wave and tidal energy.
- Having studied the availability and practicality of the allowed renewable energy sources, **solar PV is the only source that the SCA is currently evaluating further in renewable feasibility studies for NYC Public Schools**.
- NYC Department of Citywide Administrative Services (DCAS) is working directly with NYC Department of Education (DOE) to **implement Solar PV projects on existing school roofs that are deemed solar-ready**.
- Where practical on new schools, NYC SCA will attempt to deliver roof areas clear of obstructions, with a minimum area that would allow for **10% total energy savings from a future Solar PV system**.

SCA Standard Specifications

- 13602 Ballasted Photovoltaic System
- 13603 Attached Photovoltaic System

These above specification sections describe design requirements for solar PV systems, covering all PV system components and requirements for field quality control, procedural and safety measures, installation, and commissioning.

SCA Design Requirements, Building Envelope – Section 4.0

4.1.1 Building Façade

Per the SCA Design Requirements, "for both new buildings and additions, the aesthetic, scale, proportion and detail of building facades shall manifest the educational, social, cultural and civic importance of a neighborhood school, its community, and be appropriate for the age of the student population as well as the context of the site."

"Choice of materials and wall selection is to be based on the School Construction Authority's **"Façade Selection Matrix"**, which takes into account many factors such as material **longevity, building location, constructability and project duration, building aesthetic and cost.** The materials to be used in the design and construction of the school's exterior facades shall typically be limited to those materials that are specified in the Authority's Standard Specifications and the parameters established herein."

Rainscreen

Per the SCA Design Requirements,

> "Rain Screen systems may be utilized for portions of the façade, subject to approval by the School Construction Authority through the **Façade Review Process**, unless the system is selected as the best option for the entire façade through the Façade Selection Matrix. Rain screen system shall be comprised of

structural steel stud with sheathing (or concrete or masonry if dictated by design of the building) back-up wall, vapor/air barrier, insulation, thermally isolated clip and framing grid and finish material meeting an **overall assembly R-value of 30.**

“Ultra-high-performance concrete (UHPC) and terra cotta panels are the accepted systems, with selection based on the aesthetic of the finish and panel size. Panel size and rail systems spacing for system selected shall take into account the economy and constructability economy of the selected system (i.e. UPHC systems are to use sizes in the 5’x12’ range, with panels used for returns below 16” x 5’ range being uneconomical and terra cotta units are typically most economical in 16” x 5’ range to maximize effective panel economy as well as greater support system spacing.”

- Systems are to use concealed fasteners.
- System is to be kept a minimum of 2’-0” above grade to protect against snow and equipment and be flashed out. Both UHPC and terra cotta tiles are resistant to damage, but a graffiti-resistant coating as required by DR 4.2.2 is to be provided.
- A rainscreen system may not be appropriate in areas of high noise, as their low mass may not provide the required noise separation. An acoustic analysis is to be provided if proposed for an area of high noise.

“The use of other panel materials such as porcelain tile, GFRC, etc. utilizing concealed fasteners shall be reviewed and accepted through the Façade Review Process.”

“Façade is to be designed to minimize field cuts for those system not fabricated to exact sizes, as edges may fray in the future if the manufacturer’s products and instructions to treat the edges are not carefully followed.”

“Colors are to be selected from the manufacturer’s standard colors and be available from several manufacturers.”

Canopies
Per the SCA Design Requirements,

“A canopy or a building overhang may be desired to provide a sheltered area immediately preceding the entrance doors. Such canopies, when provided, shall typically be an integral part of the building.”

a. All canopy types, materials, sizes and locations are subject to approval by the Authority.

Windows
Per the SCA Design Requirements,

“The arrangement and design of windows (fenestration) shall be in scale and proportion to the building’s elevations, massing, and volume. The windows must be appropriate for the use of the space for which the windows are being provided.”

“All occupied spaces and corridors shall have windows (unless the spaces are below grade). Windows for new buildings shall typically be aluminum hopper/fixed windows (projecting inward). Additions/Adjacencies to SHPO and/or Landmark buildings may require windows other than hopper/fixed windows. Windows shall be provided as per Design Requirement 4.3.1 - Window Types."

"Use of windows other than hopper/fixed windows for new buildings or additions must be approved by the Authority."

Shading Elements
Per the SCA Design Requirements,

"Proposed shading elements to address glare shall be discussed at the Green Schools Guide IDP meeting and included in the Façade Review Process package for review and acceptance by the Authority."

Glazing
Per the SCA Design Requirements,

"Windows must be glazed with double or triple-glazed IGUs with low-e coating; **U value for projected/fixed windows shall be no greater than 0.25. U value for replicated double-hung window shall be no greater than 0.34** for projects that have to comply with the 2020 NYCECC Green Schools Rating System and LL 32/16."

"All glazing in windows that are located within 75' above grade, as well as windows adjacent to green roofs at any building height, shall meet a **Threat Factor of 25** of less as per the American Bird Conservancy's Tunnel Testing Protocol to comply with the requirements of BC 1403.8 as implemented by LL15/20."

Roof Pavers
Per the SCA Design Requirements,

"Precast pavers, **2" thick minimum** to provide wind uplift resistance, of reflectance required to meet NYC Green Schools Guide credit for Heat-Island Affect – Roof and the 2014 NYC Building Code."

"Finish material for the play area shall be concrete pavers. For roof-top play area used as Early Childhood play area; safety surface shall be provided in addition to the concrete pavers. Initial **Solar reflectance of pavers shall be 0.33."**

Relevant NYC Local Laws and Programs

Local Law 24 requires DCAS to assess the solar PV potential of all City-owned buildings over 10,000 gross square feet once every two years. A special focus is on identifying and quantifying potential capacity at solar-ready buildings, defined as buildings with roofs less than 10 years old and in fair to good condition.

Local Law 92 and Local Law 94 require all buildings that are undergoing roof decking replacement as well as any newly constructed buildings to have a sustainable roofing zone that includes either a solar PV system, a green roof, or a combination of both.

The **Clean Energy Program** administered by DCAS seeks to expand distributed energy resources, including solar PB and energy storage installations at City-owned properties. Current installations include conventional rooftop solar and solar canopies in parking lots, garages, and wastewater treatment facilities, and some installations include batter storage to supply electricity during power outages.

TECHNOLOGY IMPACTS AND CONSTRAINTS

PROS AND CONS, FAQ

Compared to conventional Building Applied Photovoltaic (BAPV), BIPV technologies are generally lighter in weight, more aesthetically pleasing, and have superior wind resistance.

The economics and aesthetics of BIPV components are optimized when integrated into the building early, during the preliminary design phase. To be optimally effective, BIPV products should, at minimum, match the dimensions, structural properties, aesthetic qualities, and life expectancy of the conventional building materials that they replace.

PV Efficiency + Output

Several factors will affect the amount of solar energy the photovoltaic cells are able to receive and the efficiency with which they can generate power. The performance of BIPV systems will be dependent on the following factors:

- Project's geographic location
    - The amount of solar exposure/access depends on the project's latitude. The project's latitude will affect the optimal tilt angle for BIPV components to receive solar radiation.
    - The latitude of the project site will determine the site's insolation, defined as the average amount of solar radiation received by a surface. Insolation is typically calculated in terms of kWh/m2/day and it is the most common way to describe the amount of solar resources available in a particular area. (New York City has a latitude of about 41 degrees north. According to NYSERDA, in New York City, each square foot of the earth's surface receives 160 kWh of solar energy per year and a PV system installed on that area can typically convert the solar energy received to 22 kWh of electrical energy per year.)
- Climate conditions at project location
    - The average seasonal outdoor temperatures at the site and local weather conditions will influence the optimal BIPV component orientation and tilt.
    - In NYC, during the hottest summer months, there may be a slight reduction in energy production as panel efficiency typically begins to diminish with high levels of heat.
    - The very cold temperatures that NYC can experience should not negatively affect the energy production of BIPV components. However, the shorter daylight hours during winter will reduce the daily energy production compared to daily production during the summer months with longer daylight hours.
    - The accumulation of snow on building surfaces that can occur in NYC during winter months will reduce the energy production of BIPV components affected.
    - The cloudy weather conditions that can occur regularly in NYC may decrease the energy production of BIPV components slightly, if the cloud cover is very dense. However, there are also times when cloud cover can increase solar production by causing a phenomenon in which the edges of clouds magnify the sunlight that falls onto building surfaces.
    - Rain, common in NYC during certain times of the year, should not impact the energy generating performance of BIPV components.

- Elevation of project
    - BIPV modules on buildings at higher altitudes will be more efficient than at lower altitudes.
- Project orientation
    - Building faces oriented to the south and west will have greater solar exposure/access. BIPV modules on these faces will be more efficient than on faces oriented to the north and east.
- Context / overshadowing
    - Buildings in locations that are in the shade of neighboring buildings, trees, or topographic features will have reduced solar exposure/access. BIPV modules on building faces shaded by context will have reduced efficiency.
- Location of BIPV modules on building
    - Per SCA security requirements, BIPV components will be installed no lower than the second-floor façade in order to mitigate damage from vandalism.
    - For optimal PV energy generation, BIPV components should be located on building surface areas that are not excessively shaded and that receive adequate solar radiation throughout the year.
- Orientation of BIPV modules on building façade / roof
    - Façade-installed modules will not be as efficient as roof-installed modules.
    - As a general rule of thumb, north of the equator, PV components perform optimally when oriented south and tilted at an angle 15 degrees higher than the site latitude.
- Color treatment / finish of BIPV module / transparency, tint of BIPV glass
    - The darker the color of the module, the greater the efficiency.
    - The less transparent, more tinted the PV glass, the greater the efficiency.
- Circulation space below/behind BIPV module
    - The efficiency of the BIPV module will be increased when air is allowed to circulate below/behind them and reduced when heat is allowed to build up below/behind them.
    - In the case of BIPV rainscreen applications, wherein BIPV components replace conventional rainscreen panels on the building façade, it is critical to ensure proper ventilation to ensure an adequate airflow velocity is achieved behind the panels. This will prevent a build-up of heat that can adversely affect the energy generation of the BIPV rainscreen panels.
    - There has been research on the potential of recovering the heat generated by BIPV rainscreen components to pre-heat air for space heating purposes within the building.
        - This approach is considered a subset of BIPV and is referred to as "BIPV with thermal energy recovery" (BIPVT). A BIPVT system will produce heat and electricity simultaneously from the same building surface area. When air is used as the heat recovery medium (BIPVT/a), the extracted thermal energy is available either for direct use for low temperature applications such as fresh air preheating, or through the mediation of heat pumps for higher temperature applications such as space heating or domestic hot water heating. Therefore, BIPVT systems produce more energy per surface area than a stand-alone BIPV system. An additional benefit of BIPVT is that under heat recovery conditions, the PV cells will be kept

cooler than in a BIPV system without thermal energy recovery and will thus have improved module efficiency.

Impact on Building Energy Performance

The application of BIPV components can affect a building's energy performance in the following ways:

- BIPV rainscreen panels will affect the thermal resistance of exterior building walls. In cases where the installed BIPV rainscreen panels increase the thermal resistance of the exterior wall over baseline design case, the building's heating load will be reduced.
- Integrated PV elements will affect glazing U-factor, visible transmittance (VT), and solar heat gain coefficient (SHGC). Increased glazing U-factor due to integrated PV will reduce the building's heating load. Properly modulated VT and SHCG can likewise reduce building heating load by offsetting heating demand with passive solar heat gain, while mitigating excessive solar heat gain during the summer to reduce building cooling load.

Reliability

The reliability of BIPV components should at minimum match traditional options both in the building and solar industries. This requires validation of the actual performance of installed BIPV components.

Troubleshooting and maintenance of BIPV components need to be at least equivalent to conventional / BAPV solar components.

Electrical issues affecting the reliability of BIPV components primarily involve the performance of the inverters. The variety of inverters that are available for BIPV products include single inverters, master-slave inverter configurations, modular inverters, and parallel-independent or string inverters. A BIPV installation is most vulnerable to a single-point failure where the power generated from the BIPV component(s) must be converted and synchronized through the inverter from DC to AC power and then fed into the building or the utility system. In this case, if the inverter fails, the entire system will malfunction.

Most inverters currently available are considered to be highly reliable. However, the practice of relying on one inverter only for a BIPV installation on a larger commercial or institutional building would still be problematic, as these systems generally consist of a large series of interconnected strings, creating a technical difficulty in determining where the installation has failed.

BIPV installations should therefore be designed with multiple coordinated inverters to increase reliability. With multiple integrated inverters, if one malfunctions or needs maintenance, it can be disconnected while the rest of the installed BIPV components continue to operate. For example, a hierarchical configuration with one "master" inverter and multiple co-operating individual sub-inverters can be used to maximize the efficiency of the installation.

Another option to maintain reliability is to use modular inverters, with each BIPV module equipped with a mini-inverter that allows for testing and performance evaluation of individual modules via a power line carrier signal integrated into the building's electrical distribution system. Individual modular inverters also increase the adaptability of BIPV components to geometrically complex building designs. Further, the use of independently operating modular inverters allows for some BIPV modules to be shaded without compromising the performance of the entire installation.

An additional factor related to modular inverters is the mismatch between their expected lifetime of 5 years compared to that of most BIPV products, which is minimum 25 years. If modular inverters need to be replaced several times throughout the lifetime of the BIPV components, this adds to the life-cycle cost of the installation.

Durability

BIPV components installed in places where there is insufficient air ventilation to dissipate heat can suffer from reliability, durability, and safety issues.

Project design teams should ensure that BIPV installations can be easily accessed for inspection, maintenance, repair, and replacement as needed.

Preventative maintenance measures should be implemented to ensure that the efficiency and power output of installed BIPV components remain optimal. Preventative maintenance should include measures to prevent nearby vegetation from shadowing installed BIPV components.

The performance of BIPV components is also affected by the accumulation of dirt on the module's surface. In urban environments, exposed BIPV components may be prone to a buildup of grime caused by fuel exhaust and other emissions. In most locations, normal rainfall can effectively remove accumulated dust and pollution on the outer surface. But in conditions and during periods where there is little rainfall, ongoing periodic maintenance to keep the BIPV modules clean would be needed to ensure that their efficiency and output remain optimal.

Wind-driven rain can lead to water penetration via the joints and overlap sections of BIPV façade components, which can lead to technical problems including condensation created by humidity.

The best practice strategy for maintaining the function and performance of BIPV components is to implement system performance monitoring. Regular monitoring is crucial for identifying system failures and implementing required changes to ensure optimal performance of the system over long periods of time.

Lifetime

Due to the dual function of BIPV products, the performance would ideally be expected to last for the entire lifetime of the building. However, it is noted that typical solar panel performance is reduced over time, with the average lifetime of a solar panel lasting only 25 years compared to the typical 50+-year lifetime of most buildings. Therefore, building owners seeking to implement BIPV products that serve an essential building function, such as rainscreen façade panels, must plan for the maintenance and/or replacement of these products, given that such products are not in all cases easily replaceable. Alternatively, building owners could opt to leave in place installed BIPV components that are no longer functioning to produce power but continue to serve their other conventional building functions (weather barrier, shading, etc.).

Failure-related maintenance measures that include repairs and replacements associated with poor performance or failure of the installed BIPV components should be covered under traditional and extended warranties from the manufacturer. Currently, most BIPV manufacturers offer warranties for up to 25 years.

Embodied Carbon Impact

The implementation of BIPV components can contribute toward material savings and therefore embodied carbon reductions by substituting conventional building components. Additionally, it is notable that BIPV technologies, including rainscreen façade panels, are well-suited to deep energy building retrofit projects. In this way, BIPV technologies can contribute toward extending the lifetime of retrofitted buildings and therefore help to prevent the demolition of existing structures which typically has an intensive embodied carbon impact.

However, the embodied carbon emissions associated with the production and end-of-life of all solar PV products, including BIPV, are significant. It is expected that the high embodied carbon emissions of PV products versus the expected operational carbon savings those products can achieved will attract increased scrutiny as electric grids decarbonize and the energy performance of buildings continues to rapidly improve.

According to IEA, cadmium-telluride (CdTe)-based PV systems are calculated to have an embodied carbon impact that is approximately 63% lower than monocrystalline-based PV systems for each kWp, with an embodied carbon intensity of about 867 kgCO2e per kWp. Beyond this general comparison of CdTe versus monocrystalline-based PV systems, there is little information available on the embodied carbon impacts of specific products. The current lack of Environmental Product Declarations available for PV and BIPV products hinders the ability of the industry to optimize the embodied carbon impacts of the technology.

Safety / Product Certification

Regarding electrical safety of BIPV installations, it is noted that lightning, ground faults, and power line surges can cause high voltages in low-voltage BIPV components. It is expected that federal electric code regulations and building codes will be updated to include PV technologies to address specific fire and safety issues relating to BIPV design, installation, and maintenance.

The mandate that BIPV products are certified to UL 61730 may be challenging since product sizes are typically customized for every project. Current certification protocols are dependent on a standard tested size of BIPV panel with a size deviation allowance of up to 20%. Standards are currently focused on applications that typically use a common size. Roof-top or field array PV panel applications typically use a standard size, and manufacturers may test and offer only a few sizes for these standard applications. In contrast, BIPV requirements for a typical building application can have a variety of sizes to meet the design requirements of the project. UL 61730 testing can take approximately 5 months. Depending on the complexity of the design, some projects could potentially require several different custom-sized modules. Performing UL 61730 certification testing for every size on a given project like this would not be practical from a schedule or cost perspective.

Per DOE, there are not currently clear federal regulations on permitted designs for BIPV roof and façade products. There are no clear guidelines currently for issues like required ventilation shafts, hurricanes, or severe wind resistance requirements for a roof.

Current certification requirements are poorly aligned with BIPV applications. Current codes are more directed to passive building standards. This can create excessive cost and complexity for satisfying such requirements for BIPV applications.

BIPV products must currently conform to both building codes and electrical system codes because of the dual function.

Aesthetics

As BIPV components will in most applications be highly visible and can make up a significant portion of a building's exterior surface area, it is critical that they achieve a level of attractiveness and flexibility that is on par with traditional building products.

Project teams need to be able to achieve a uniform aesthetic using BIPV components in conjunction with "non-active" / traditional building components.

Per DOE Summary Report, the aesthetic variety of commercially available BIPV products is now large enough to enable the use of BIPV in any construction project.

For retrofit applications, BIPV components may be used to conceal unattractive or degraded building exteriors.

Structural Impact

Per information provided by selected manufacturers, the weight and installation methods of BIPV components will not result in impacts to structural design.

BIPV components that serve a structural function will be subject to structural code requirements. Per feedback included in the DOE Summary Report, there remains some confusion among building professionals as to how to apply existing structural codes to BIPV applications.

Architectural Design Coordination

Depending on the specific BIPV application to be integrated, the level of coordination required during the architectural design process will increase.

Design process integration has been identified as a critical factor affecting the success of BIPV applications. It is critical that project teams are able to effectively evaluate different uses of varying BIPV components to meet design intent, aesthetic goal, and coordination with interrelated building systems (façade, roofing, thermal envelope, glazing, structural, electrical, etc.)

Installation

The ease of the installation process is critical to the effective implementation of BIPV applications. Per feedback from consulted BIPV manufacturers, the installation process and time for currently available BIPV components is comparable to conventional building products and conventional PV systems.

It is noted that the DC electrical system design required by BIPV products is not standard and could therefore result in challenges for designers and installers unfamiliar with it.

Construction schedule impacts

Per information provided by selected manufacturers, if BIPV components are integrated into the project at the appropriate time during the design process, there should not be significant impacts on the project's construction schedule.

Commissioning of BIPV

Commissioning a BIPV system is essential for ensuring optimal, expected energy generation performance as it verifies that the system is accurately designed, engineered, and installed and identifies the appropriate method for resolving any technical issue found to be compromising the system's performance.

BIPV components are interconnected and linked to inverters by wires and connectors through which the solar power generated is delivered to the building or network. A portion of the power generated will be lost in this transmission process, but the loss can be significantly mitigated by ensuring correct design and installation. The system must therefore be designed so that interconnecting cables are correctly concealed and protected, and the installer must ensure that all wiring and connectors are accurately installed.

There is a current lack of guidelines that address a full commissioning process for BIPV systems, however, the basic commissioning process for BIPV systems should include the following criteria:

- Structural compliance: system conforms to both the specific electrical standards and building codes;
- Electrical safety: system will not increase safety risks to the owner;
- System calibration: forecasted system output is met

End of Life

The typical recycling process for PV products can successfully recover up to 90% of the glass and semiconductor material contained in the product. However, at present, the process for recycling PV systems is generally considered to be costly, energy intensive, and polluting. According to the International Renewable Energy Agency (IRENA), there are currently no federal regulations in the US for collecting and recycling end-of-life PV products, and therefore general waste regulations apply.

As the PV recycling industry is expected to expand significantly over the next 10-15 years, according to IRENA, it is anticipated that PV-specific waste regulations will be adopted within the US. The development of recycling and treatment standards for PV products is predicted to contribute toward more efficient and affordable options for end-of-life management of PV products and may also promote more sustainable life cycle practices and greater resource efficiency by PV manufacturers.

It should be noted that BIPV is used as a substitute for other components, such as in place of cladding or a rainscreen, therefore BIPV provides the benefit of the net removal of the embodied carbon of the business-as-usual component it replaces. Additionally, if BIPV is used in place of traditional solar, it can provide a net material reduction as BIPV can be deployed with less infrastructure compared to the typical cladding of traditional solar.

Cost

A primary benefit of BIPV technology is derived from the fact that the application of PV technology in such a way that it provides one or more building functions in addition to power generation serves to avoid the hard and soft costs associated with the building system(s) that it has replaced.

It is recommended that BIPV components be evaluated in terms of life-cycle cost, and not just initial cost as the overall cost should likely be reduced by the avoided costs of the conventional building materials and associated labor that the BIPV products replace. By avoiding the cost of conventional materials, the incremental cost of BIPV is reduced, and its life-cycle cost is improved. BIPV products often have lower overall costs than conventional BAPV systems that typically require separate, dedicated, mounting systems.

The following table shows the costs (per square foot) quoted for each type of BIPV product by manufacturers.

Figure 4: Quoted Cost for BIPV Product

Product Type	Quoted Cost for BIPV Active Product (per square foot)
Rainscreen Panel	$85 - $95
Window Fix (sash with frame)	$35
Rooftop Paver	$45 - $48
Canopy	$50 - $150

The following table shows the costs (per watt) quoted for each type of BIPV product by manufacturers.

Figure 5: Quoted Cost for BIPV Product Types

Product Type	Quoted Cost for BIPV Active Product (per watt)
Rainscreen Panel	$6 - $8
Window Glazing	$7
Rooftop Paver	$3 - $4
Canopy	$7 - $10^

^Includes cost of installing canopy structure.

Tax Implications

There may be additional cost benefits to installing BIPV technology via the Clean Energy Investment Tax Credit. While the SCA is a non-taxable entity, the IRS has established a "direct pay" option for tax exempt organizations to be eligible to receive this tax credit. Systems larger than 1 MW must meet labor and wage requirements to receive the full 30% credit, while those that are smaller than 1 MW do not need to meet these labor standards. It is advised that the SCA consider researching the potential for claiming the Clean Energy Investment Tax Credit if considering BIPV or other on-site energy generation.

REFERENCES

SWA referenced the following sources in researching BIPV technology impacts and constraints:

- U.S. Department of Energy (DOE), Solar Energy Technologies Office (SETO): "Summary: Challenges and Opportunities for Building-Integrated Photovoltaics RFI" https://www.energy.gov/eere/solar/summary-challenges-and-opportunities-building-integrated-photovoltaics-rfi#:~:text=On%20March%207%2C%202022%2C%20the%20U.S.%20Department%20of,opportunities%20for%20building-integrated%20and%20built-environment-integrated%20photovoltaic%20systems%20%28BIPV%29.

- NIBS Whole Building Design Guide, Building Integrated Photovoltaics (BIPV) https://www.wbdg.org/resources/building-integrated-photovoltaics-bipv#rcas

- DOE, NREL, Building-Integrated Photovoltaic Designs for Commercial and Institutional Structures: A Sourcebook for Architects https://www.nrel.gov/docs/fy00osti/25272.pdf

- Gholami H, Nils Røstvik H, Steemers K. The Contribution of Building-Integrated Photovoltaics (BIPV) to the Concept of Nearly Zero-Energy Cities in Europe: Potential and Challenges Ahead. Energies. 2021; 14(19):6015. https://doi.org/10.3390/en14196015

- Wheeler, V. M., Kim, J., Daligault, T., Rosales, B. A., Engtrakul, C., Tenent, R. C., & Wheeler, L. M. (2022). Photovoltaic windows cut energy use and CO2 emissions by 40% in highly glazed buildings. *One Earth*, *5*(11), 1271–1285. https://doi.org/10.1016/j.oneear.2022.10.014

- NRCan, Building-integrated Photovoltaics https://natural-resources.canada.ca/energy/efficiency/data-research-and-insights-energy-efficiency/buildings-innovation/solar-photovoltaic-energy-buildings/building-integrated-photovoltaics/21280

- Senthil, R. (2019). Recycling And Recovery Of Building Integrated Solar PV And Thermal Energy Systems. INTERNATIONAL JOURNAL OF SCIENTIFIC & TECHNOLOGY RESEARCH, 8(11), 1226–1229. http://www.ijstr.org/final-print/nov2019/Recycling-And-Recovery-Of-Building-Integrated-Solar-Pv-And-Thermal-Energy-Systems.pdf

- Weckend, S., Wade, A., & Heath, G. (2016, June 30). End-of-Life Management: Solar Photovoltaic Panels. (International Renewable Energy Agency (IRENA)) https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2016/IRENA_IEAPVPS_End-of-Life_Solar_PV_Panels_2016.pdf

- U.S. Internal Revenue Service (IRS): "Treasury, IRS finalize rules on elective payments of certain clean energy credits under the Inflation Reduction Act" https://www.irs.gov/newsroom/treasury-irs-finalize-rules-on-elective-payments-of-certain-clean-energy-credits-under-the-inflation-reduction-act

REGULATORY CONSTRAINTS

Codes

For use in New York City building projects, BIPV systems must meet the same filing requirements as other solar panel projects. A BIPV product must meet code requirements for both solar generating equipment and for the building component it is serving as (rainscreen/cladding, glazing, pavers, etc.).

For existing buildings, solar installation work should comply with **NYC Construction Codes, NYC Electrical Code, NYC Energy Conservation Code and applicable zoning regulations.**

Per the 2014 Administrative Code, section 28-101.4.3 and 2016 ECC 101, additions, alterations, renovations or repairs to installed systems shall conform to what is required for new installations without necessarily requiring the existing installation to comply with all requirements of this Code.

In addition, other City agencies have their own requirements which must be met, including, but not limited to the: **Fire Department of the City of New York (FDNY), the Department of Environmental Protection (DEP), the Landmarks Preservation Commission (LPC), and the Department of City Planning (DCP).**

Solar panels that are connected to the plumbing, electrical, and/or structural systems of a building require work permits.

The equipment vendor does not need to be registered or licensed by the department, but contractors performing installation must be registered.

Electrical work including installation of panels and wiring must be installed by Licensed Electricians registered in NYC.

All solar systems, including BIPV systems, may be filed as part of the primary application for construction, unless the building owner intends to pursue Solar Property Tax Abatement, in which case a separate filing for the solar panel installation is required.

Solar panels are also regulated by the Zoning Resolution. Rooftop solar installations are permitted obstructions on a roof per the Zone Green Text Amendment.

The Consultant Team has identified the following local codes that are applicable to all PV technologies and which would therefore extend to BIPV products, dependent on specific application of BIPV technology:

- Structural Analysis and Mounting Details (BC Chapter 16, 2022)
- Special Flood Hazard Area (BC Appendix G and ASCE 24-05)
- Special and Progress Inspections 9BC Chapter 17)
- Tenant Protection (AC 28-104.8.4)
- FDNY Requirements (Rooftop Landings, Rooftop Access, Edge Protection and Color Coding of Conduit) (FC 504.4 and FCs12)
- Electrical Diagram (EC Article 690 and EC 27-3018)
- NYCESS Analysis and Commissioning (ECC 101.5.2, ECC C408, 1 RCNY 5000)

Office of Technical Certification and Research (OTCR) Process

The NYC Department of Buildings has a process for reviewing and approving new sustainability technologies in the market. Interested parties seek approval for new products or technologies through the Office of Technical Certification and Research (OTCR).

The OTCR oversees technical certifications of approved agencies and entities performing inspections, tests, material approvals, and evaluates new technology that enhances safety, sustainability, and efficiency. Evaluation of the following falls within the purview of OTCR:

- OTCR Battery Energy Storage Systems (BESS)
- Indoor Automated Parking Garage Systems
- Solid Fuel Ovens
- Electrical Equipment

Per the **OTCR Rule**, found here: https://www.nyc.gov/assets/buildings/rules/1_RCNY_101-12.pdf

> "OTCR shall prepare and maintain a Schedule of Materials and Equipment that shall be used to identify third-party tested and/or listed materials on construction documents. For such materials, a registered design professional filing construction documents shall be required to incorporate the Schedule into their construction documents, shall provide material listing information as identified on the Schedule, and shall maintain third-party certification documents for a period of six (6) years following sign-off of the work."

The Consultant Team recommends that SCA coordinate with the BIPV manufacturers identified in this report to complete the OTCR1 application process for all BIPV products proposed for use on SCA projects and described within the Case Study section of this report, to ensure that these products are added to the Schedule of Materials and Equipment.

OTCR 1 Application

Per the OTCR website,

> "An applicant for materials approval may elect to have OTCR determine if materials are code-prescribed or alternative materials by submitting an OTCR 1 application and six-hundred-dollar ($600.00) fee to OTCR, as prescribed in Table 28-112.8 of the Administrative Code. OTCR shall notify the applicant of its determination in writing. If the material is found to be alternative, the application will be evaluated in accordance with subdivision (f) of this section and the fee required to determine whether the materials are code-prescribed or alternative materials shall be applied to OTCR's fee for the evaluation of standards for alternative materials prescribed in subdivision (f) of this section."

OTCR 2 Application (Site-Specific Approval Application)

Projects seeking site-specific approval of materials must submit an OTCR 2 application. Per the OTCR website,

> "Use and/or installation of the following materials requires site specific approval by the department, on a case-by-case basis:
>
> (i) Materials too large to be tested in a laboratory;
> (ii) Component parts, which must be assembled in the field; or
> (iii) Foreign-made materials unavailable for testing prior to installation, which may require on-site testing;
> (iv) Other materials as determined by the commissioner."

The OTCR1 application process has the potential to facilitate the ease of BIPV implementation in NYC generally and not be dependent on a case-by-case basis per the OTCR2 application process. OTCR Application Status

Per feedback from the OTCR, the application review process for OTCR1 applications is paused pending the appointment of a deputy director in charge of overseeing the process. The Consultant Team and SCA have requested that OTCR provide direct notification as to when new OTCR1 applications will be accepted for review.

References

SWA referenced the following sources in researching the regulatory constraints related to BIPV technology:

- NYC Buildings, Solar Panels
  https://www.nyc.gov/site/buildings/codes/solar-panels.page
- NYC Buildings, Solar Installation Frequently Asked Questions
  https://www.nyc.gov/site/buildings/codes/solar-faq.page
- NYC DCAS, Clean Energy Generation
  https://www.nyc.gov/site/dcas/agencies/clean-energy-generation.page

Available Manufacturers

Per the DOE/SETO RFI Summary Report, the US BIPV market appears to be still only in early stages of development. There are a limited number of manufacturers offering products. Of the products available, there is very little data to reference to get an accurate estimation of performance, cost, lifetime, reliability, etc. There are few if any appropriate modeling tools for predicting cost and performance.

The tables below share contact information and product descriptions for existing manufacturers that SWA has identified as feasibly able to provide BIPV products to building projects in New York City. As this is a growing industry, additional players in the market have been included in the tables below to reflect the products that are available. A feasibility assessment with the two case study schools were not conducted for all manufacturers.

Manufacturer Contact Information

Figure 6: Manufacturer Contact Information

Company	**Product**	**Contact**	**Address**
Mitrex	Solar Façade: Rainscreen System; Solar Glass	+1 646-583-4486 sales@mitrex.com info@mitrex.com	1 Rockefeller Plaza Fl 11 New York, NY 10020, USA
Elemex	Solstex BIPV Rainscreen System	+1 844-435-3639 info@elemex.com	530 Admiral Dr. London, Ontario N5V 0B2
Onyx Solar	PV Glass; PV Flooring/ Pavers	+1 917-261-4783 usa@onyxsolar.com	79 Madison Avenue, Ste. #933 New York, 10016

PVilion	Solar Canopies	+1 718-852-2528 ctouhey@pvilion.com	64 John St. Brooklyn, NY 11201
Helios Facade	Cladding Systems; Window Systems	+1 561-895-2656 netzero@heliosfacade.com	10055 Yamato Road, Suite 112, Boca Raton, FL 33496
Solarlab	Rain screens, Curtain walls, Louvers	info@solarlab-northamerica.com +1 (888) 995-7822	SolarLab North America 370 Jay Street, floor 7 Brooklyn, NY-11201 USA
Merlin Solar	Merlin™ Panels (Roofing)	+1 (844) 637-5461	5225 Hellyer Ave, Suite 200 San Jose, CA 95138

Detailed description of products

The following table includes descriptions of the BIPV products currently available from the manufacturers identified above and which SWA has assessed for feasibility of application on SCA projects.

Figure 7: BIPV Product Information

Company	Product	Description
Mitrex	Solar Façade: Rainscreen System; Solar Glass	Mitrex is a global BIPV manufacturer with a head office is in Ontario, Canada, with sales offices in New York, New York, and Los Angeles, California. These customizable BIPV systems may be directly integrated into building facades, with frameless modules, hidden mounting, and homogeneous surfaces. BIPV products include but are not limited to solar facades, glass, roof, siding, greenhouses, and railings. **Solar Façade: Rainscreen System** https://mitrex.com/retrofit/ Features and Benefits: • Weather resistant: Air pressurized cavity wall eliminates water penetration while allowing ventilation; continuous AWB • Multifunctional: Continuous insulation; Reduced thermal bridging through fewer connection points • Lightweight: Panels are 2 lbs/SF and the system is 4 lbs/SF

		• Design flexibility: May achieve irregular designs; Panels may cover floor to floor or be attached as slabs; new construction and retrofits
		• Customizable: Unlimited colors and patterns
		
		Types of Rainscreen Systems:
		
		• Stick-Build Cladding
		  o Installation is panel by panel
		  o Backup wall required
		• Pre-Assembled Cladding
		  o Installed as a single, prefabricated unit
		  o No backup wall required, only structural slabs
		
		Solar Glass:
		Mitrex PV glass is comprised of high-output monocrystalline silicon or thin-film technology. Two layers of heat tempered, laminated, and low-iron glass surround integrated solar cells. Insulated glass units can have interior glass that is low-iron, low-E, or regular glass. This PV glass is suitable for facades, windows, balcony railings, spandrel panels, acoustic noise barriers, and more.
		Features and benefits:
		• Customizable: Transparency and design options; various colors and patterns
		• Design flexibility: May be integrated into any structure
		• Sustainability: Green manufacturing and low carbon embodiment
		Types of Rainscreen Systems:
		• Transparent
		• Semi-Transparent
		• Transitional
		• Semi-Opaque
		• Opaque (Available in unlimited colors and patterns)
		
		https://mitrex.com/solar-glass/

Elemex	Solstex BIPV Rainscreen System	Elemex manufactures façade panel systems in North America, along with offering technical support and design and engineering resources. Using its Unity® integrated attachment technology, façade products include rainscreen systems, aluminum cladding panels, and BIPV systems. It may serve varying designs, from flat panels to complex shapes. **Rainscreen Systems**: • Exterior wall detail with cladding that stands off from the water barrier, avoiding building water damage and allowing for drainage and evaporation

		• May be added during new construction and renovation or rebuilding
		
		Types of rainscreen cladding systems:
		
		• Rear Ventilated Rainscreen (RVR):
		  o Open-joint system
		  o Allows you to see between the panels and the cavity of the wall system, exposing insulation and the air/vapor barrier to the elements and the sun's harmful ultraviolet (UV) rays
		  o Traditionally a vertical framed system
		• Pressure-Equalized Rainscreens:
		  o Closed-joint system
		  o Uses infill strips that act as air dams in both vertical and horizontal joints
		  o Pressure equalization (PE) reduces the pressure difference across the cladding using compartmentalization and back venting, keeping rain and snow from being driven into the wall cavity. Residual moisture is returned to the exterior at the drainage plane
		  o Installed with vertical or horizontal framing
		
		https://elemex.com/rainscreen-systems/
		
		Solstex BIPV:
		
		Solstex ® is Elemex's BIPV façade system, consisting of thin-film CdTe technology or crystalline silicone technology between two sheets of heat-strengthened glass which is adhered to the Unity® attachment technology.
		
		Features and benefits:
		
		• Return on Investment: Installation cost covered after 10-12 years
		• Design flexibility: May be integrated with other Elemex façade elements
		• Sustainability: Industry's smallest water and carbon footprint during manufacturing process
		• Lightweight: Standard weight of less than 3.5 lbs per square foot to ease installation
		• Large format: Maximizes coverage and energy generation
		• Weather resistant: Tested and certified to exceed IEC standards
		• Efficiency: Deliver up to 17.6 W per square foot
		
		https://elemex.com/products/solstex/

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<tr><th>Model</th><th>Nominal Power (W)</th><th>Voltage at Pmax (V)</th><th>Current at Pmax (I)</th><th>Efficiency (%)</th><th>Open Circuit Voltage (V)</th><th>Short Circuit Current (I)</th></tr>
<tr><td>F-Series</td><td>440-470</td><td>182.6-188.8</td><td>2.36-2.44</td><td>17.1-18.3</td><td>219.2-222.9</td><td>2.54-2.59</td></tr>
<tr><td>K-Series</td><td>263-289</td><td>34.5</td><td>7.5-8.3</td><td>15.6-17.1</td><td>40.6</td><td>8.1-8.9</td></tr>
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<tr><th>Model</th><th>Standard Panel Size</th><th>Standard Thickness</th><th>Weight</th><th>Finish</th></tr>
<tr><td>F-Series</td><td>48.5” x 79” (1232mm x 2009mm)</td><td>1/4” (6mm)</td><td>~3.5-5.5 lbs/SF</td><td>1/8” (2.8 mm) heat-strengthened glass that presents as a gloss black</td></tr>
<tr><td>K-Series</td><td>39.56" x 66.14 (1005mm x 1680mm</td><td>5/16” (8mm)</td><td>~3.5-5.5 lbs/SF</td><td>Made with 5/32" (4mm) Kromatix™ colored front glass with an opaque back glass</td></tr>
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<td>Onyx Solar</td>
<td>PV Glass; PV Flooring/ Pavers</td>
<td>
Onyx Solar is a global manufacturer of photovoltaic glass and pavement with offices in Spain and the US. Founded in 2009, Onyx has completed over 400 projects in 60 countries, meeting international quality and safety standards.
PV Glass:
Onyx’s transparent photovoltaic glass is made from layers of heat-treated safety glass. They can be installed on existing buildings as building facades, curtain walls, atriums, canopies, terrace floors, and more.
https://onyxsolar.com/about-onyx/company
Features and benefits:

<u>Multifunctional</u>: Can replace conventional glass by providing thermal and sound insulation; filters 99% of UV harmful radiation and up to 95% of IR radiation can be absorbed
<u>Easy to install</u>: Installation no different than conventional glass
<u>Return on Investment</u>: Generate return through high-performance building envelope and electricity generation; Long term energy savings, tax credits and incentives
<u>Customizable</u>: May choose shape, color, size, thickness, and grade of transparency (up to 30% visible light transmittance levels)

Types of glass:

Amorphous silicon photovoltaic glass

Produces more power than crystalline silicon glass on overcast and high-temperature days
https://onyxsolar.com/product-services/amorphous-pv-glass

Crystalline silicon glass

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		o Produces twice as much energy as amorphous glass per SqFt and may therefore optimize space used o Ideal for buildings with good solar orientation seeking maximum energy output o Best for canopy and skylight applications, spandrel glass, solid walls, and guardrails o Glass efficiency may be up to 16% o https://onyxsolar.com/product-services/crystalline-pv-glass **PV Flooring/Pavers:** Onyx Solar has also developed the first PV pavement that may be placed on terrace floors, sidewalks, and other outdoor surfaces. PV pavers use Onyx solar technology made of amorphous Silicon and crystalline Silicone. Features and benefits: • Usage: For pedestrian traffic only; Can withstand up to 400kg (point load); Anti-slip • Customizable: May be manufactured in standard dimensions or customized by project • Compliance: Can comply with the highest and most strict quality standards https://onyxsolar.com/product-services/photovoltaic-glass-solutions/pv-floor
PVilion	Solar Canopies	Pvilion integrates solar cells with fabric that can provide charging, lighting, ventilation, and climate control. Its products are manufactured in Brooklyn, New York, including solar canopies, solar military tents, grid-tied long span structures, solar powered charging stations, building facades, backpacks, and clothing. Pvillion offers a variety of customization possibilities for pre-existing designs and new designs. The Solar Canopies utilizes Pvilion Patented Technology using high-strength PVC coated polyester fabric and anodized aluminum frame. The canopies fabrics are available in five colors. https://www.pvilion.com/products/solar-canopies/ **Solar Canopies:** Features and benefits: • Lightweight: Lightweight material • Resilience: Can function off-the-grid and anywhere exposed to sun

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<u>Weather resistant</u>: May withstand extreme climate conditions; Waterproof, fire-retardant, and UV-resistant
<u>Silence</u>: Silently powered
<u>Mobility</u>: Various structures easy to transport, set up, and relocate
<u>Return on Investment:</u> Eligible for 26% Investment Tax Credit; save on annual energy costs

Types of Solar Canopies:

Lightweight Solar Canopy

Relocatable canopy with integrated solar panels
Dimensions: 10’ L x 12’ W x 11’ H
Modular “gangable” units
Energy output:

Low: 210W, 12 Volt Output
Medium: 420W, 12 Volt Output
High: 630W, 12 Volt Output

Heavy Duty Solar Canopy

May meet long-term needs as a permanent structure with increase durability and expanded as a parallel structure
Dimensions: 24’L x 10’W x 19’H
Modular “gangable” units
Energy output:

Low: 600W, 12 Volt Output
Medium: 1,200W, 1,500 VA Output (continuous)
High: 2,400W, 1,500 VA Output (continuous)

</td></tr>
<tr><td>Helios Facade</td><td>Cladding Systems; Window Systems</td><td>
Helios Façade utilizes a patented solar cladding technology capable of cladding any surface or window type to generate energy through the façade envelope. The product can be installed on new development projects or retrofitted on existing buildings, effectively replacing any conventional window and/or cladding systems. Their products are fully customizable to fit the project design, with a variety of colors, designs, and textures. From clear vision to fully customized prints, including brick, wood, metal, stucco, or terracotta.

https://heliosfacade.com/

Features & Benefits

<u>Customizable</u>: Fully customizable to meet the needs and design intent of the project; Can use their product with any supplier
<u>Compliance</u>: Can comply with the highest and most strict quality standards

</td></tr>
</table>

		• <u>Multifunctional</u>: Can be installed on new projects or retrofitted on existing buildings • <u>Easy to install</u>: Installation no different than conventional glass • <u>Return on Investment:</u> Eligible for tax credits; Save on annual energy costs Product Types • Energy-generating cladding systems: Rainscreen panels, AMC panels, metal panels, ventilated systems, non-ventilated systems • Energy-generating window systems: punch window, window wall, curtain wall, storefront
SolarLab	Ventilated rain screens, Curtain walls, Louvers/Brise-Soleil	**SolarLab** provides custom integrated solar facades and solar cladding solutions to both new and retrofit projects. Manufacturing occurs in Denmark using mostly recycled resources and sustainable energy. https://solarlab.global/ Features & Benefits • <u>Product Lifecycle</u>: Between 95% to 97% of the materials of SOLAR LAB BIPV can be recycled; Facades made with glass and aluminum that ensures durability with a 50 to 80 year operational life • <u>Sustainable Production</u>: Manufactured with mostly recycled resources (30-80% recycled materials) and sustainable energy • <u>Customizable</u>: Colors: Glass Frit Print and natural, metallic-like, or ceramic-like coatings; Finishes: Crystal, Satin, or Textured. • <u>Multifunctional</u>: Can be installed on new projects or retrofit projects • <u>Light-weight and glare-free</u> • <u>No maintenance</u> Product Types • Ventilated rain screen • Curtain & Window Wall facades (unitized or stick-built) • Louvers, or Brise-Solei
Merlin Solar	Merlin™ Panels (Roofing)	**Merlin Solar** has developed a Merlin™ Grid patented technology, available for usage such as with commercial transportation, mobile tents, and roofing. Their roofing products are manufactured in the US and can be used for both residential and commercial/industrial purposes.

		https://www.merlinsolar.com/mobile
		
		Features & Benefits
		• Design Flexibility: Well suited for applications that present difficult geometries and may be a good approach for factory-built insulation for prefab assemblies as it may be more resilient in transport.
		• Light-weight: Good for projects where a low weight load is needed.
		
		Product Types
		• Residential
		  o Residential Roofs
		  o Carports
		  o Tensioned Fabric
		• Commercial & Industrial
		  o Oil and gas storage tanks
		  o Membrane roofs
		  o Standing seam metal roofs

MAINTENANCE, REPAIRS, AND END OF LIFE

Owner Feedback

The study found that there is currently limited application of BIPV components in the U.S. market. This may be due to the limited number of manufacturers providing BIPV products and the perception within the building industry that BIPV is still an emerging technology that carries a higher level of risk.

SWA was therefore unable to collect direct feedback regarding BIPV maintenance from BIPV project owners.

Warranties

The following table includes the warranties that each identified manufacturer currently provides for each of the BIPV products evaluated.

Figure 8: Manufacturer Warranty Information

Company	Product	Warranty
Mitrex	Solar Façade: Rainscreen; Solar Glass	25-year limited product warranty 25-year limited performance warranty See here for further details: https://mitrex.com/warranty/
Elemex	Solstex BIPV Rainscreen System	1-year manufacturer (10-year limited surface warranty) 30-year limited power warranty.
Onyx	PV Glass; PV Flooring/	25-year warranty and all parts and components

Solar	Pavers	25-year warranty on labor, service, and repairs 25-year warranty monitoring and production guarantee 25-year roofing warranty (with solar + roofing) 10-year defect free workmanship warranty
PVilion	Solar Canopies	2-year warranty on materials and workmanship 20-year pro-rated warranty (for base fabric) Solar power output warranty: 80% of rated power after 20 years

End of Life Considerations

In general, as BIPV components are meant to serve a dual building function (weather barrier, shading, etc.), once the PV-generating capacity of the product has diminished to a point beyond efficacy, the product can be disconnected from electronic components and left in-situ to continue serving its other building function(s). If inactive BIPV components are to be removed, it would currently fall within the building owner’s responsibility to dispose of the components. Currently, it is uncommon for manufacturers to offer Extended Producer Responsibility (EPR) programs for product end of life take-back or recycling. However, Solar Lab claims that between 95% to 97% of their materials can be recycled. Solar Lab also engages in sustainable production practices with their BIPV products manufactured with mostly recycled resources and sustainable energy.

TECHNOLOGY APPLICABILITY

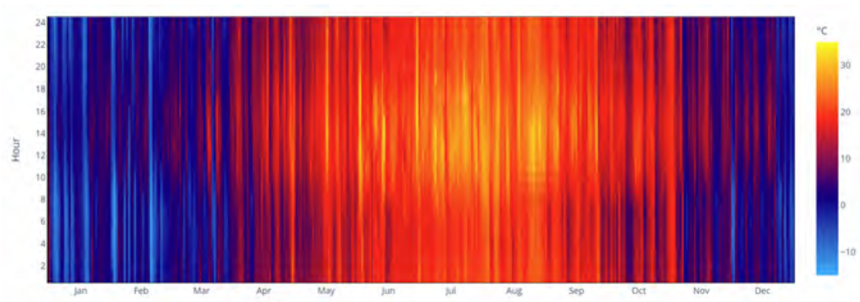
CASE STUDIES

To help understand the real-world applicability of BIPV for SCA buildings, two public school buildings in New York City were chosen as case studies for potential BIPV installation. The selected buildings represent different built typologies and surroundings in an effort to understand BIPV applicability in different scenarios throughout the city. To begin the analysis, SWA conducted a solar insolation analysis to determine the maximum potential solar generation at each location.

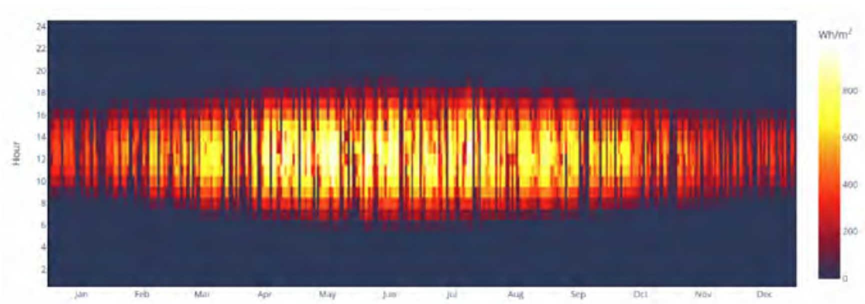
To ensure consistency, the same EPW (EnergyPlus Weather) file was used for both schools.

The following microclimatic data was studied to provide a comprehensive understanding of the region's solar conditions:

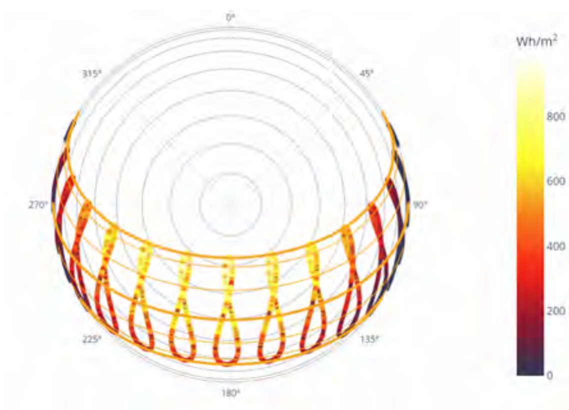
- Heatmap chart

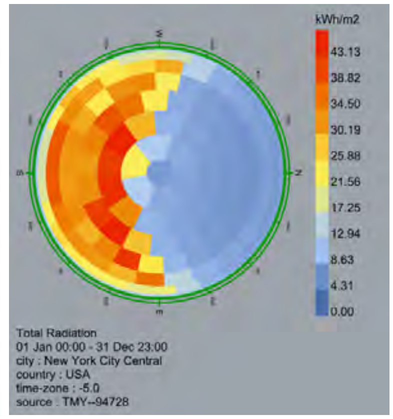


- Global horizontal radiation



- Sun path for global horizontal radiation





NYC School Building A

Mitrex Feasibility Assessment Overview

For the first case study building, NYC School Building A, Mitrex provided a feasibility assessment that proposes installation of BIPV rainscreen panels (Ombra product) in place of UHPC rainscreen panels and spandrel panels at curtain wall included in the project's retrofit design on all elevations. The Ombra BIPV rainscreen panel product generates 13 watts per square foot.

The proposal also includes installing PV glazing to replace a portion of existing window glass on the south, west, and east elevations. The PV glazing product generates 5 watts per square foot.

The tables below summarize per elevation the area of proposed BIPV components to be installed, the cost, the predicted PV generation, and the estimated resulting carbon reduction.

Figure 9: Mitrex - Ombra BIPV Rainscreen Panel for NYC School Building A

Mitrex					
Product	Ombra BIPV Rainscreen Panel (replacing Spandrel Panel at Curtain Wall)		**Generation**		
Elev.	**Active PV Area (ft^2)**	**Standard Mitrex Cost (Supply Only)**	**-kW DC**	**BIPV-kWh/ Year**	**Carbon Reduction^ (tons/yr)**
West	2,860	$100,107.32	36	25,723	14
East	3,867	$135,361.29	49	33,699	18
Total	**6,728**	**$235,468.60 ($35/SF)**	**86**	**59,421**	**32**

^Assuming a marginal emission factor of 0.54 short tons CO2/MWh (NYSERDA)

Figure 10: Mitrex - Ombra BIPV Rainscreen Panel for NYC School Building A

Mitrex							
Product		Ombra BIPV Rainscreen Panel (replacing UHPC Rainscreen Texture 1)			Generation		
Elev.	Active PV Area (ft^2)	Standard Mitrex Cost (Supply + Install)	Non-Active (Sqft)	Standard Mitrex Cost (Supply + Install)	-kW DC	BIPV-kWh/ Year	Carbon Reduction^ (tons/yr)
North	0	-	2,751	$233,839.82	0	0	-
South	1,628	$154,646.16	287	$24,417.81	21	18,346	10
West	1,562	$148,388.08	276	$23,429.70	20	14,047	8
Total	**3,190**	**$303,034.24 ($95/SF)**	**3,314**	**$281,687.33 ($85/SF)**	**41**	**32,393**	**18**
				$584,721.57 ($90/SF)			

^Assuming a marginal emission factor of 0.54 short tons CO2/MWh (NYSERDA)

Figure 11: Mitrex - Ombra BIPV Rainscreen Panel for NYC School Building A

Mitrex							
Product		Ombra BIPV Rainscreen Panel (replacing UHPC Rainscreen Texture 3)			Generation		
Elev.	Active PV Area (ft^2)	Standard Mitrex Cost (Supply + Install)	Non-Active (Sqft)	Standard Mitrex Cost (Supply + Install)	-kW DC	BIPV-kWh/ Year	Carbon Reduction^ (tons/yr)
North	0	-	1,144	$97,244.63	0	0	-
South	1,173	$111,475.69	207	$17,601.42	15	13,225	7
West	940	$89,313.23	166	$14,102.09	12	8,455	5
East	48	$4,596.58	9	$725.78	1	422	0.23
Total	**2,162**	**$205,385.50**	**1,525**	**$129,653.92**	**28**	**22,101**	**12**
				$335,039.42			

^Assuming a marginal emission factor of 0.54 short tons CO2/MWh (NYSERDA)

Figure 12: Mitrex - Ombra BIPV Rainscreen Panel for NYC School Building A

Mitrex					
Product	PV Glass - Transparent		Generation		
Elev.	Active PV Area (ft^2)	Standard Mitrex Cost (Supply Only)	-kW DC	BIPV-kWh/ Year	Carbon Reduction^ (tons/yr)
South	503	$17,613.87	3	2,229	1
West	2443	$85,495.31	12	8,635	5
East	3468	$121,397.35	17	11,880	6
Total	**6,414**	**$224,506.53 ($35/SF)**	**32**	**22,744**	**12**

^Assuming a marginal emission factor of 0.54 short tons CO2/MWh (NYSERDA)

Installation Method:

Figure 13: Mitrex Panel Installation Method

Elemex Feasibility Assessment Overview

For NYC School Building A, Elemex provided a feasibility assessment that proposes installation of BIPV rainscreen panels (Solstex O-series product) to replace the UHPC rainscreen panels and spandrel panels at curtain wall included in the project's retrofit design on all elevations. The Solstex O-series BIPV rainscreen panel product generates 13 watts per square foot.

The table below summarizes per elevation the area of proposed BIPV components to be installed, the cost, the predicted PV generation, and the estimated resulting carbon reduction.

Figure 14: Elemex - Solstex O-Series BIPV Rainscreen Panel for NYC School Building A

Elemex					
Product	Solstex O-Series BIPV Rainscreen Panel		**Generation**		
Elev.	**Active PV Area (ft^2)**	**Standard Elemex Cost (Supply + Install)**	**kW DC**	**BIPV-kWh/Year**	**Carbon Reduction^ (tons/yr)**
North	3,733	$332,237	48.5	17,144	9
South	3,172	$282,308	41.27	45,007	23
East	4,905	$436,545	63.82	58,158	29
West	6,112	$543,968	79.52	48,639	24
Total	**17,922**	**$1,595,058 ($90/SF)**	**233**	**168,948**	**85**

^Assuming a marginal emission factor of 0.54 short tons CO2/MWh (NYSERDA)

Figure 15: Elemex - NYC School Building A Product Information

Project Info per Wall	**North**	**South**	**East**	**West**
System Size (kW DC)	48.5	41.27	63.82	79.52
Area Utilized (sq. ft.)	3,733	3,172	4,905	6,112
kWh/kWp	353	1,091	911	612
After "1" Year				
Generation [kWh]	17,144	45,007	58,158	48,639
Return [$$$]	3,904	10,248	13,242	11,075
CO2 Displaced [Tons]	9	23	29	24
Equivalent Trees Planted	221	579	749	626
After "26" Years				
Generation [kWh]	399,125	1,047,775	1,353,917	1,132,312
Return [$$$]	140,090	367,761	475,214	397,433
CO2 Displaced [Tons]	200	526	680	568
Financials				
Budget [$]	332,237	282,308	436,545	543,968
Incremental Cost of Solar [$]	201,582	171,288	264,870	330,048
Cost of Solar Power ($/KWh)	0.51	0.16	0.20	0.29
Cost of Power Today ($/KWh)	0.22	0.22	0.22	0.22
IRR (Internal Rate of Return)	-2%	6%	4%	1%

Onyx Feasibility Assessment Overview

For NYC School Building A, Onyx provided a feasibility assessment that proposes installation of BIPV rooftop paver tiles (GL.01, with anti-slip treatment) over the portion of the building's roof area walkway.

Each GL.01 BIPV roof paver tile with anti-slip treatment generates 79 watts and is composed of 2-ply fully tempered glass (5/16" over 5/16") with the textured treatment. Without the anti-slip treatment, the generation of each tile would increase by approximately 13%.

These BIPV roof tiles are intended to be supported on a pedestal system, or aluminum substructure. Typically, approximately 5 inches of clearance are needed below the roof tile to make the electrical interconnections. The paver tiles can be installed as an open joint system or as a sealed system.

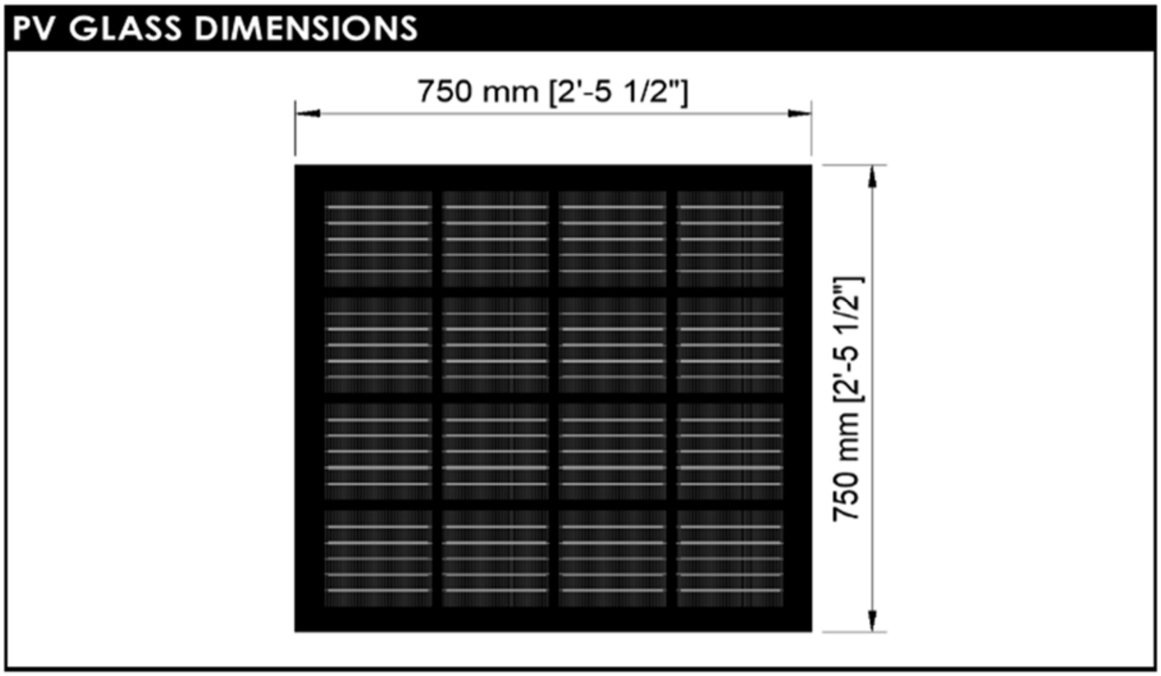
The table below summarizes per elevation the area of proposed BIPV components to be installed, the cost, the predicted PV generation, and the estimated resulting carbon reduction.

Figure 16: Oynx Solar - GL.01 Rooftop Paver for NYC School Building A

Oynx Solar					
Product	GL.01 Rooftop Paver (anti-slip textured frontal glass)		**Generation**		
	Active PV Area (ft^2)	**Standard Onyx Cost (Supply + Install)**	**kW DC**	**BIPV-kWh/Year**	**Carbon Reduction^ (tons/yr)**
Roof	1,580 (282 tiles)	$45-48/SqFt ($71,100-$75,840	22	25,400	14

^Assuming a marginal emission factor of 0.54 short tons CO2/MWh (NYSERDA)

Figure 17: Oynx Solar – PV Glass Information



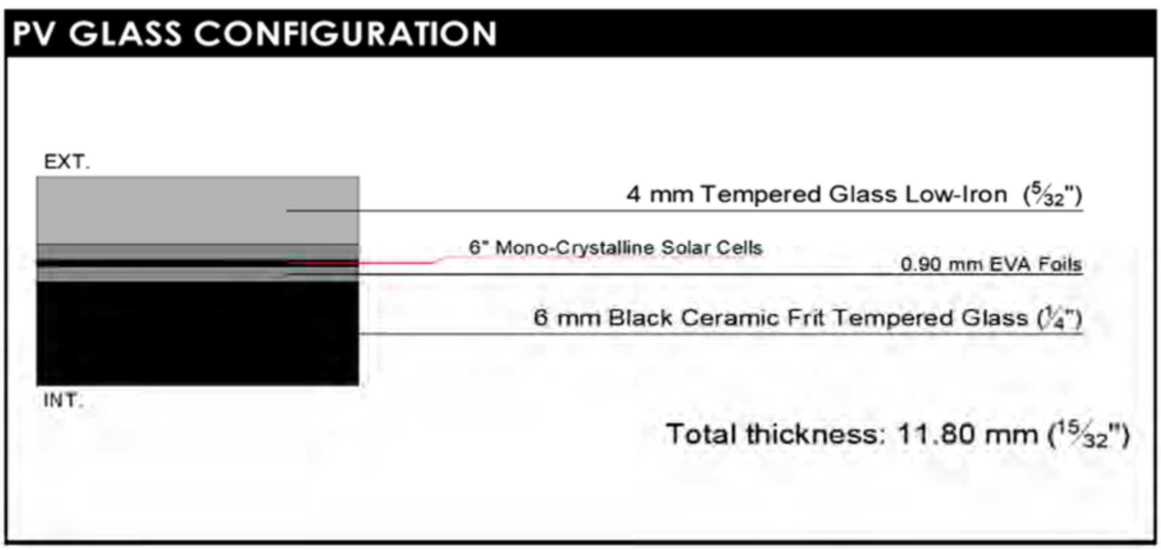


Figure 18: Onyx solar roof paver tile with anti-slip treatment

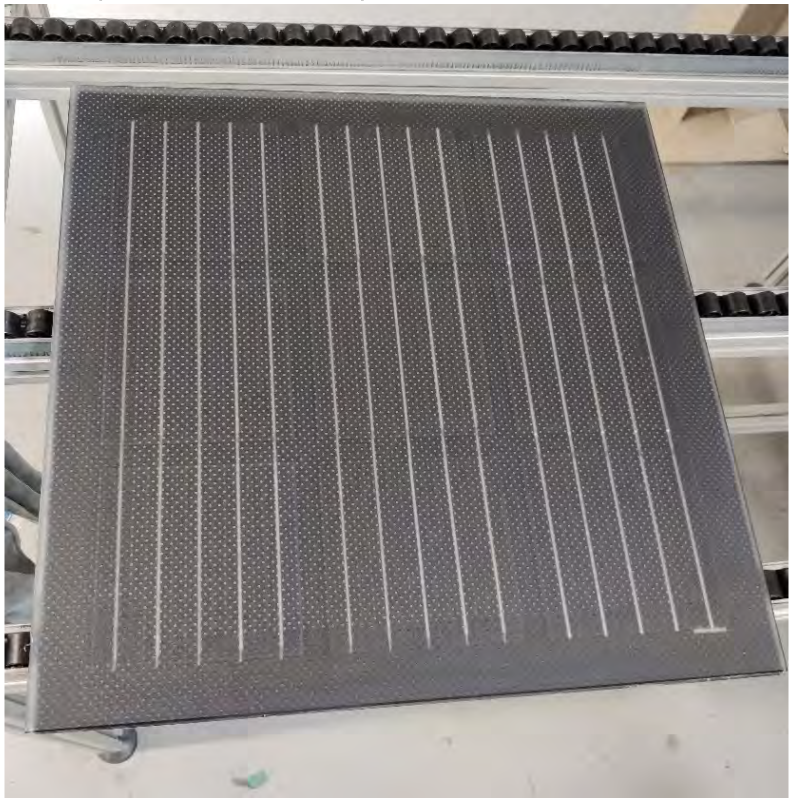
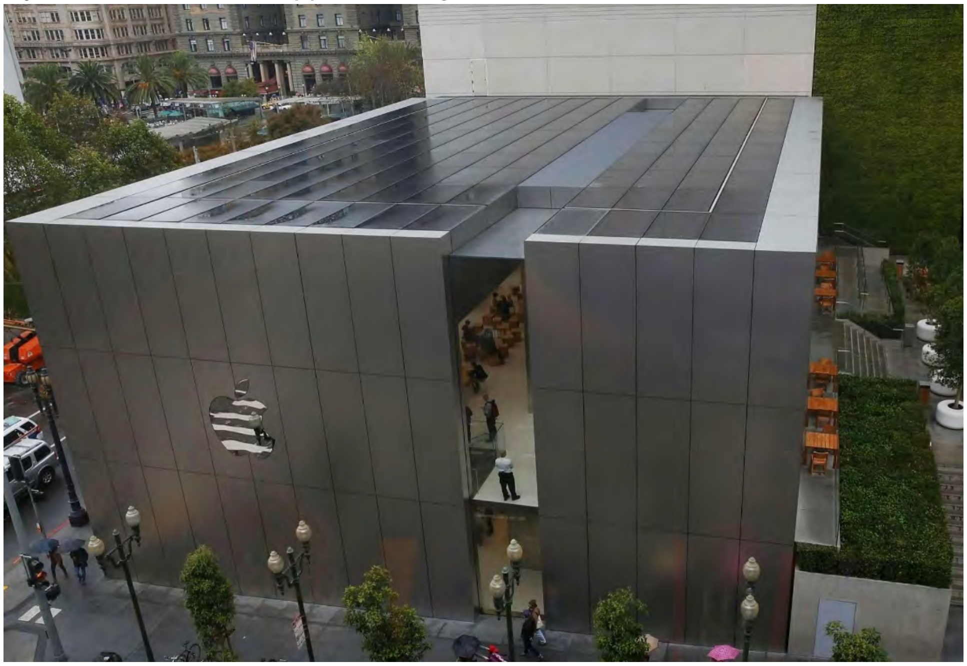


Figure 19: Pedestal system for Onyx solar roof paver tiles

Figure 20: Onyx solar roof tiles at Apple building, San Francisco, CA



NYC School Building A Site Conditions and Context

The analysis for the case study NYC School Building A - a three-floor public school building in New York City, involves evaluating the potential for solar energy integration. The site context consists of a compact neighborhood with buildings of similar or slightly more floors surrounding it.

Solar Insolation Analysis

One crucial factor in this assessment is the solar radiation available at the site. The site has an estimated 3.6693e+7 kWh of solar radiation potential (based on Ladybug modelling results on Rhino). This data provides valuable information about the solar energy potential for a site, enabling further analysis of the project's viability and the potential benefits of integrating solar energy systems. Radiation results have been obtained for this case study building, with the southwest wall as the most favorable option for BIPV installation due to its high radiation potential. Conversely, the northeast and northwest facades are deemed less suitable due to their low radiation potential.

i. Radiation Potential: The radiation results indicate that the southwest wall receives the highest amount of solar radiation, making it the most favorable location for BIPV, followed by the southeast wall. This positioning allows the panels to capture more sunlight, resulting in increased energy production. In contrast, the north-east and northwest facades exhibit low radiation potential, implying limited solar exposure and reduced energy generation.

ii. Advantages of Southwest Wall Placement:

   a. High Solar Radiation: The southwest wall's orientation towards the sun ensures prolonged exposure to direct sunlight, leading to optimal energy generation.

b. Energy Efficiency: Placing BIPV on the southwest wall enables the building to harness solar energy efficiently, potentially reducing its reliance on grid power and lowering operational costs.
c. Aesthetic Considerations: The southwest wall, being more visible to the surrounding neighborhood, offers an opportunity to showcase the public school's commitment to renewable energy and sustainability.

iii. Limitations of Northeast and Northwest Facades:
   a. Low Solar Radiation: The northeast and northwest facades receive limited direct sunlight, resulting in reduced energy output. BIPV installation on these surfaces may not provide substantial benefits and could result in inefficient use of resources.
   b. Potential for Future Shading: Buildings or structures adjacent to the northeast and northwest facades may cast shadows over the BIPV panels, further diminishing their energy generation potential.

Recommendations

Based on the analysis, the following recommendations are proposed:

i. Install BIPV on the Southwest Wall: Given its high radiation potential, the southwest wall should be the primary focus for BIPV installation. This placement maximizes energy generation and capitalizes on the building's sun-facing orientation.
ii. Consider Complementary Energy Solutions: While the northeast and northwest facades may not be suitable for BIPV, alternative energy solutions such as passive solar design elements or reflective coatings, could be explored to enhance energy efficiency on these surfaces.
iii. Architectural Integration: Collaborate with architects and designers to ensure the seamless integration of BIPV into the school building's aesthetic and functional aspects, reinforcing the school's commitment to renewable energy, while maintaining a visually appealing facade.
iv. Future Expansion: If feasible, plan for potential expansion or additional BIPV installations on other viable surfaces as technology advances or surrounding structures change, allowing for increased energy generation and sustainability efforts.

MITREX
BUILDING INTEGRATED SOLAR TECHNOLOGY

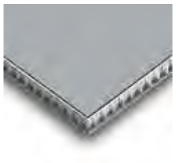
MITREX CONDENSED PROPOSAL

New York City Government

PRESENTED BY:	Terri Oswald
DATE:	May 4, 2023

OVERVIEW

Project Scope Mitrex Overview – PS - Manhattan

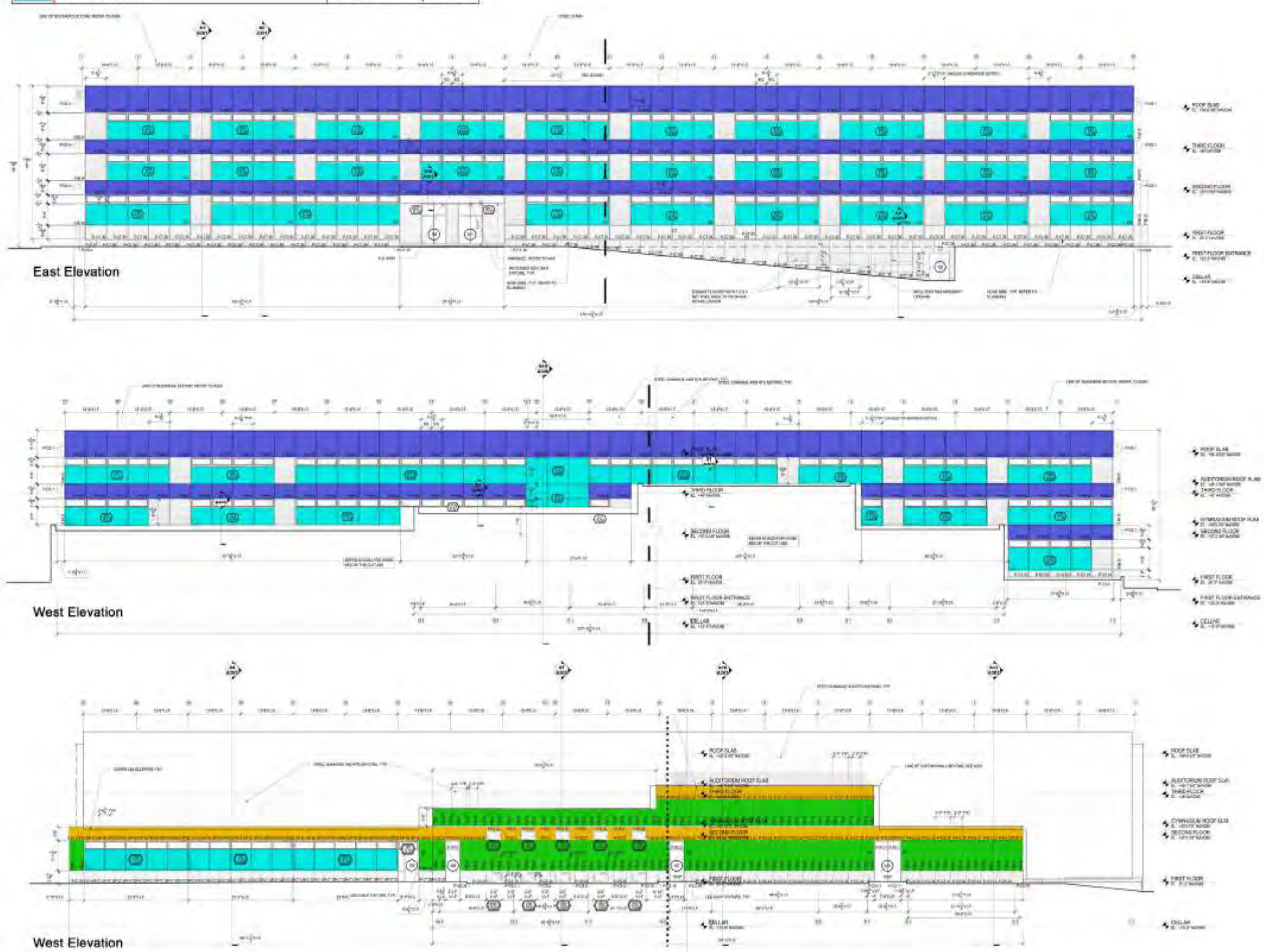


M-Solid-Ombra - 13W/sq.ft.

M-Glass-Transparent - 5W/sq.ft.

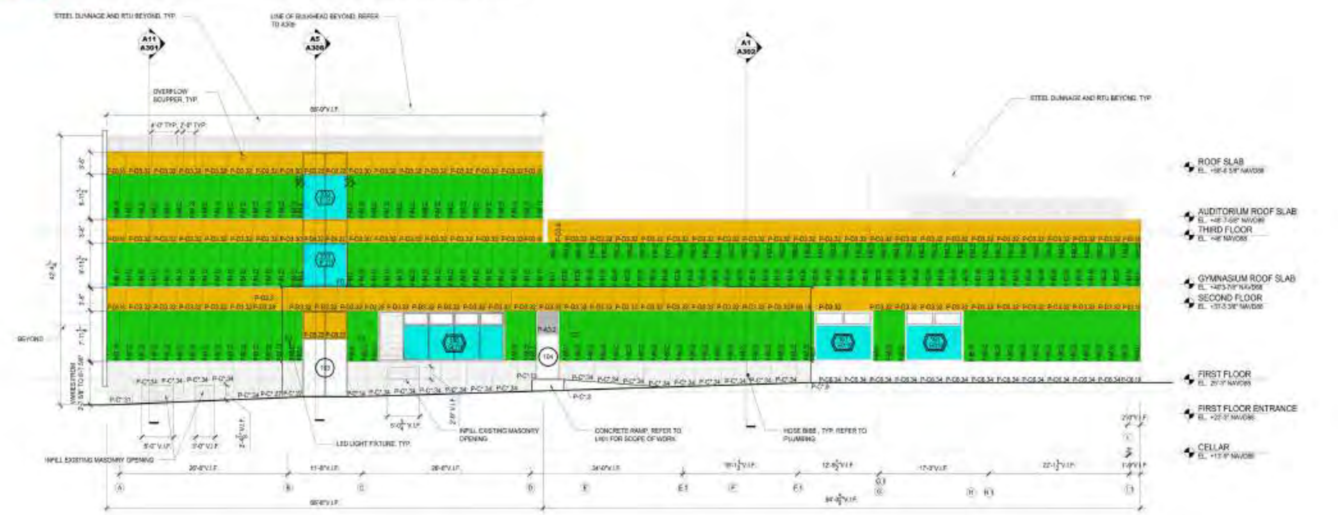
PROJECT HIGHLIGHTS

	UHPC Rainscreen Texture 1	M-Solid-Ombra
	UHPC Rainscreen Texture 3	M-Solid-Ombra
	Spandrel Panel at Curtain Wall	M-Solid-Ombra
	Window Glass	M-Glass-Transparent

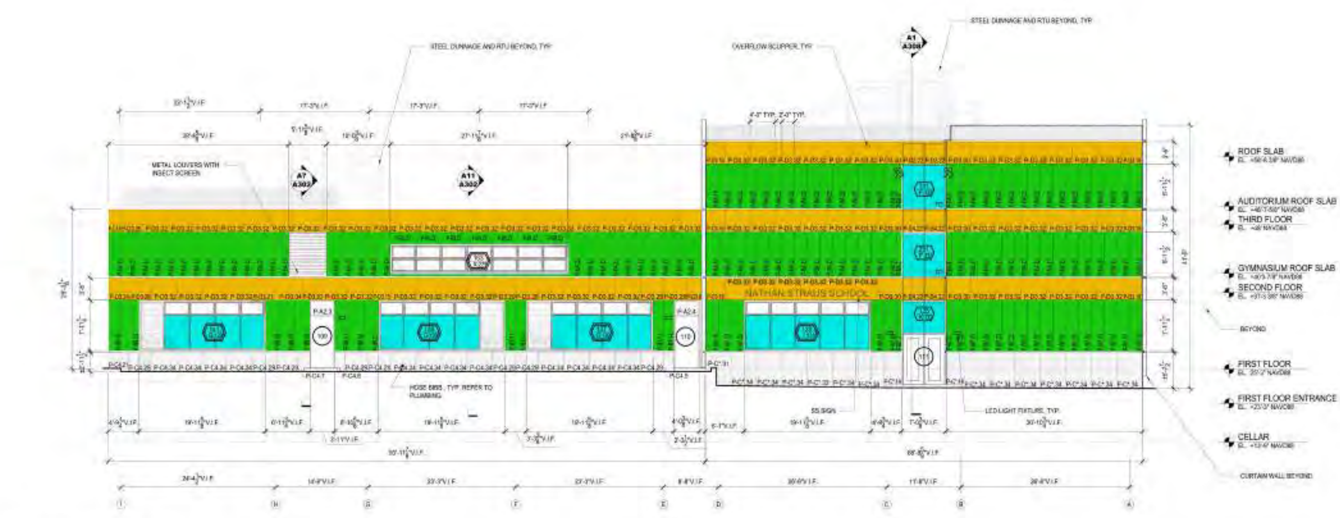


PROJECT HIGHLIGHTS

(green)	UHPC Rainscreen Texture 1	M-Solid-Ombra
(orange)	UHPC Rainscreen Texture 3	M-Solid-Ombra
(blue)	Spandrel Panel at Curtain Wall	M-Solid-Ombra
(cyan)	Window Glass	M-Glass-Transparent



G1 NORTH ELEVATION



A1 SOUTH ELEVATION

PRICING SUMMARY

Material	Spandrel Panel at Curtain Wall		SUPPLY ONLY		
Panel	Ombra				

	Mitrex				
	Active (Sqft)	$	~KW	BIPV-Kwh / Year	$
West	2860	$ 100,107.32	36	25723	$ 5,401.74
East	3867	$ 135,361.29	49	33699	$ 7,076.75
Total	**6728**	**$ 235,468.60**	**86**	**59421**	**$ 12,478.49**
	Total	**$ 235,468.60**			

Material	Window Glass		SUPPLY ONLY		
Panel	Transparent				

	Mitrex				
	Active (Sqft)	$	~KW	BIPV-Kwh / Year	$
South	503	$ 17,613.87	3	2229	$ 468.18
West	2443	$ 85,495.31	12	8635	$ 1,813.36
East	3468	$ 121,397.35	17	11880	$ 2,494.72
Total	**6414**	**$ 224,506.53**	**32**	**22744**	**$ 4,776.25**
	Total	**$ 224,506.53**			

+1-416-497-7120 info@mitrex.com 41 Racine Rd., Toronto, ON M9W 2Z4 mitrex.com

PRICING SUMMARY

Material	UHPC Rainscreen Texture 1	SUPPLY & INSTALL					
Panel	Ombra						

	Mitrex						
	Active (Sqft)	$	Non Active (Sqft)	$	~KW	BIPV-Kwh / Year	$
North	0	$ -	2751	$ 233,839.82	0	0	$ -
South	1628	$ 154,646.16	287	$ 24,417.81	21	18346	$ 3,852.71
West	1562	$ 148,388.08	276	$ 23,429.70	20	14047	$ 2,949.93
Total	**3190**	**$ 303,034.24**	**3314**	**$ 281,687.33**	**41**	**32393**	**$ 6,802.63**
			Total	**$ 584,721.57**			

Material	UHPC Rainscreen Texture 3	SUPPLY & INSTALL					
Panel	Ombra						

	Mitrex						
	Active (Sqft)	$	Non Active (Sqft)	$	~KW	BIPV-Kwh / Year	$
North	0	$ -	1144	$ 97,224.63	0	0	$ -
South	1173	$ 111,475.69	207	$ 17,601.42	15	13225	$ 2,777.20
West	940	$ 89,313.23	166	$ 14,102.09	12	8455	$ 1,775.53
East	48	$ 4,596.58	9	$ 725.78	1	422	$ 88.54
Total	**2162**	**$ 205,385.50**	**1525**	**$ 129,653.92**	**28**	**22101**	**$ 4,641.27**
			Total	**$ 335,039.42**			

MITREX INTEGRATED SOLAR CLADDING | Cladify

INSTALLATION METOD

SOLSTEX

Solar Facade System

elemex®

Architectural Facade Systems

530 Admiral Drive, London, Ontario, Canada N5V 0B2 • Tel: 1-844-435-3639 • elemex.com

Panels Utilized: 16,760 sqft. of Standard Black Solstex O-Series Panels (approx.)

Description:
Client requests for the solar estimates on all the sides of the building. In order to evaluate the viability of the Solstex O-Series, careful consideration has been given to the orientation of the building as well as its location.

Layout:

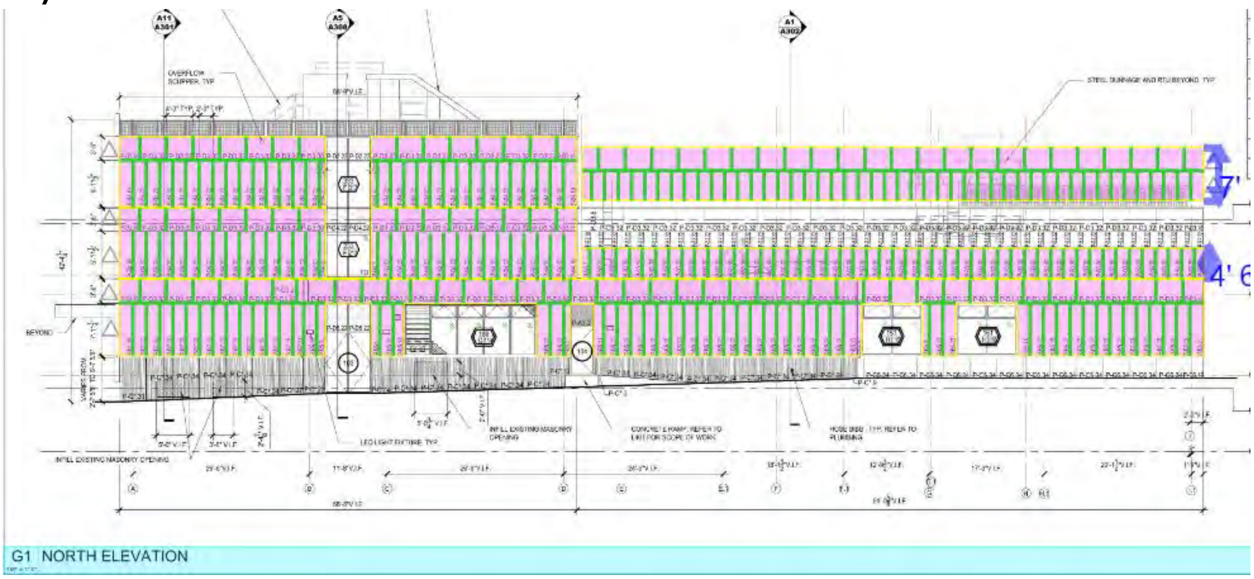


Figure 1: North Wall Overlaid with Solstex O-Series

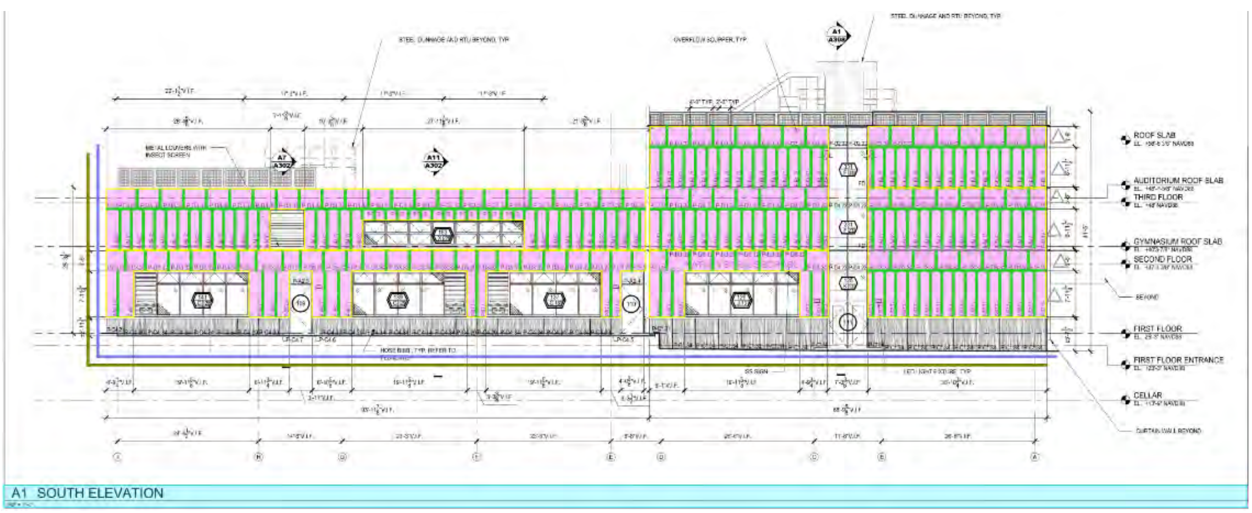
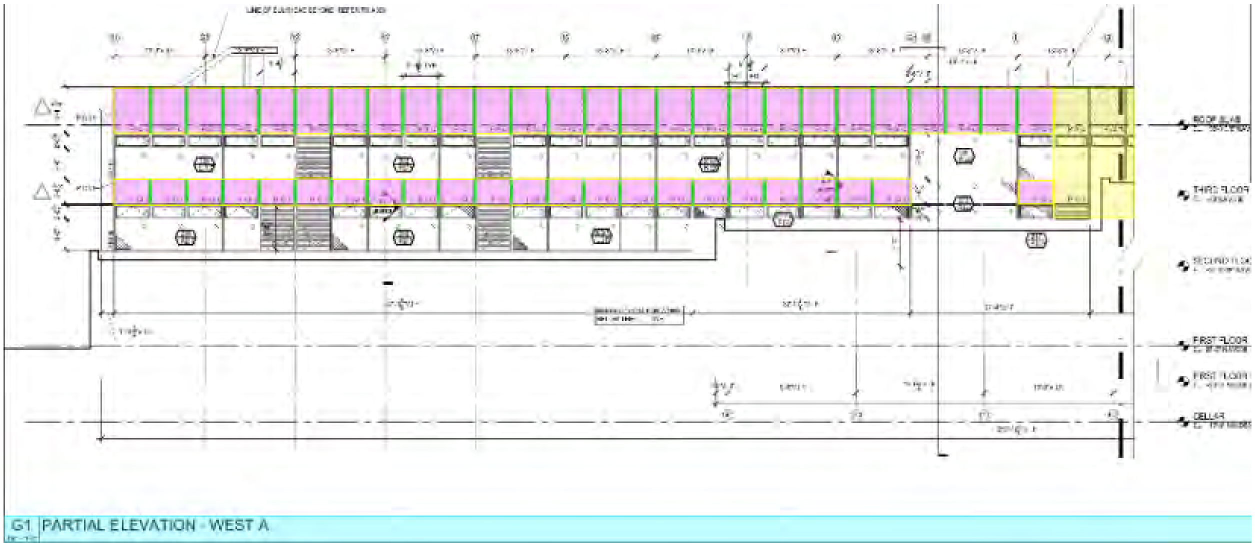


Figure 2: South Wall Overlaid with Solstex O-Series

Per Drawing Sheets A201, A202, A203 dated August 24th, 2022.
Date: June 27th, 2023

Figure 3: Partial East A and B Wall Overlaid with Solstex O-Series



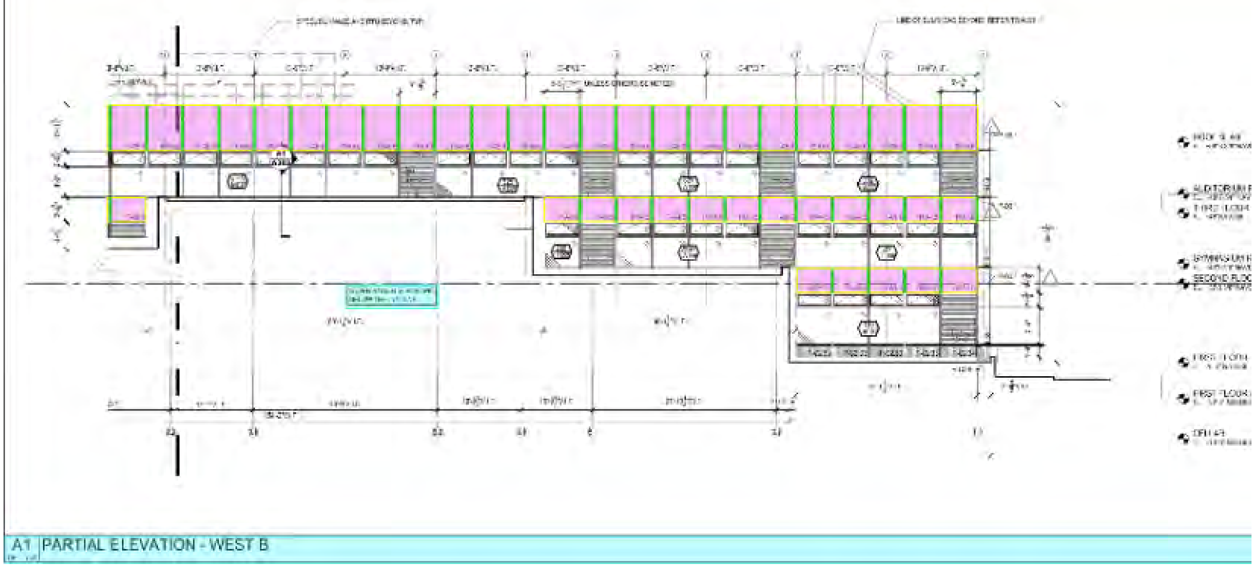


Figure 4: Partial West A and B Wall Overlaid with Solstex O-Series

Per Drawing Sheets A201, A202, A203 dated August 24th, 2022.
Date: June 27th, 2023

Typical Color Options:

Different color options available for Solstex O-Series.

Figure 5: O-Series Color Options

Different colors of solar panels vary in efficiency; mentioned beneath each color of solar panel is the power density of that given color, measured in watts per meter squared. The proposal incorporated the color selection of standard black however it is possible to customize the proposal with any color as per the client's specific request.

*All numbers given in this report are estimates only. Any generation info contained in this report is for informational purposes and is not a future guarantee of performance. Elemex cannot guarantee any future performance of Solstex Systems, nor can Elemex be held liable for any performance deviations from the information contained within this report.

Typical Attachment System:

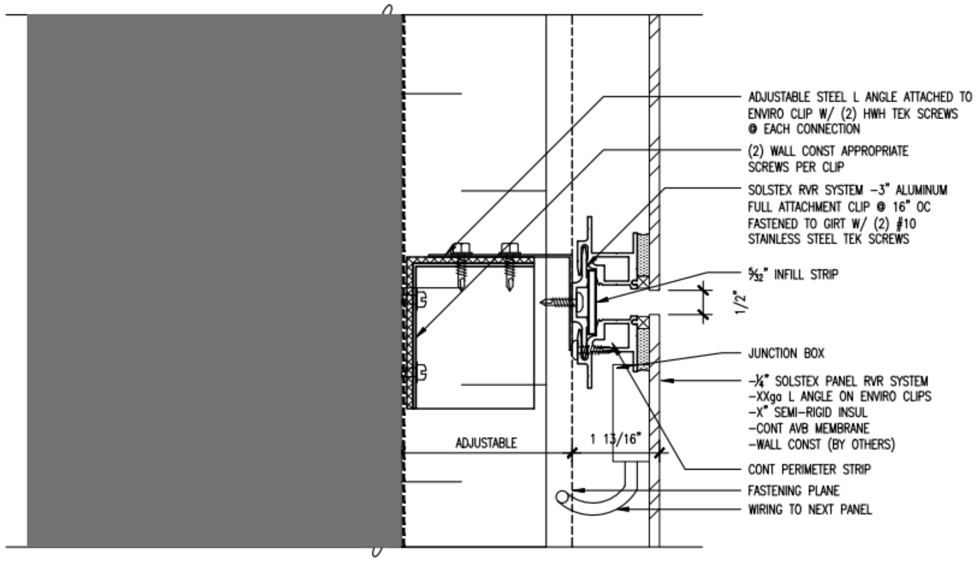


Figure 6: Horizontal Joint for Solstex

Typical Electrical System:

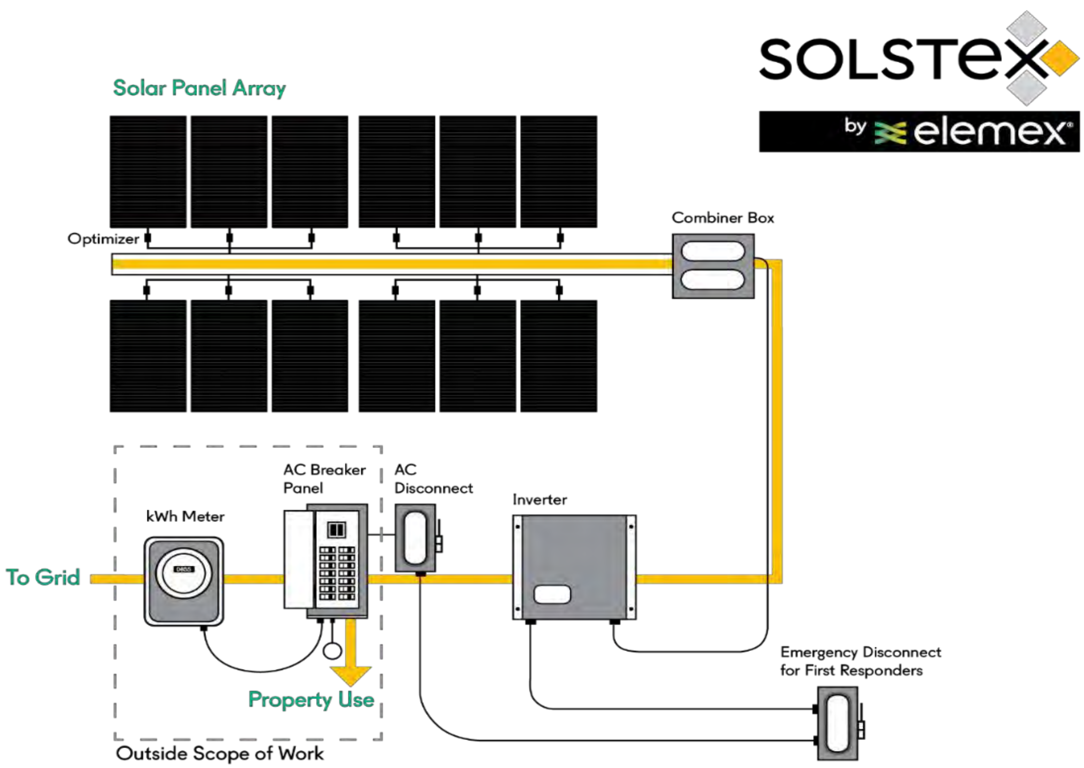


Figure 7: Solstex General Electrical Flow Diagram

Solstex® Generation Proposal

Project Details:

Project Info	North Wall	East Wall	South Wall	West Wall	Entire Project
System Size (kW DC)	65	68	53	92	277
Area Utilized (sq. ft.)	3,939	4,093	3,175	5,553	16,760
kWh/kWp	332	862	1,025	596	680
1st Year Stats					
Generation [kWh]	21,652	58,360	53,846	54,794	188,652
Return [$$$]	3,765	10,148	9,363	9,528	32,803
CO_2 Displaced [Tons]	11	29	27	28	95
Equivalent Trees Planted	279	751	693	705	2,428
Cumulative Stats Over 25 years					
Generation [kWh]	504,072	1,358,632	1,253,549	1,275,602	4,391,854
Return [$$$]	135,106	364,154	335,989	341,900	1,177,150
CO_2 Displaced [Tons]	253	682	629	640	2,205
Financials					
Budget [$]	287,547	298,789	231,775	405,369	1,223,480
Incremental Cost of Solar [$]	149,682	155,534	120,650	211,014	636,880
Cost of Solar Energy ($/kWh)	0.30	0.11	0.10	0.17	0.15
Cost of Energy Today ($/kWh)			0.17		
IRR (Internal Rate of Return)	-1%	7%	9%	4%	5%

Table 1: Quick Project Facts

Assumptions:

- Supply of panels and supply of balance of system components
- Local price of electricity: $0.17/kWh with an average annual increase of 3.5%
- System Degradation Rate of 0.6%/year
- Inverter efficiency is 96%

Per Drawing Sheets A201, A202, A203 dated August 24th, 2022.

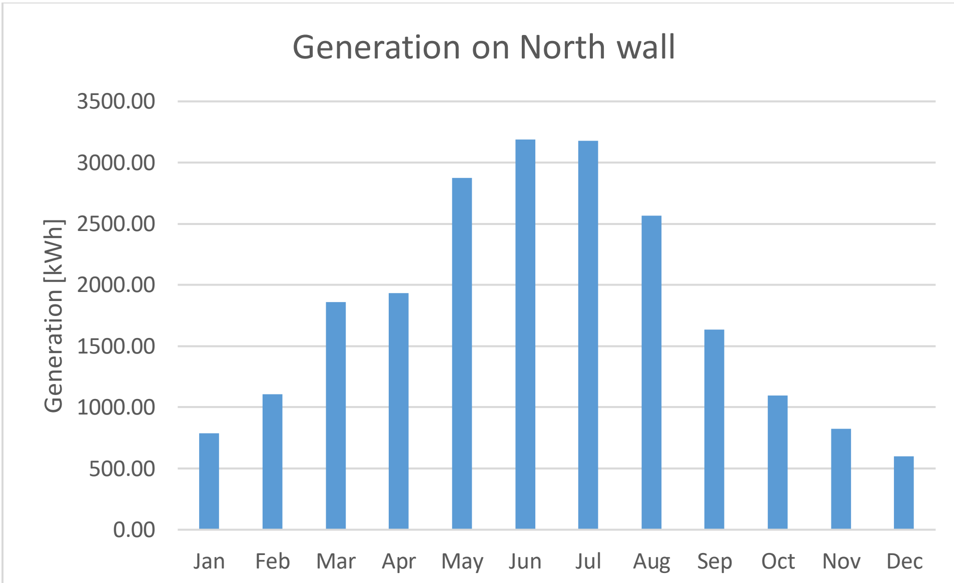
Date: June 27th, 2023

*All numbers given in this report are estimates only. Any generation info contained in this report is for informational purposes and is not a future guarantee of performance. Elemex cannot guarantee any future performance of Solstex Systems, nor can Elemex be held liable for any performance deviations from the information contained within this report.

Solstex® Generation Proposal

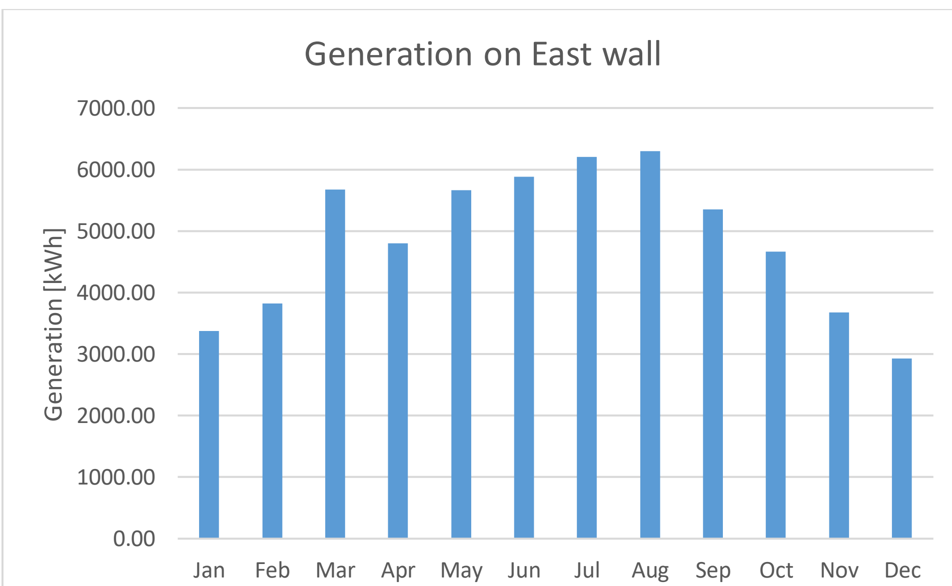
Generation Estimates: Power generation from panels per wall per month.

North Wall:



Graph 1: Electricity Produced Monthly on North Wall

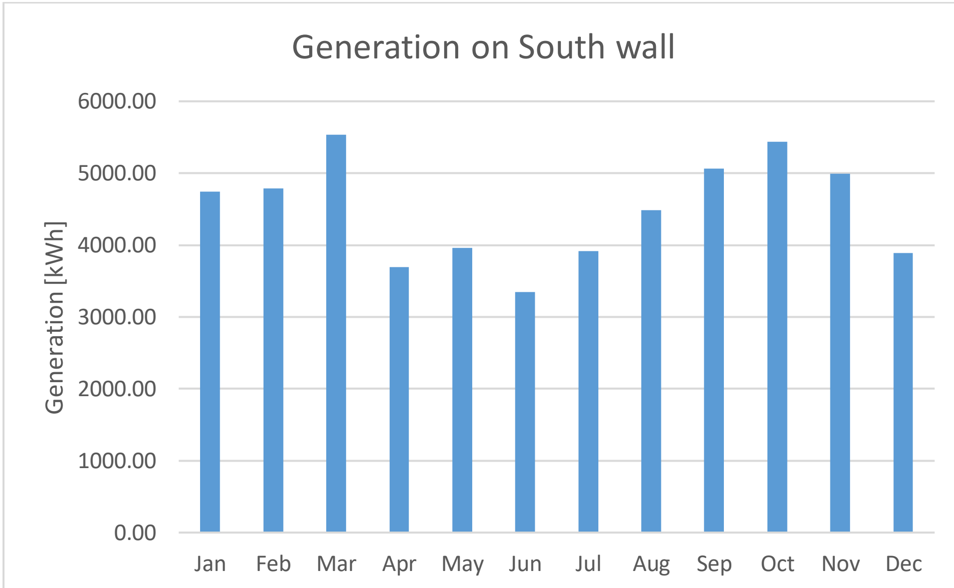
East Wall:



Graph 2: Electricity Produced Monthly on East Wall

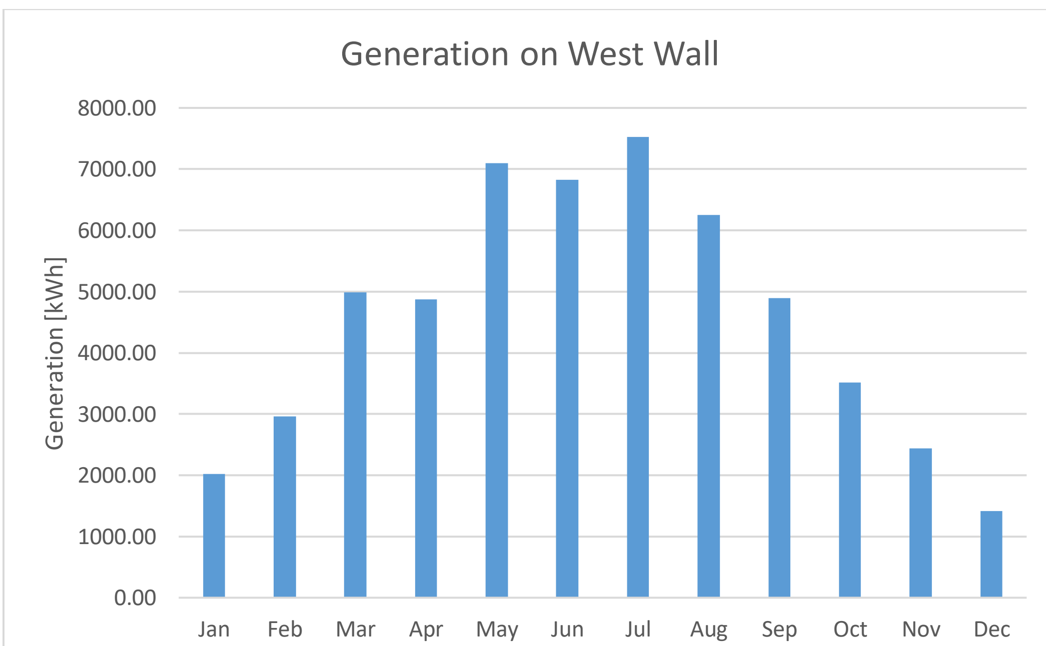
Solstex® Generation Proposal

South Wall:



Graph 3: Electricity Produced Monthly on South Wall

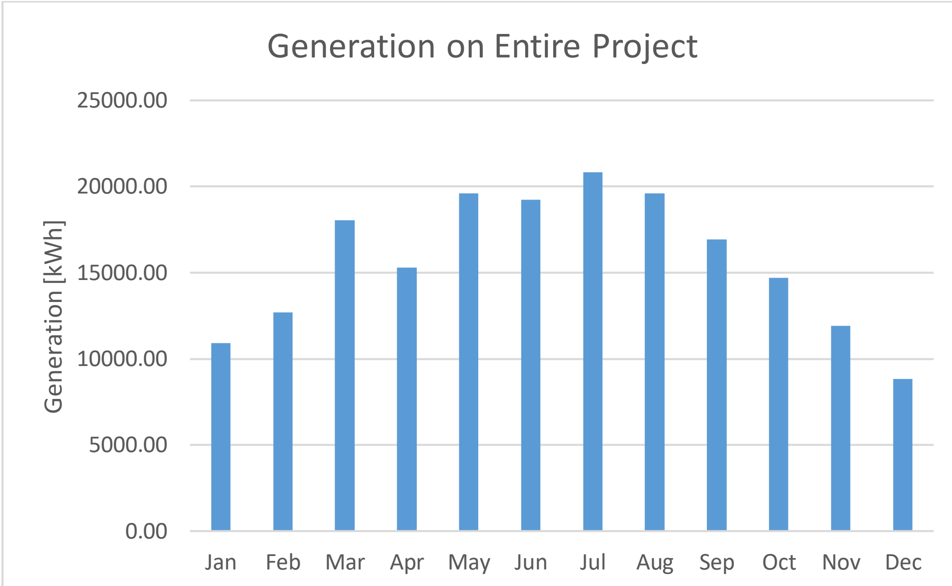
West Wall:



Graph 4: Electricity Produced Monthly on West Wall

Per Drawing Sheets A201, A202, A203 dated August 24th, 2022.
Date: June 27th, 2023

Entire Project:



Graph 5: Electricity Produced Monthly on Entire Project

Generation varies throughout the year, due to the vertical nature of the façade, and the latitude of the project.

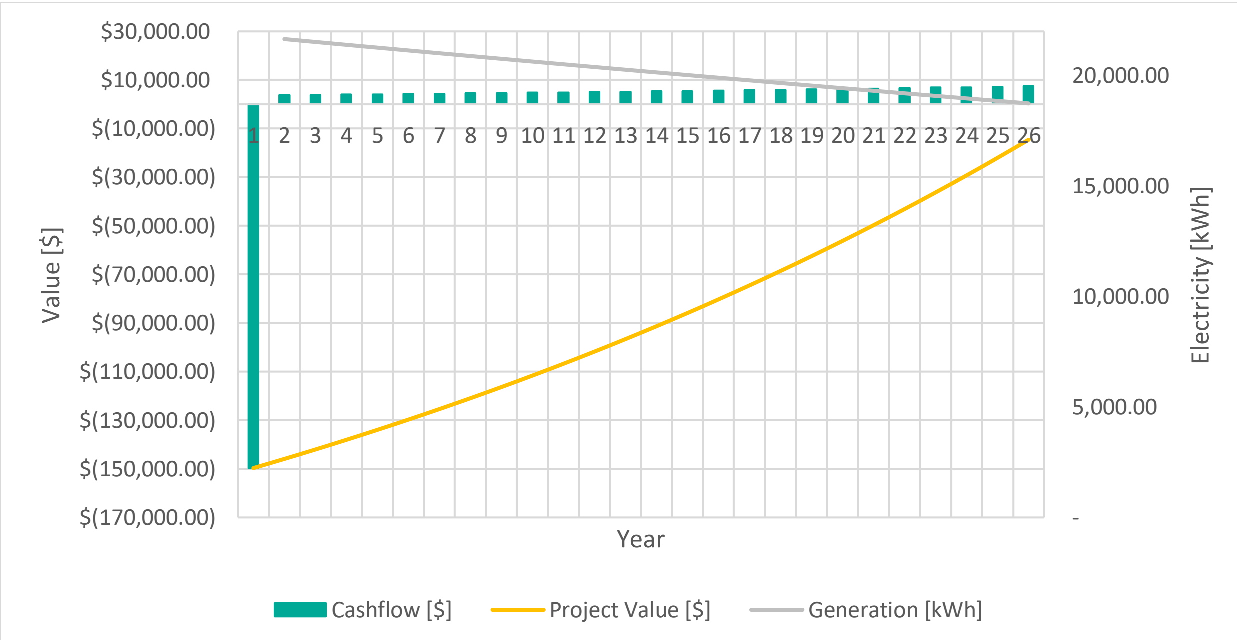
Recommended Contract Style - Net Metering:

Net metering allows people who generate electricity from renewable energy technologies to send excess energy to the electrical grid in exchange for a credit towards future electricity costs. Excess generation means that renewable energy technology is generating more energy than required. Excess generation is more common during the summer months, so credits can be carried forward for a consecutive 12-month period. This allows excess generation credits accrued in the summer to be used during the winter, where the power generation is lower.

Financial Model:

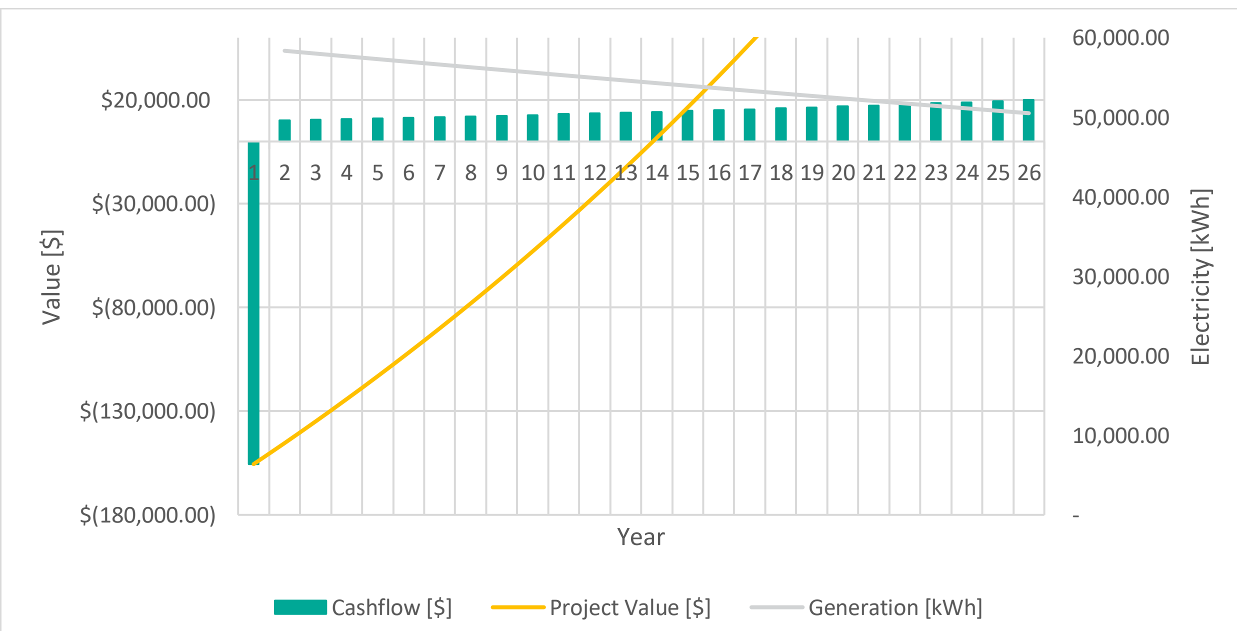
Return on Investment over the span of 26 years with respect to power generation.

North Wall:



Graph 6: ROI Graph North Wall

East Wall:

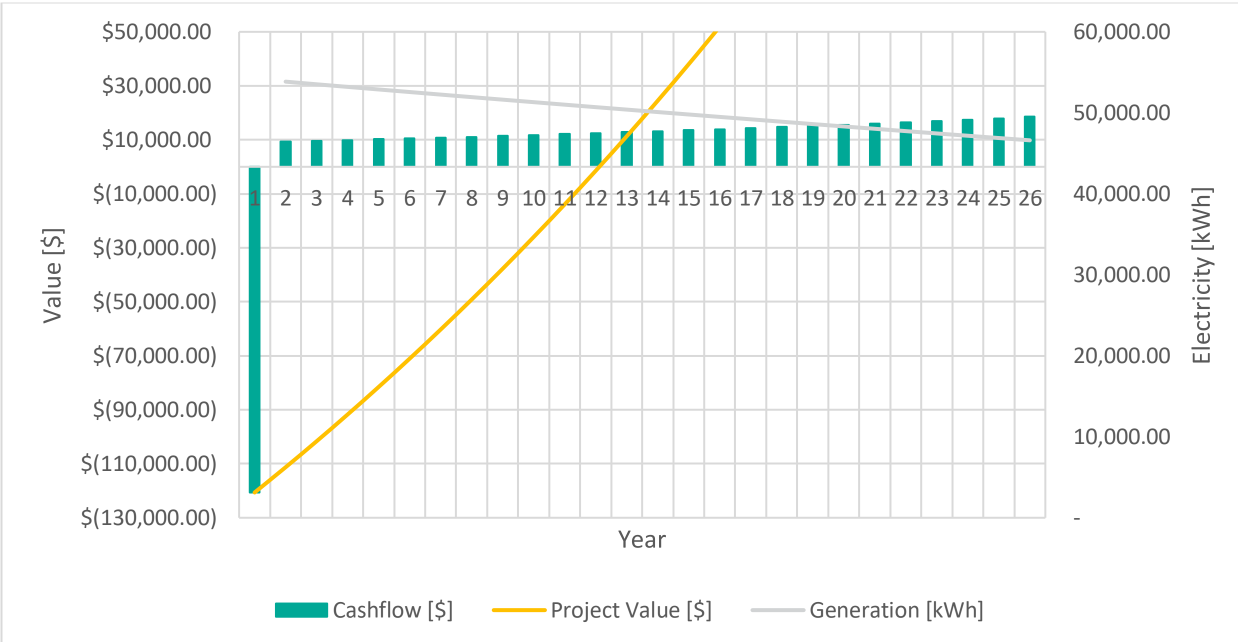


Graph 7: ROI Graph East Wall

Per Drawing Sheets A201, A202, A203 dated August 24th, 2022.

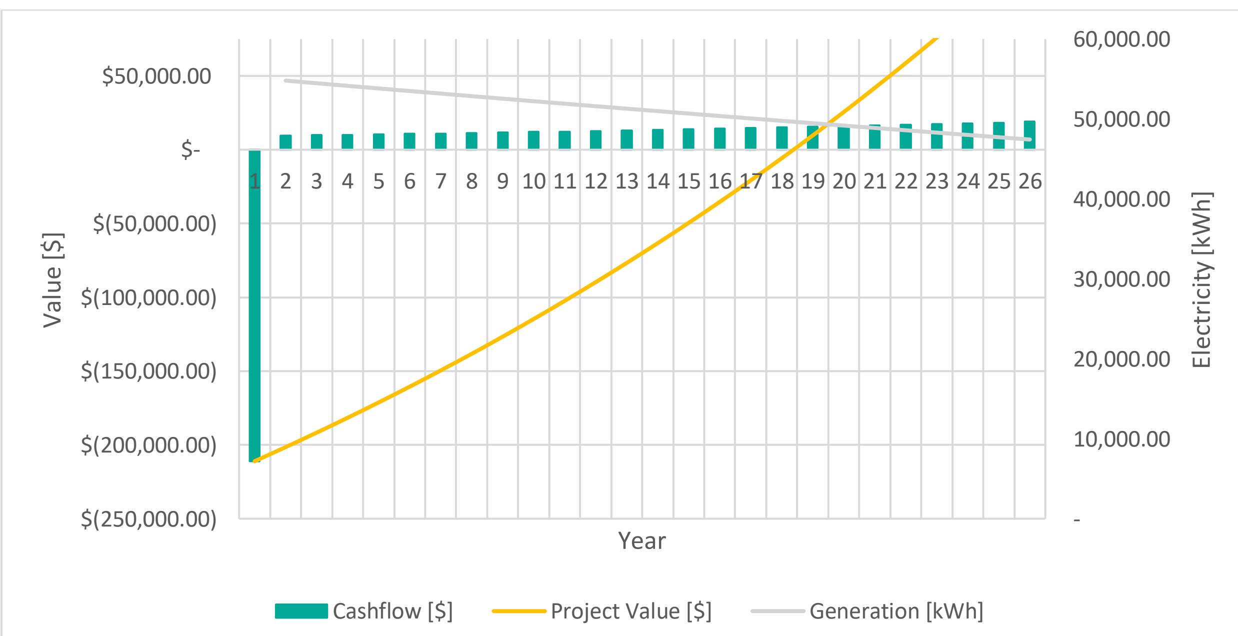
Date: June 27th, 2023

South Wall:



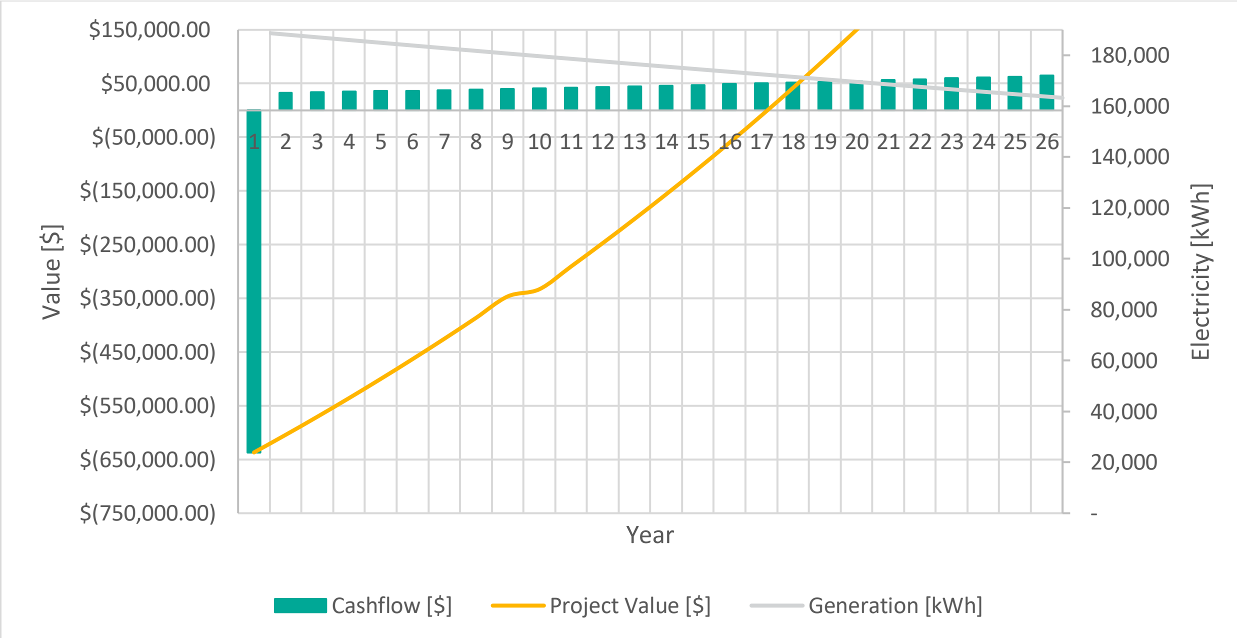
Graph 8: ROI Graph South Wall

West Wall:



Graph 9: ROI Graph West Wall

Entire Project:



Graph 10: ROI Graph on Entire Project

Assumptions:

- Solstex Budget number given as ($73.00/sf) approx. and the other wall panels, ACM panels priced at ($35.00/sf).
- Budget numbers are in USD.
- Inverter replacement in year 10

Generation decreases across the life of the project, due to panel degradation. Cashflows will increase across the life of the project as electrical prices increase.

Government Incentives:

Business Energy Investment Tax Credit

If a solar project is started in 2023, it is eligible for a tax credit that is equivalent to 30% of the total cost of the solar system. This tax credit was not part of the financial analysis above and can help project economics. Please consult your accountant/tax advisor for more information about the utilization of these credits.

NYC School Building B

Mitrex Feasibility Assessment Overview

For the second case study building, NYC School Building B, Mitrex provided a feasibility assessment that proposes installation of BIPV rainscreen panels (Fennec product) as cladding on north, west, and east elevations. The Fennec BIPV rainscreen panel product generates 9 watts per square foot.

The proposal also includes installing dark and light transparent PV glazing on the north, west, and east elevations. The dark PV glazing product generates 7 watts per square foot. The light PV glazing product generates 5 watts per square foot.

The tables below summarize per elevation the area of proposed BIPV components to be installed, the cost, the predicted PV generation, and the estimated resulting carbon reduction.

Figure 21: Mitrex – Fennec Cladding for NYC School Building B

Mitrex							
Material	Cladding				**Generation**		
Panel	Fennec						
Elev.	**Active PV Area (ft^2)**	**Standard Mitrex Cost (Supply + Install)**	**Non-Active (Sqft) / Returns & Flashings**	**Standard Mitrex Cost (Supply + Install)**	**kW DC**	**BIPV-kWh/ Year**	**Carbon Reduction^ (tons/yr)**
North	8473	$804,892	6,410	$474,327	128	42,020	23
South	0	-	13,958	$1,098,905	0	0	0
West	6690	$635,513	4,287	$278,731	101	71,297	39
East	6265	$595,169	4,510	$344,732	94	64,693	35
Total	**21,421**	**$2,035,575 ($95/SF)**	**29,165**	**$2,196,695 ($75/SF)**	**323**	**178,010**	**97**
				$4,232,270 ($85/SF)			

^Assuming a marginal emission factor of 0.54 short tons CO2/MWh (NYSERDA)

Figure 22: Mitrex – Dark Transparent PV Glass for NYC School Building B

Mitrex					
Product	PV Glass – Transparent - Dark		**Generation**		
Elev.	**Active PV Area (ft^2)**	**Standard Mitrex Cost (Supply Only)**	**-kW DC**	**BIPV-kWh/ Year**	**Carbon Reduction^ (tons/yr)**
North	229	$8,025.34	2	528	0.5
West	594	$20,784.94	4	2,939	2
East	187	$6,544.86	1	897	0.5
Total	**1,010**	**$35,355.13 ($35/SF)**	**7**	**4,364**	**3**

^Assuming a marginal emission factor of 0.54 short tons CO2/MWh (NYSERDA)

Figure 23: Mitrex – Light Transparent PV Glass for NYC School Building B

Mitrex					
Product	PV Glass – Transparent - Light		**Generation**		
Elev.	**Active PV Area (ft^2)**	**Standard Mitrex Cost (Supply Only)**	**-kW DC**	**BIPV-kWh/ Year**	**Carbon Reduction^ (tons/yr)**
North	1,799	$62,948.52	9	2,959	2
West	1,235	$43,225.46	6	4,366	2.5
East	2,077	$72,706.11	10	7,115	4
Total	**5,111**	**$178,880.10 ($35/SF)**	**26**	**14,439**	**8.5**

^Assuming a marginal emission factor of 0.54 short tons CO2/MWh (NYSERDA)

Elemex Feasibility Assessment Overview

For NYC School Building B, Elemex provided a feasibility assessment that proposes installation of BIPV rainscreen panels (Solstex O-series product) to replace the UHPC rainscreen panels and spandrel panels at curtain wall included in the project's retrofit design on all elevations. The Solstex O-series BIPV rainscreen panel product generates 13 watts per square foot.

The table below summarizes per elevation the area of proposed BIPV components to be installed, the cost, the predicted PV generation, and the estimated resulting carbon reduction.

Figure 24: Elemex –Solstex O-Series for NYC School Building B

Elemex					
Panel	Solstex O-Series		**Generation**		
	Active PV Area (ft^2)	**Standard Elemex Cost (Supply + Install)**	**kW DC**	**BIPV-kWh/Year**	**Carbon Reduction^ (tons/yr)**
North	10,137	$861,645	132	48,811	25
South	9,481	$805,885	123	139,627	42
East	6,863	$583,355	89	84,307	70
West	6,960	$591,600	91	58,297	29
Total	**33,441**	**$2,842,485 ($85/SF)**	**435**	**331,042**	**166**

^Assuming a marginal emission factor of 0.54 short tons CO2/MWh (NYSERDA)

Figure 25: Elemex – NYC School Building B Product Information

Project Info per Wall	North	East	South	West
System Size (kW DC)	132	89.3	123.36	90.56
Area Utilized (sq. ft.)	10,137	6,863	9,481	6,960
kWh/kWp	370	944	1,132	644
After "1" Year				
Generation [kWh]	48,811	84,307	139,627	58,297
Return [$$$]	11,114	19,197	31,793	13,274
CO2 Displaced [Tons]	25	42	70	29
Equivalent Trees Planted	628	1,085	1,797	750
After "26" Years				
Generation [kWh]	1,136,335	1,962,690	3,250,542	1,357,171
Return [$$$]	398,844	688,888	1,140,914	476,356
CO2 Displaced [Tons]	570	985	1,632	681
Financials				
Budget [$]	861,645	583,355	805,885	591,600
Incremental Cost of Solar [$]	557,535	377,465	521,455	382,800
Cost of Solar Power ($/KWh)	0.49	0.19	0.16	0.28
Cost of Power Today ($/KWh)	0.22	0.22	0.22	0.22
IRR (Internal Rate of Return)	-2%	5%	6%	2%

Onyx Feasibility Assessment Overview

For NYC School Building B, Onyx provided a feasibility assessment that proposes installation of BIPV rooftop paver tiles (GL.01, with anti-slip treatment) over the portion of the building's roof area walkway.

Each GL.01 BIPV roof paver tile with anti-slip treatment generates 79 watts and is composed of 2-ply fully tempered glass (5/16" over 5/16") with the textured treatment. Without the anti-slip treatment, the generation of each tile would increase by approximately 13%.

The table below summarizes per elevation the area of proposed BIPV components to be installed, the cost, the predicted PV generation, and the estimated resulting carbon reduction.

Figure 26: Oynx Solar –Rooftop Pavers for NYC School Building B

Oynx Solar					
Panel	Rooftop Pavers		**Generation**		
Material	Anti-slip textured frontal glass; 1,179 PV tiles				
	Active PV Area (ft^2)	**Standard Oynx Cost (Supply + Install)**	**kW DC**	**BIPV-kWh/Year**	**Carbon Reduction^ (tons/yr)**
Roof	6,600	$45-48/SF ($297,000-$316,800)	93	107,000	58

^Assuming a marginal emission factor of 0.54 short tons CO2/MWh (NYSERDA)

PVilion Feasibility Assessment Overview

For NYC School Building B, PVilion provided a feasibility assessment that proposes installation of their Heavy Duty Solar Canopy product at the building's rooftop play yard.

The Heavy Duty Solar Canopy is composed of PV cells integrated into high-strength PVC coated polyester fabric on an anodized aluminum frame and generates approximately 1,300 kWh/kW/year. The cost per watt, including the canopy structure, is $7 - $10.

The installation process would involve craning structural frame members to the roof, where the erection of the canopy would be completed.

The table below summarizes per elevation the area of proposed BIPV components to be installed, the cost, the predicted PV generation, and the estimated resulting carbon reduction.

Figure 27: Pvilion – Play Yard Canopy for NYC School Building B

PVilion						
Panel	Play Yard Canopy: Heavy Duty Solar Canopy	**Generation**				
Scheme	**Canopy Roof Surface Area (ft^2)**	**Active PV Area (ft^2)**	**Standard Pvilion Cost ($50-$150/SF)**	**kW DC**	**BIPV-kWh/Year (*~1300kWh /kW/yr*)**	**Carbon Reduction^ (tons/yr)**
1	7,140	3,018	$368,858 - $477,346	40.8	53,040	29
2	10,000	4,386	$497,376 - $643,663	58.7	76,310	41
3	9,560	3,960	$452,734 - $585,891	52.7	68,510	37

^Assuming a marginal emission factor of 0.54 short tons CO2/MWh (NYSERDA)

Figure 28: Pvilion Fabric Canopy

Figure 29: PVilion Heavy Duty Portable Solar Canopy installation

Figure 30: Installation of PVilion Heavy Duty Canopy system

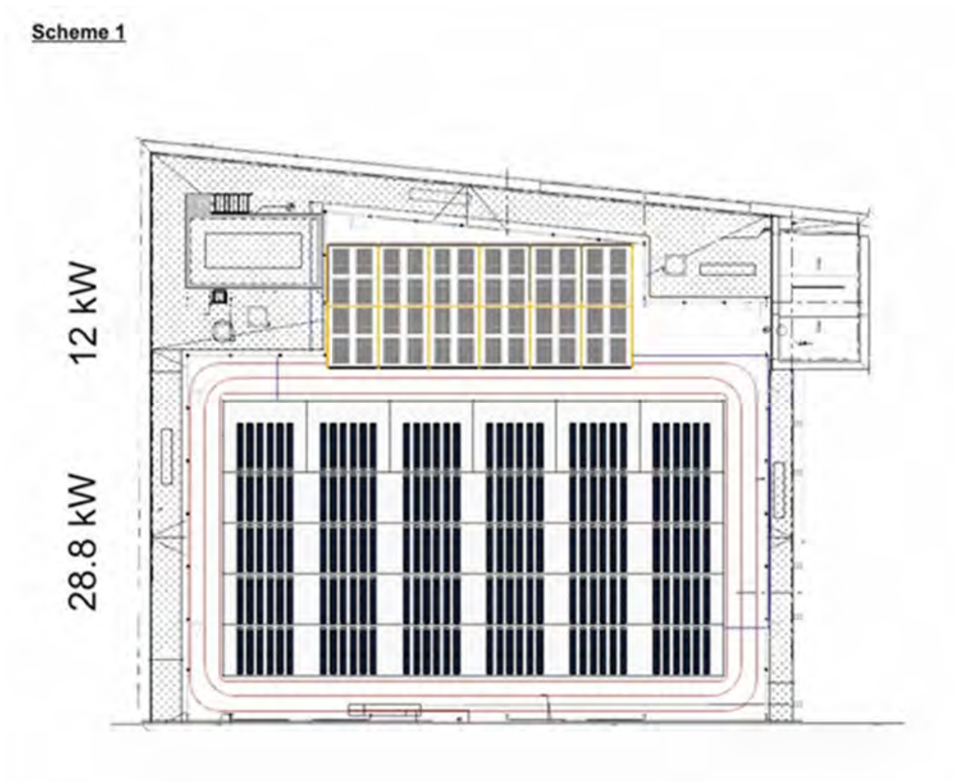
Figure 31: PVilion Quad Pole Solar Sail installation at New York Botanical Garden

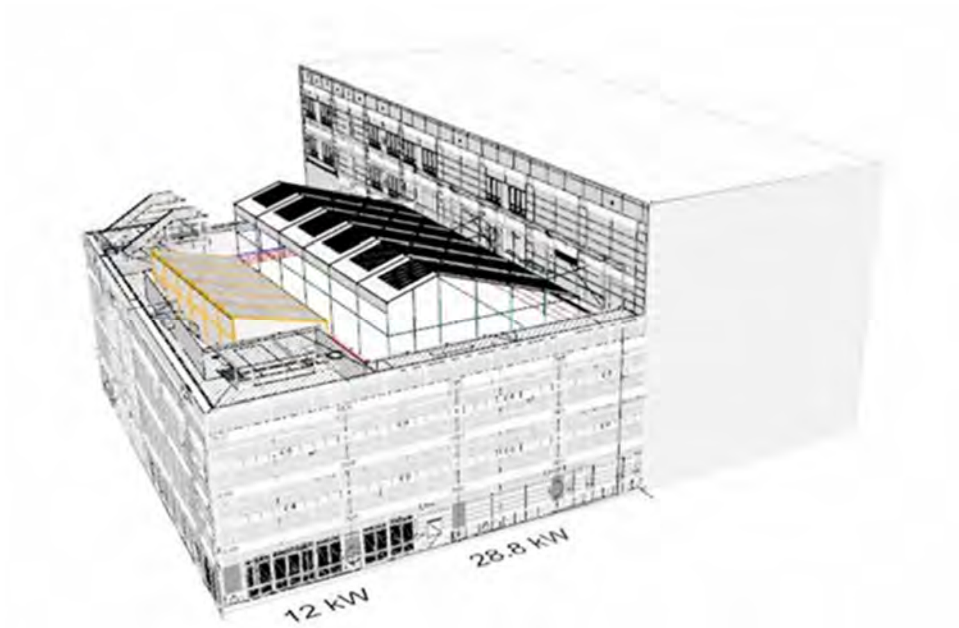
Figure 32: PVilion Construction of PVilion custom project for 2014 Solar Decathlon – Techstyle Haus

Figure 33: Pvilion custom solar fabric carport at Google

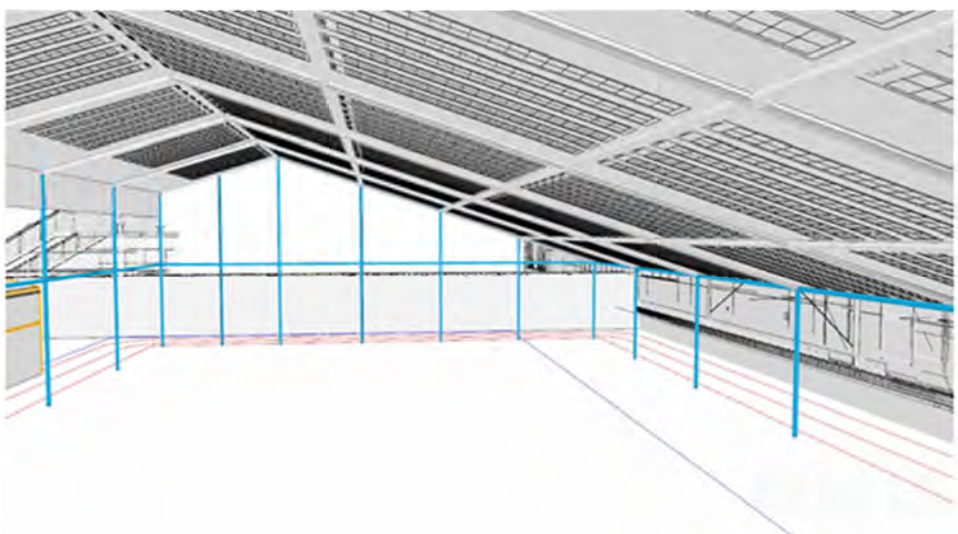
Figure 34: PVilion Solar Sails at Skyland Park, Atlanta

Proposed Schemes:

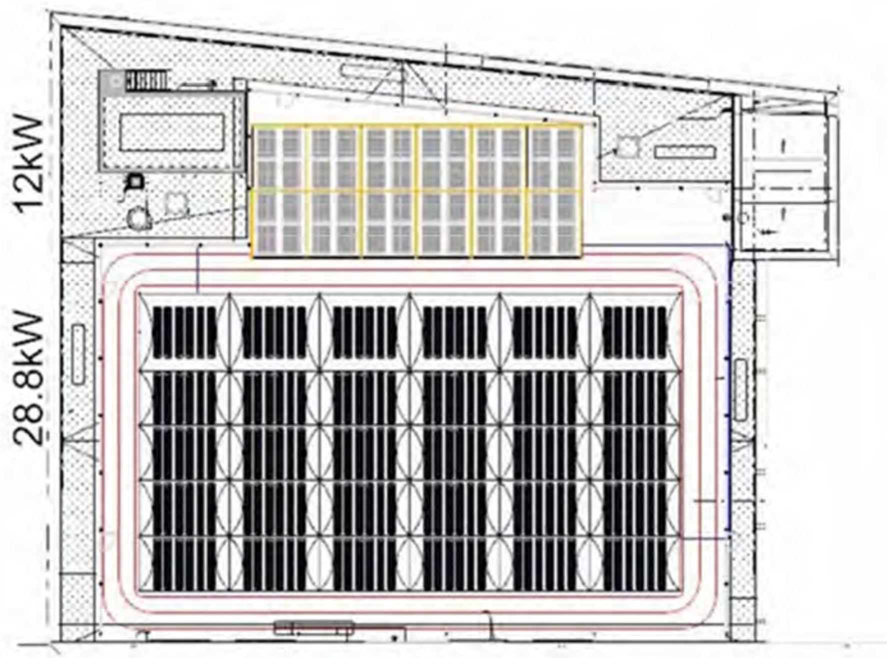


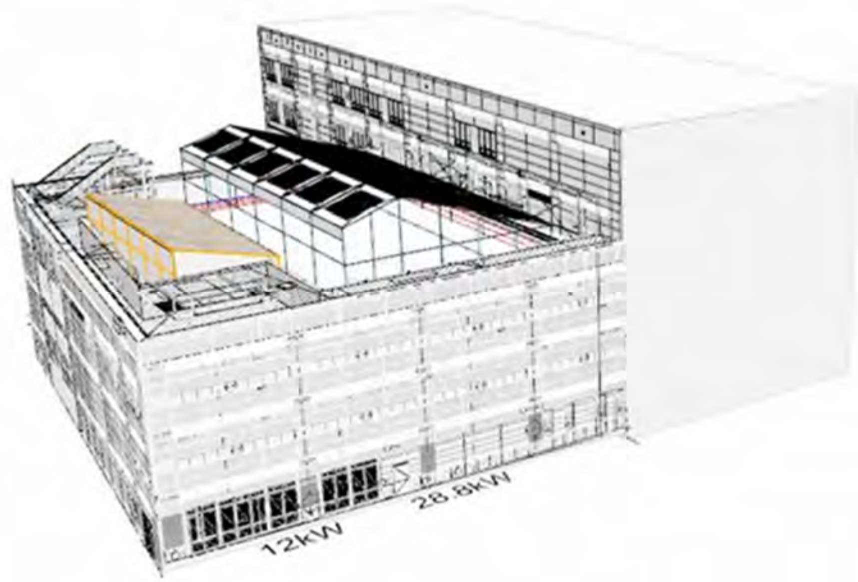


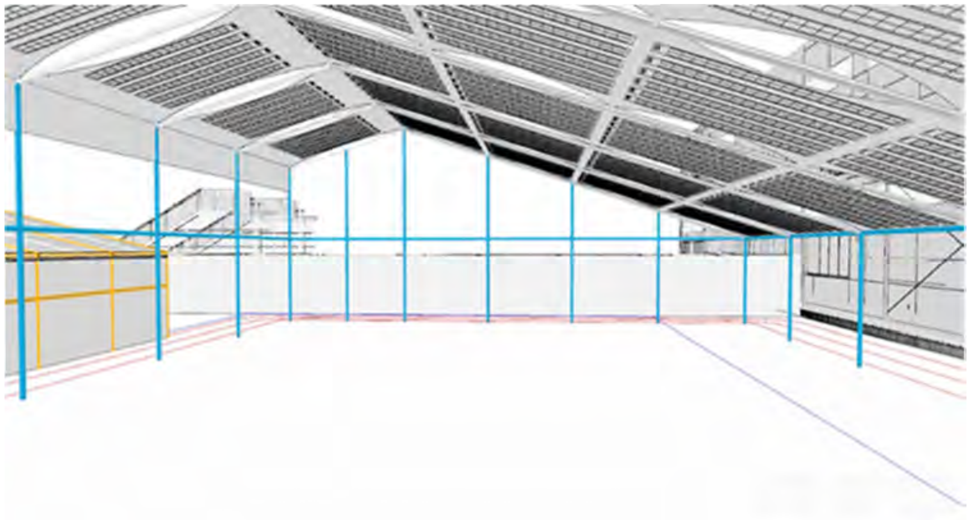
28.8 kW
12 kW



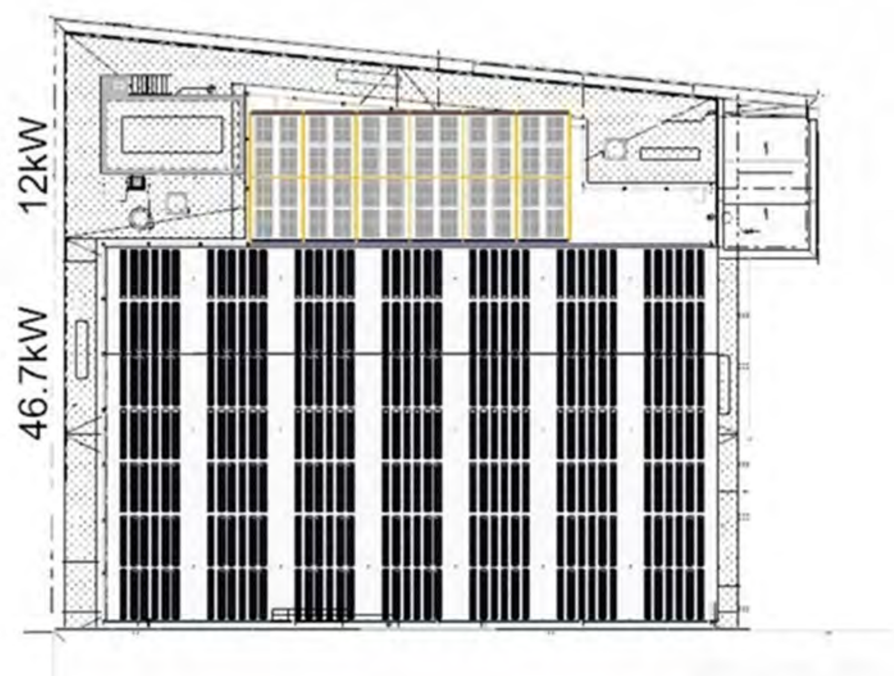
Scheme 1A

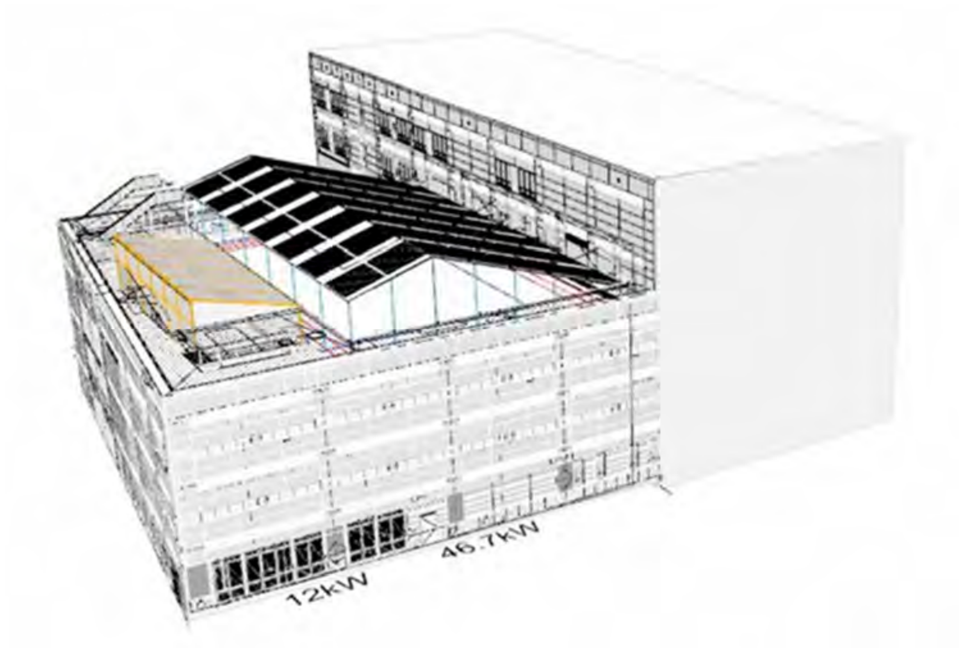


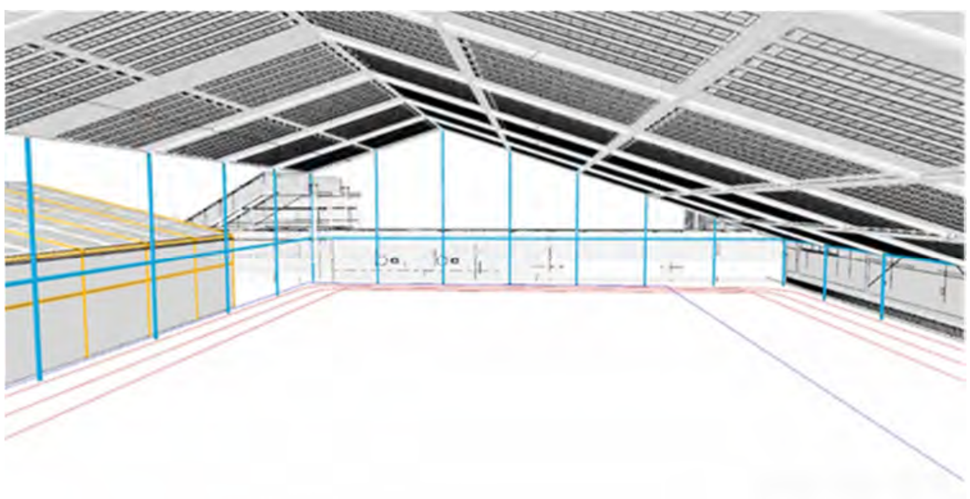




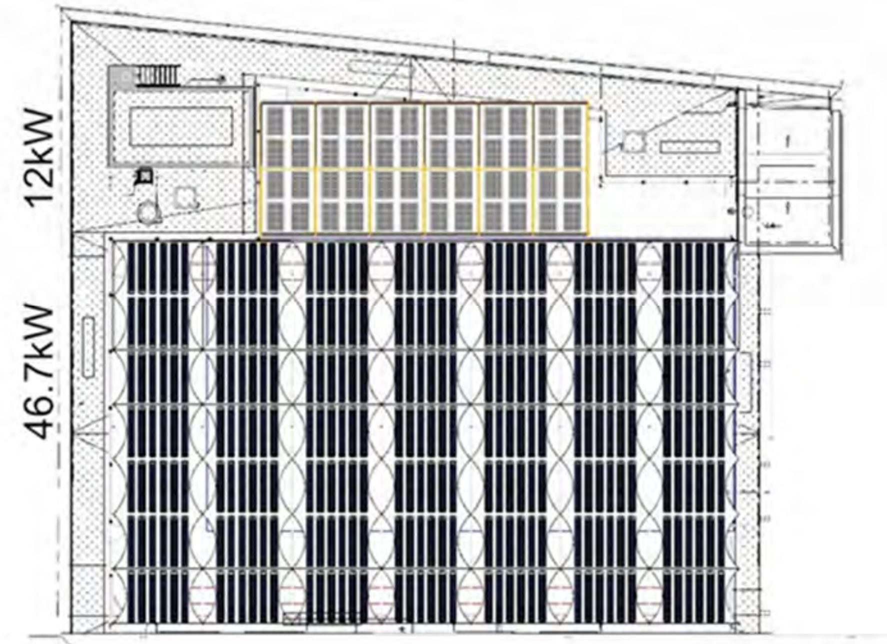
Scheme 2

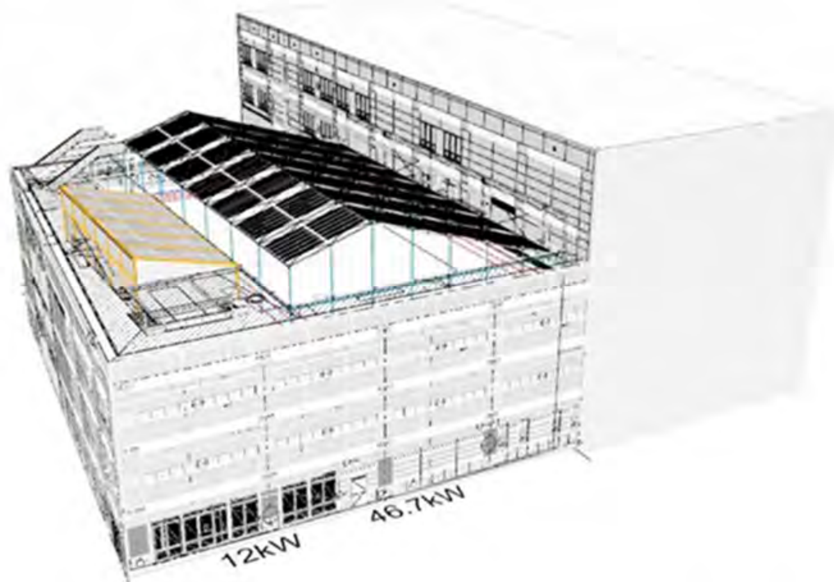


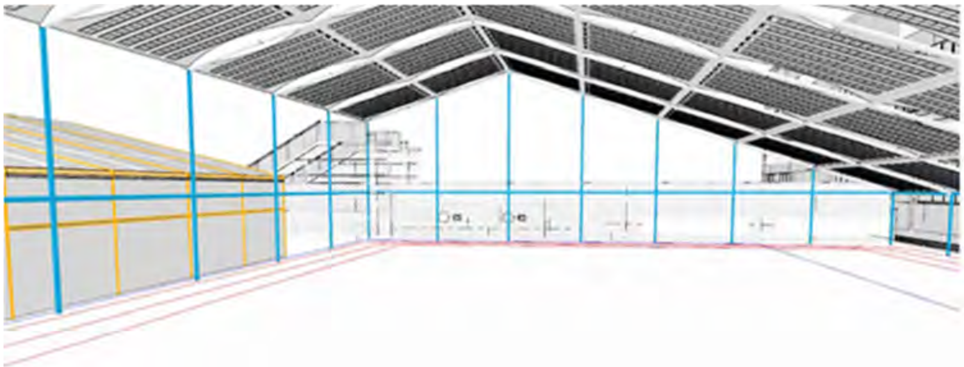

12kW
46.7kW



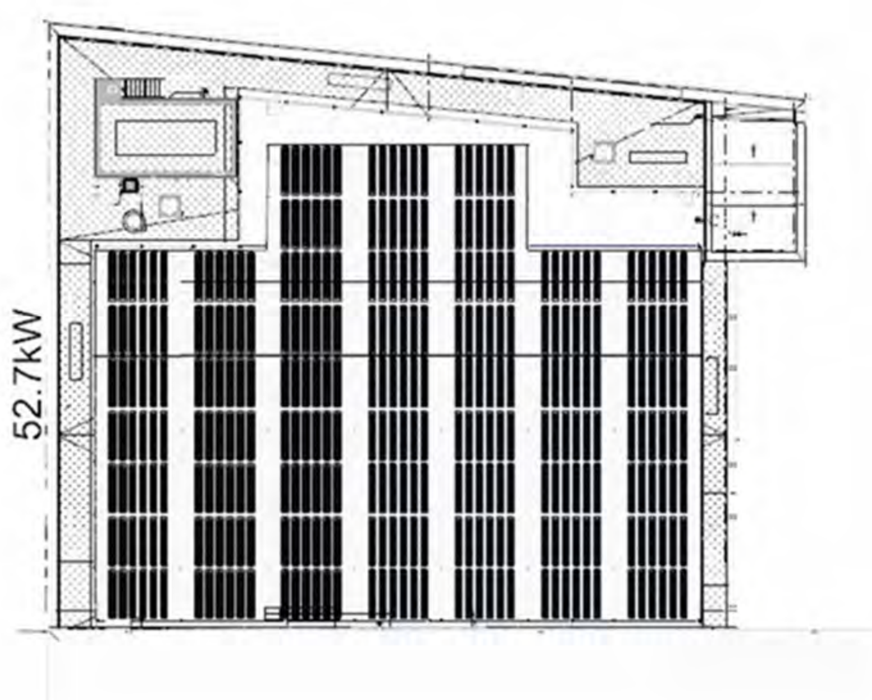
Scheme 2A

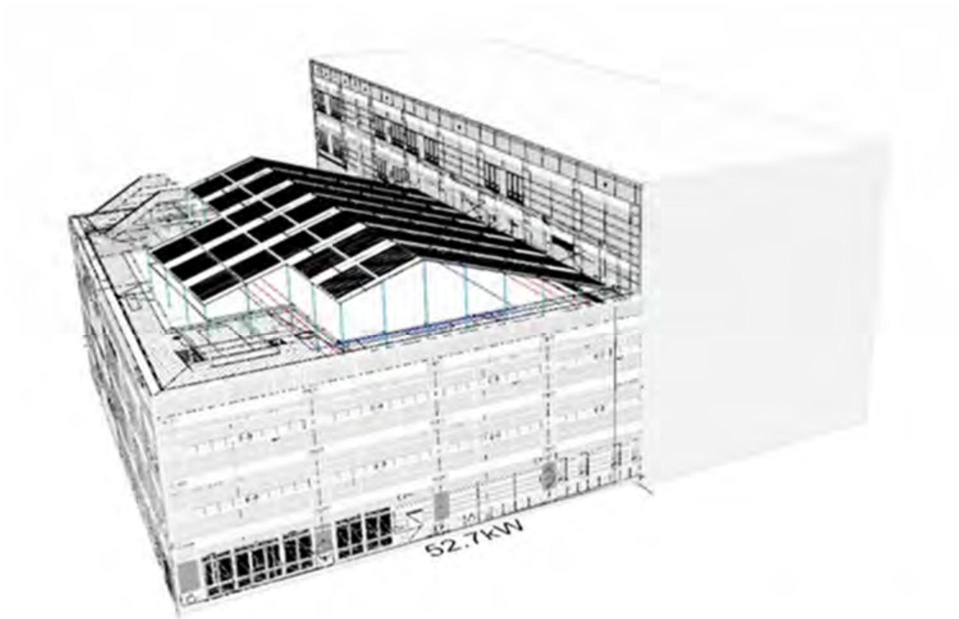


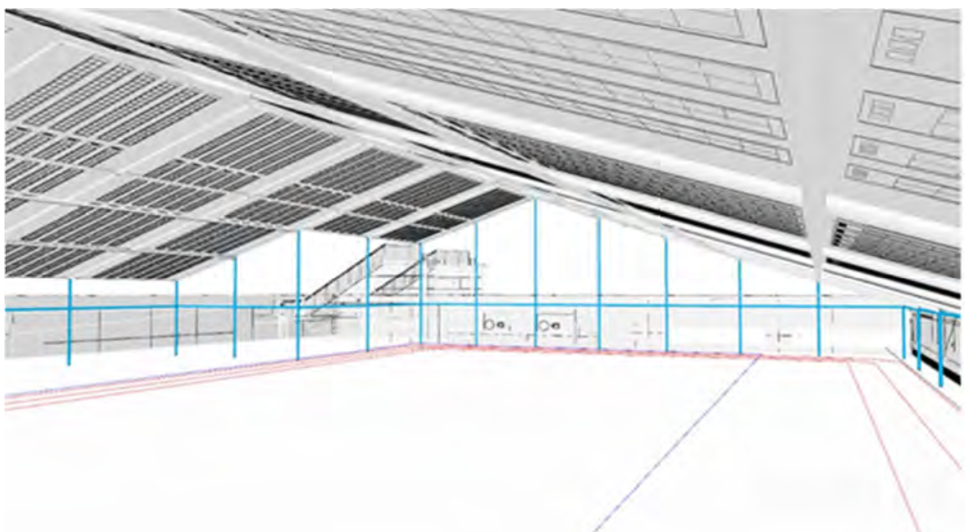




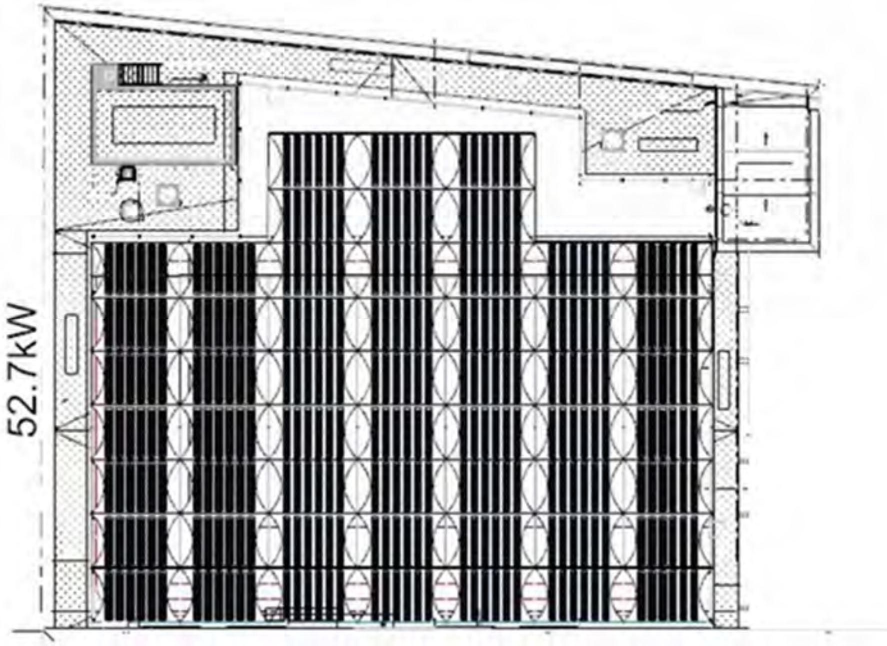
Scheme 3

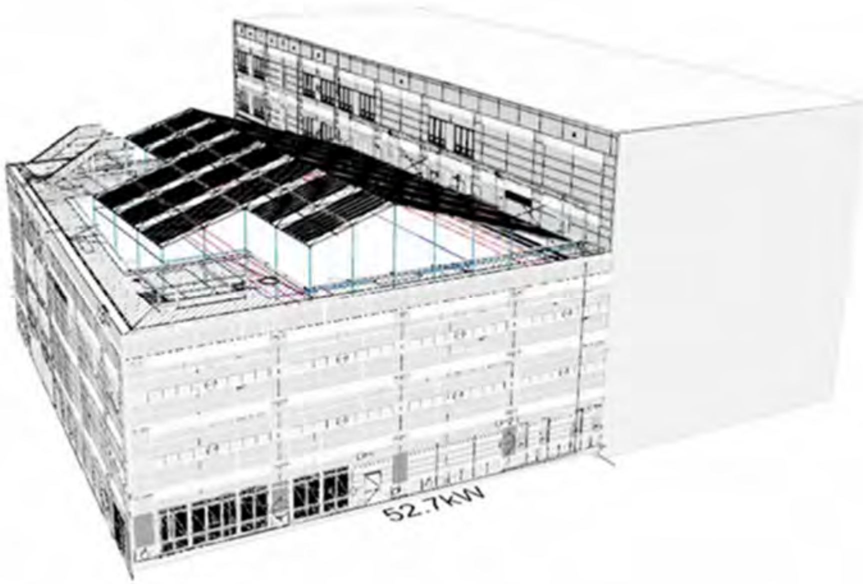


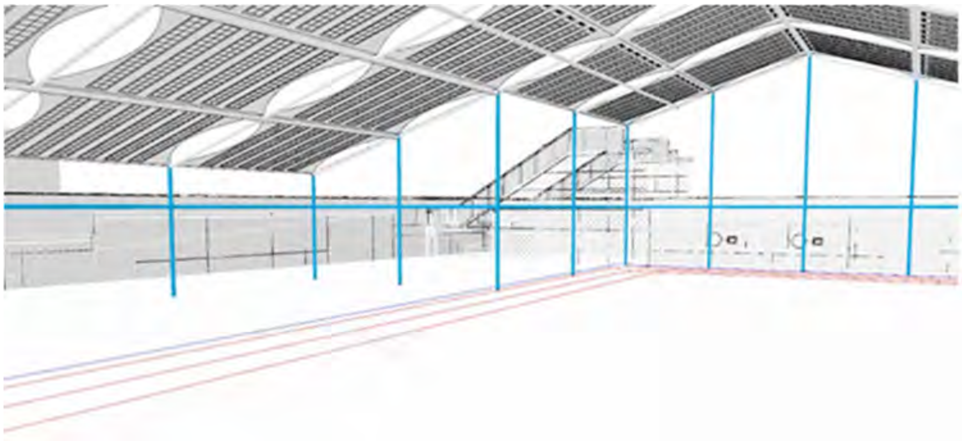

52.7kW



Scheme 3A







NYC School Building B Site Conditions and Context

The assessment for the NYC School Building B case study involves evaluating the potential for solar energy integration in a five-floor public school building located in New York City. The site context comprises a compact neighborhood, with a predominant tall building on the west façade. This context has implications for solar energy access and shading patterns.

Solar Insolation Analysis

This analysis focuses on the potential integration of Building Integrated Photovoltaics (BIPV) in NYC School Building B.

The site's context includes a tall building to the southwest of the school building, which will have a substantial impact on the solar radiation potential. The shading caused by the tall building obstructs direct sunlight, limiting the solar gain on the south and west walls, which are typically expected to have strong radiation potential.

In terms of solar radiation, the site receives an estimated 3.2554e+7 kWh, indicating the available solar energy potential. This data provides a valuable starting point for assessing the feasibility of integrating solar energy systems into the project.

i. South and West Facades: Despite having the potential for strong radiation, the south and west walls of the school building do not receive sufficient sunlight due to shading from the neighboring tall buildings. This significantly diminishes their solar potential, making them less suitable for BIPV integration.

ii. Northeast Facades: Only the northeast facade of the public-school building receives some radiation, indicating a comparatively higher solar potential than the other facades. However, the solar gain on this facade might still be inadequate for optimal BIPV integration and significant energy generation.

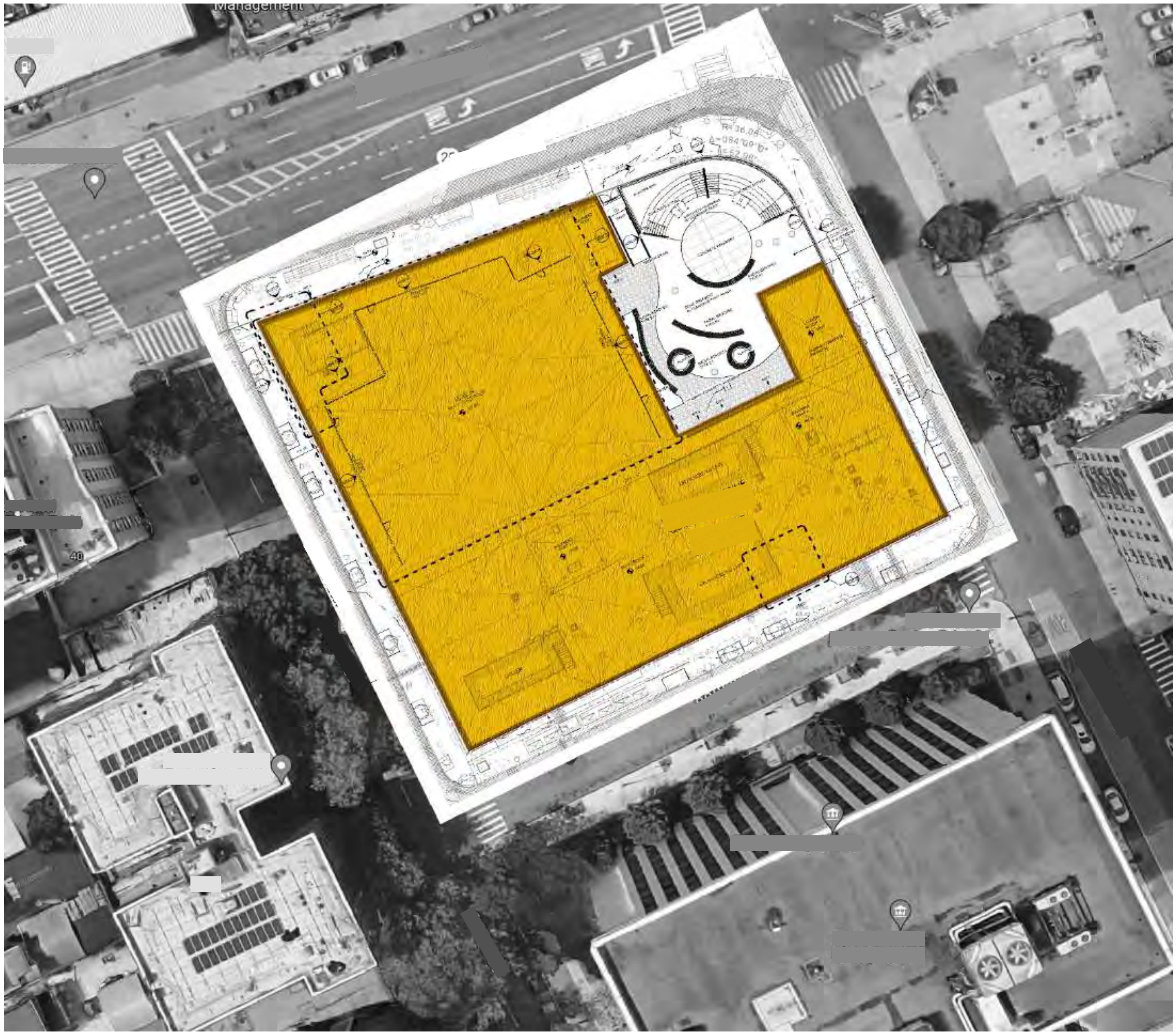
Recommendations

Considering the limited solar potential of the south, west, southeast, and southwest facades, along with the shading impact of the neighboring tall building, this school building may not be ideal for BIPV integration. The restrictions on solar exposure impose significant limitations on the potential energy generation and overall effectiveness of BIPV systems.

Mitrex Case Study Report

MITREX
BUILDING INTEGRATED SOLAR TECHNOLOGY

MITREX CONDENSED PROPOSAL



New York City Government

PRESENTED BY:	Terri Oswald
DATE:	May 4, 2023

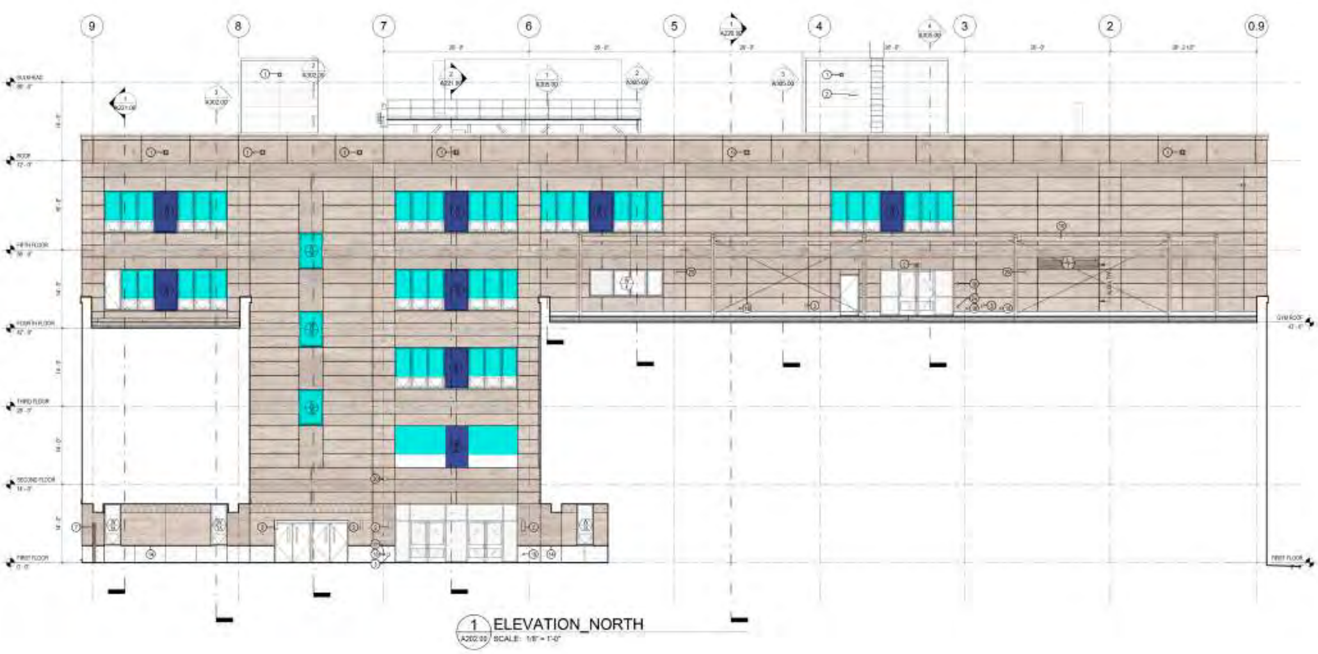
OVERVIEW

Project Scope Mitrex Overview

M-Limestone-Fennec - 15W/sq.ft.

M-Glass-Transparent (Dark)- 7W/sq.ft.

M-Glass-Transparent (Light)- 5W/sq.ft.



PROJECT HIGHLIGHTS

	Cladding	M-Limestone-Fennec
	Glazing - Dark	M-Railing-Transparent
	Glazing - Light	M-Railing-Transparent

1 ELEVATION_NORTH
A202.00 SCALE: 1/8" = 1'-0"

2 ELEVATION_WEST-165TH ST
A202.00 SCALE: 1/8" = 1'-0"

MITREX INTEGRATED SOLAR CLADDING | Cladify

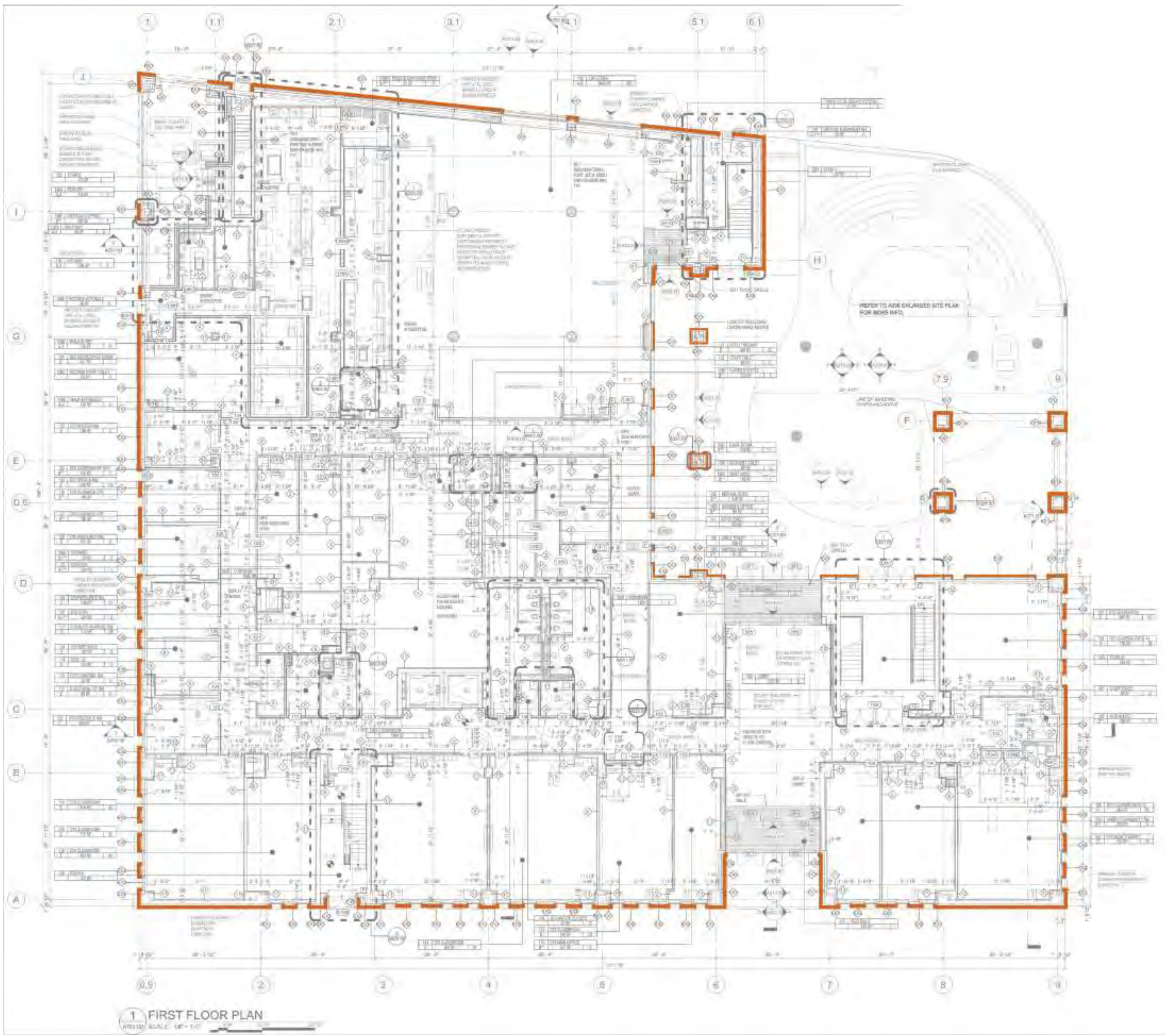
PROJECT HIGHLIGHTS

PROJECT HIGHLIGHTS

	Cladding	M-Limestone-Fennec
	Glazing - Dark	M-Railing-Transparent
	Glazing - Light	M-Railing-Transparent

+1-416-497-7120 info@mitrex.com 41 Racine Rd., Toronto, ON M9W 2Z4 mitrex.com

PROJECT HIGHLIGHTS



PRICING SUMMARY

Material	Cladding	SUPPLLY & INSTALL
Panel	Fennec	

	Mitrex									
	Active (Sqft)	$	Non Active (Sqft)	$	Returns & Flashings	$	-KW	BIPV-Kwh/Year	$	
North	8473	$ 804,892.64	5325	$ 452,618.29	1085	$ 21,708.82	128	42020	$ 8,824.26	
South	0	$ -	12612	$ 1,071,991.38	1346	$ 26,914.03	0	0	$ -	
West	6690	$ 635,513.14	2969	$ 252,378.69	1318	$ 26,351.94	101	71297	$ 14,972.29	
East	6265	$ 595,169.03	3916	$ 332,847.41	594	$ 11,884.24	94	64693	$ 13,585.49	
Total	21427	$ 2,035,574.81	24822	$ 2,109,835.77	4343	$ 86,859.03	323	178010	$ 37,382.04	
					Total	$ 4,232,269.61				

Material	Glazing - Dark	SUPPLY ONLY
Panel	Dark Window	

	Mitrex				
	Active (Sqft)	$	-KW	BIPV-Kwh/Year	$
North	229	$ 8,025.34	2	528	$ 110.89
West	594	$ 20,784.94	4	2939	$ 617.19
East	187	$ 6,544.86	1	897	$ 188.30
Total	1010	$ 35,355.13	7	4364	$ 916.38
	Total	$ 35,355.13			

Material	Glazing - Light	SUPPLY ONLY
Panel	Light Window	

	Mitrex				
	Active (Sqft)	$	-KW	BIPV-Kwh/Year	$
North	1799	$ 62,948.52	9	2959	$ 621.30
West	1235	$ 43,225.46	6	4366	$ 916.81
East	2077	$ 72,706.11	10	7115	$ 1,494.11
Total	5111	$ 178,880.10	26	14439	$ 3,032.22
	Total	$ 178,880.10			

MITREX INTEGRATED SOLAR CLADDING | Cladify

INSTALLATION METOD

Architectural Facade Systems

530 Admiral Drive, London, Ontario, Canada N5V 0B2 • Tel: 1-844-435-3639 • elemex.com

Solstex® Generation Proposal

Panels Utilized: 38,374 sqft. Standard Black Solstex O-Series Panels (approx.)

Description:

Client requests for the solar estimates on all the sides of the building. In order to evaluate the viability of the Solstex O-Series, careful consideration has been given to the orientation of the building as well as its location.

Layout:

Figure 1: South Wall Overlaid with Solstex O-Series

Figure 2: West Wall Overlaid with Solstex O-Series

Per Drawing Sheets A201, A202, A203 dated April 11th,2022.

Date: June 27th ,2023

*All numbers given in this report are estimates only. Any generation info contained in this report is for informational purposes and is not a future guarantee of performance. Elemex cannot guarantee any future performance of Solstex Systems, nor can Elemex be held liable for any performance deviations from the information contained within this report.

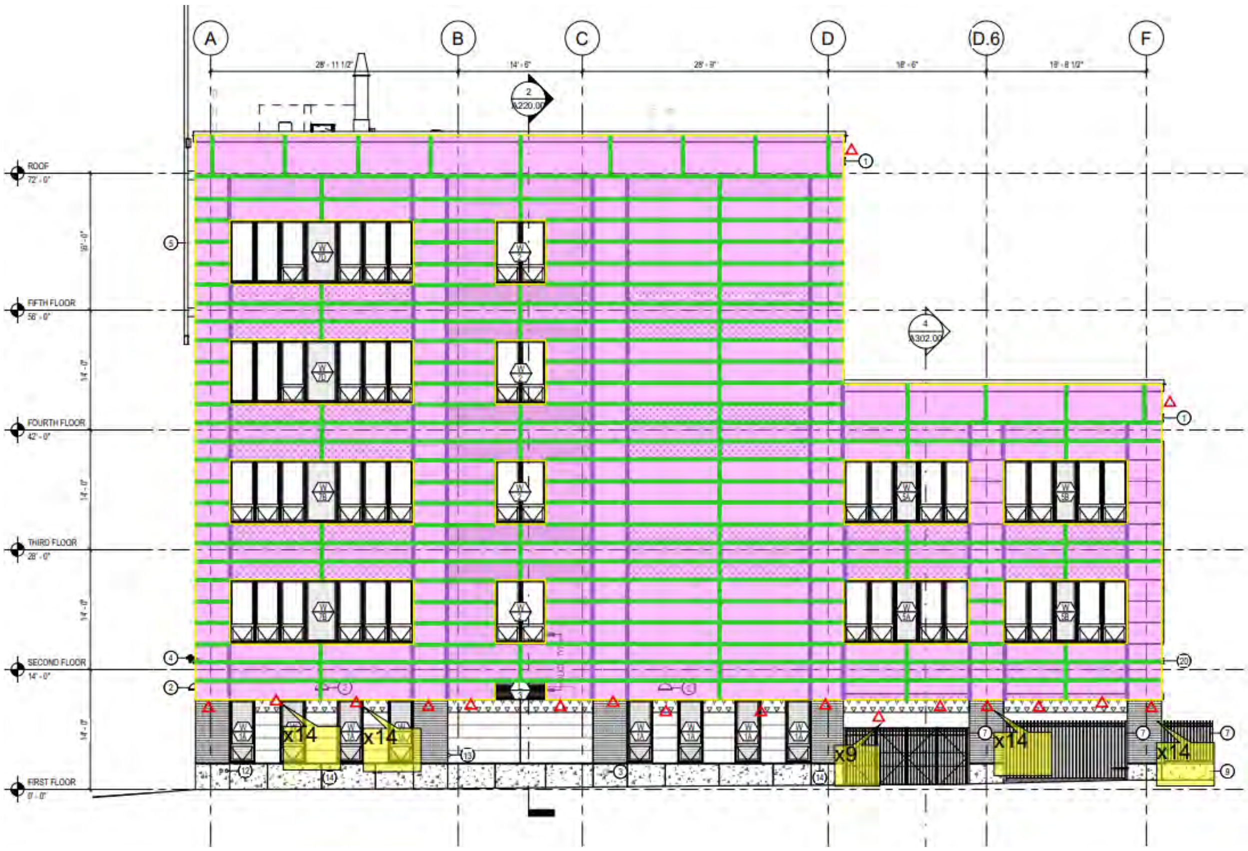


Figure 3: East Wall Overlaid with Solstex O-Series

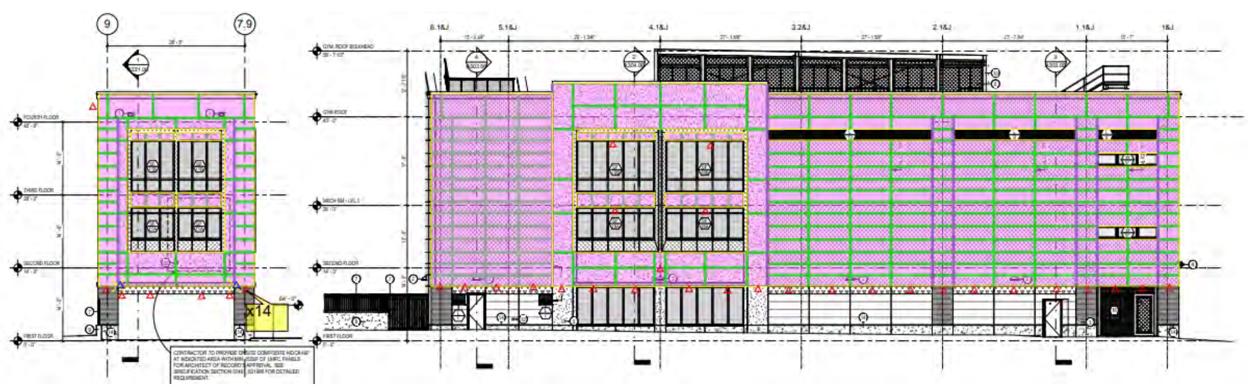


Figure 4: North Walls Overlaid with Solstex O-Series

Per Drawing Sheets A201, A202, A203 dated April 11th,2022.
Date: June 27th ,2023

Typical Color Options:

Different color options available for Solstex O-Series.

Figure 5: O-Series Color Options

Different colors of solar panels vary in efficiency; mentioned beneath each color of solar panel is the power density of that given color, measured in watts per meter squared. The proposal incorporated the color selection of standard black however it is possible to customize the proposal with any color as per the client's specific request.

Typical Attachment System:

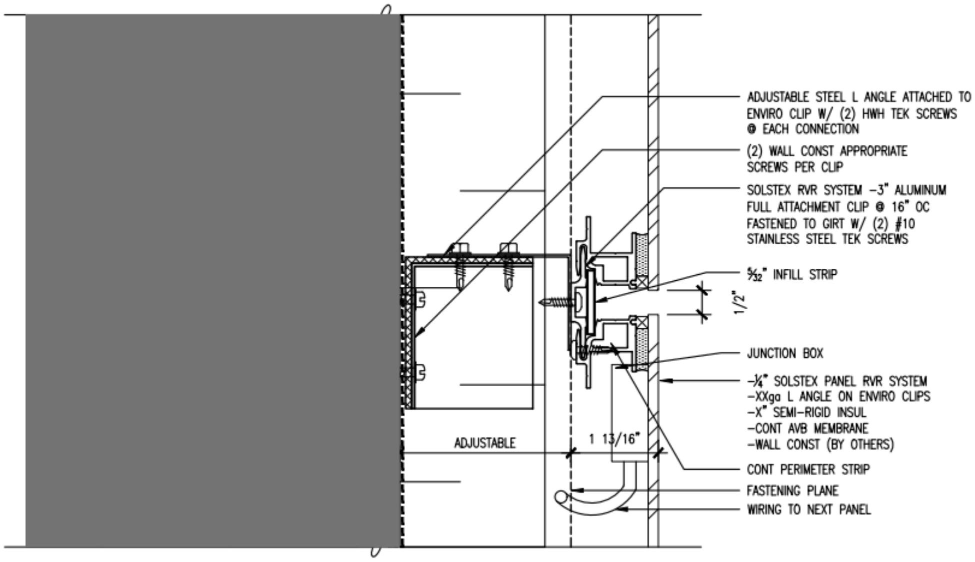


Figure 6: Horizontal Joint for Solstex

Typical Electrical System:

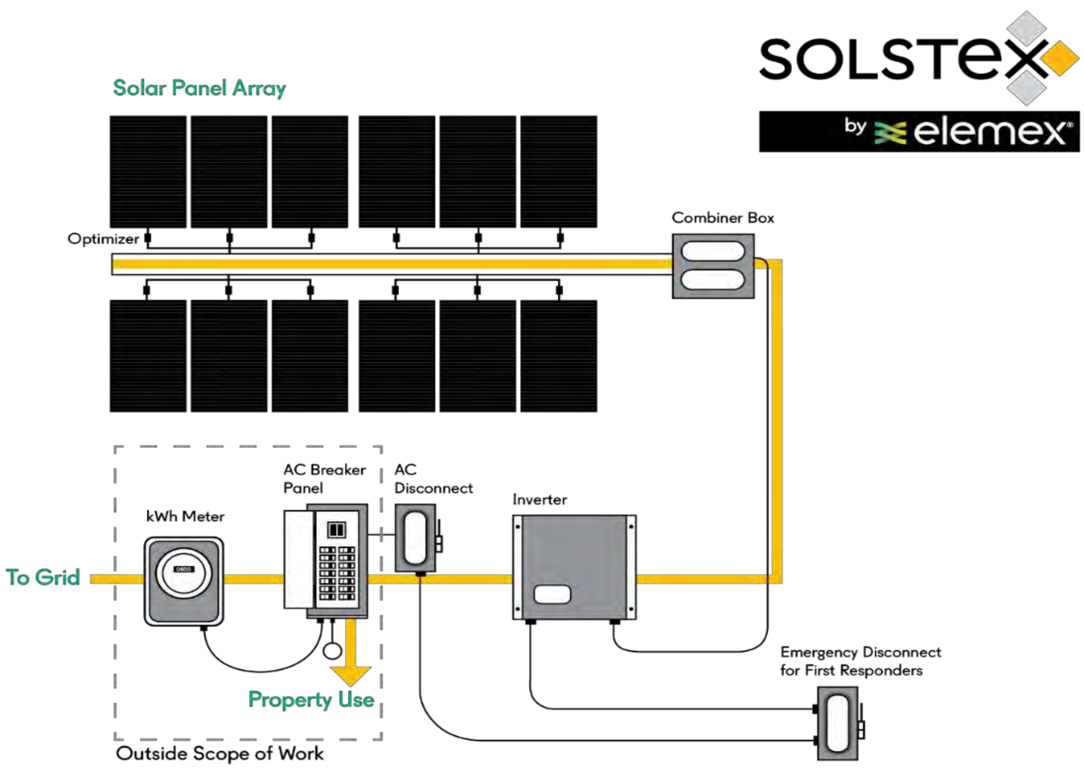


Figure 7: Solstex General Electrical Flow Diagram

Solstex® Generation Proposal

Project Details:

Project Info	North Wall	East Wall	South Wall	West Wall	Entire Project
System Size (kW DC)	200	123	178	133	635
Area Utilized (sq. ft.)	12,096	7,452	10,762	8,064	38,374
kWh/kWp	327	866	1,040	595	688
1st Year Stats					
Generation [kWh]	65,450	106,781	185,106	79,404	436,741
Return [$$$]	11,381	18,567	32,186	13,807	75,941
CO2 Displaced [Tons]	33	54	93	40	219
Equivalent Trees Planted	842	1,374	2,383	1,022	5,622
Cumulative Stats Over 25 years					
Generation [kWh]	1,523,693	2,485,871	4,309,288	1,848,538	10,167,391
Return [$$$]	408,396	666,289	1,155,019	495,464	2,725,168
CO2 Displaced [Tons]	765	1,248	2,163	928	5,104
Financials					
Budget [$]	895,104	551,448	796,388	596,736	2,839,676
Incremental Cost of Solar [$]	532,224	327,888	473,528	354,816	1,688,456
Cost of Solar Energy ($/kWh)	0.35	0.13	0.11	0.19	0.17
Cost of Energy Today ($/kWh)			0.17		
IRR (Internal Rate of Return)	-2%	6%	7%	2%	4%

Table 1: Quick Project Facts

Assumptions:
- Supply of panels and supply of balance of system components
- Local price of electricity: $0.17/kWh with an average annual increase of 3.5%
- System Degradation Rate of 0.6%/year
- Inverter efficiency of 96%

Per Drawing Sheets A201, A202, A203 dated April 11th, 2022.

Date: June 27th, 2023

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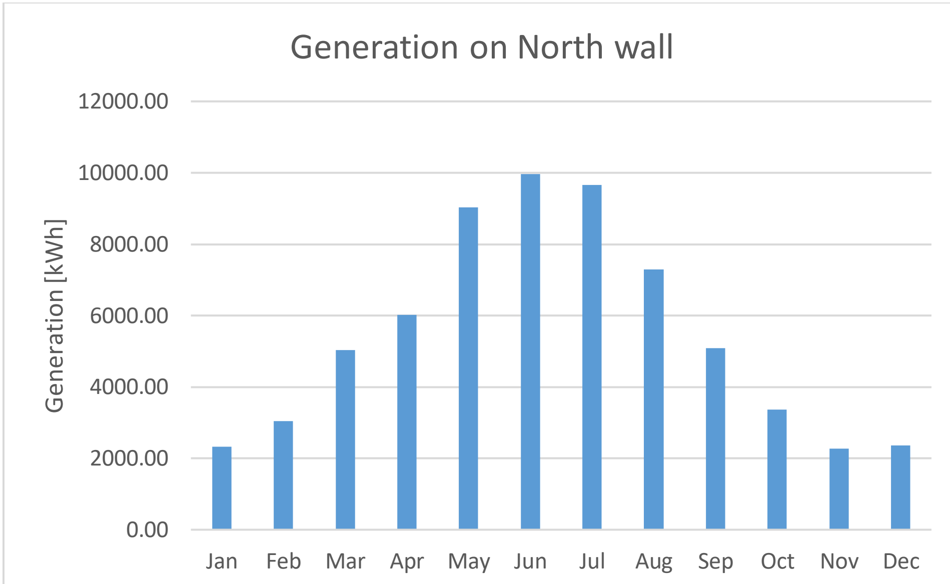
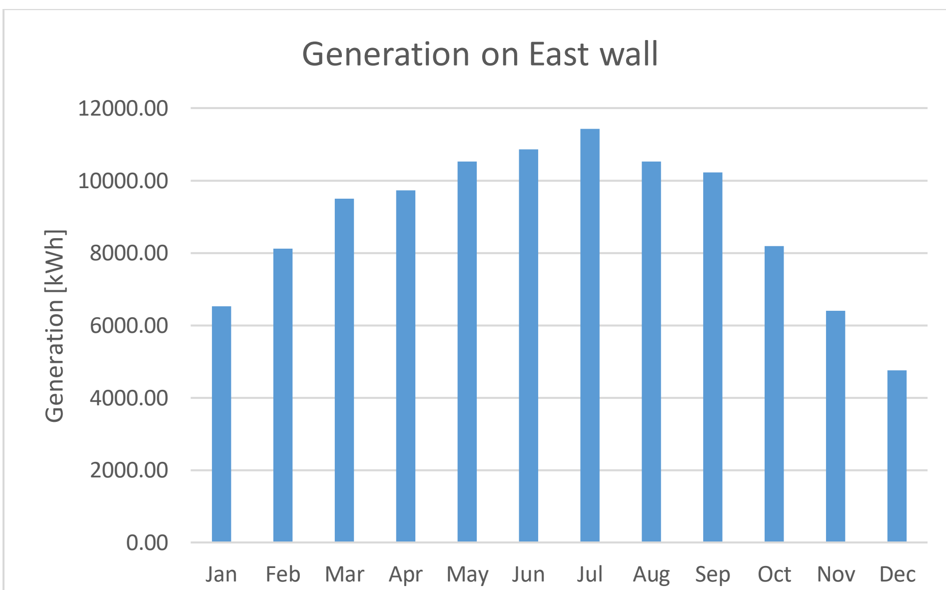
Generation Estimates: Power generation from panels per wall per month.

North Wall:



Graph 1: Electricity Produced Monthly on North Wall

East Wall:



Graph 2: Electricity Produced Monthly on East Wall

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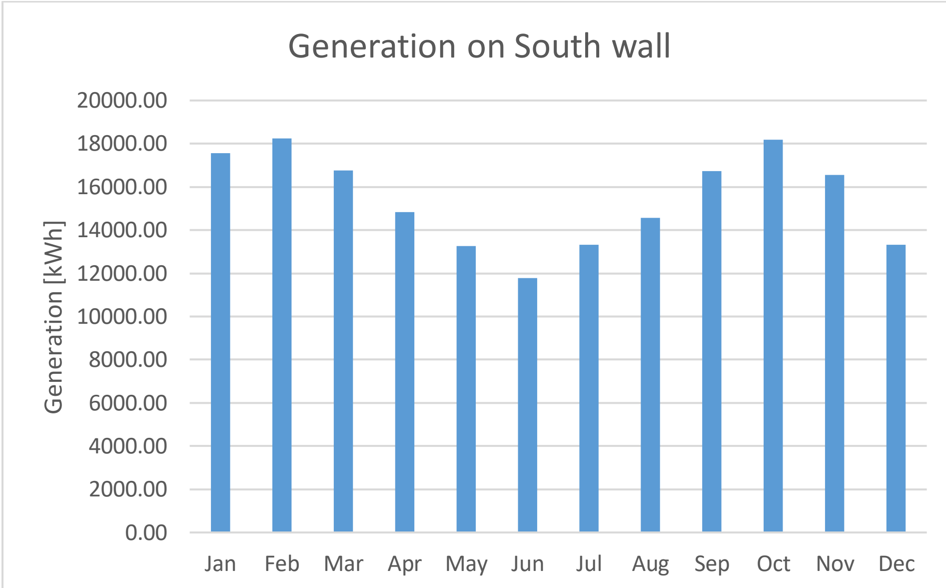
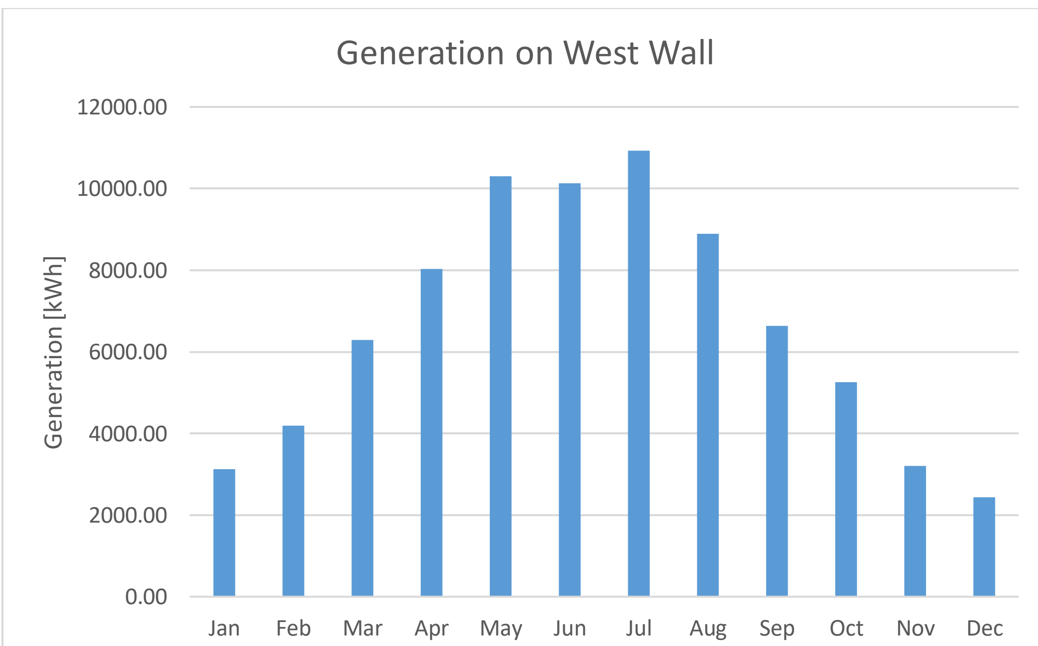
South Wall:



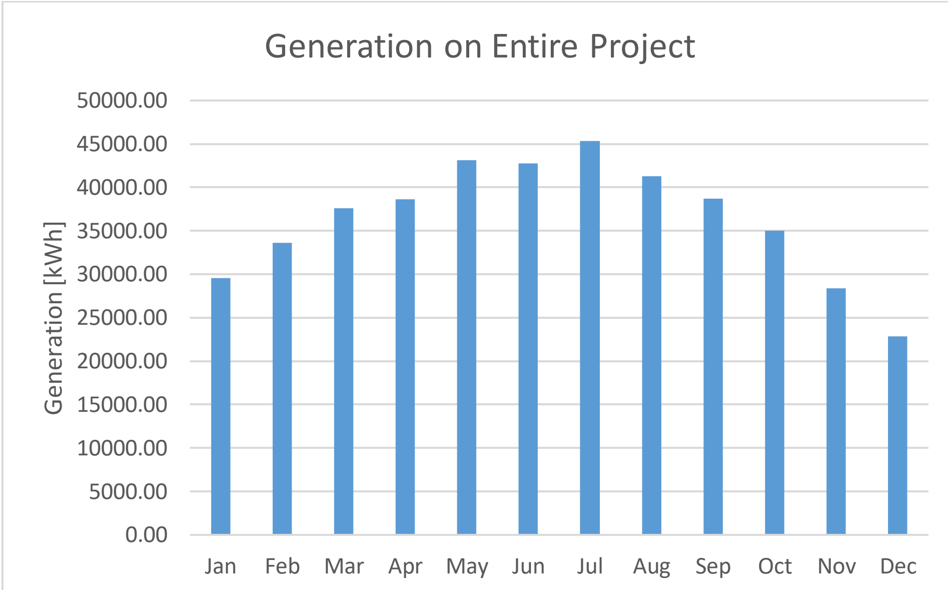
Graph 3: Electricity Produced Monthly on South Wall

West Wall:



Graph 4: Electricity Produced Monthly on West Wall

Entire Project:



Graph 5: Electricity Produced Monthly on Entire Project

Generation varies throughout the year, due to the vertical nature of the façade, and the latitude of the project.

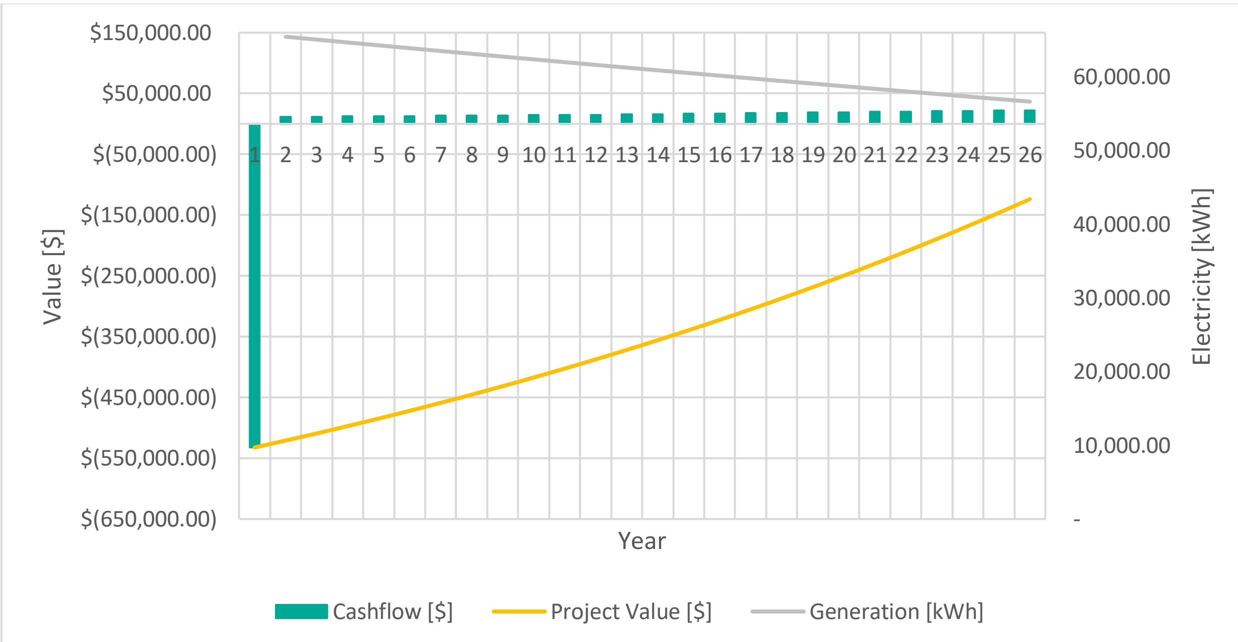
Recommended Contract Style - Net Metering:

Net metering allows people who generate electricity from renewable energy technologies to send excess energy to the electrical grid in exchange for a credit towards future electricity costs. Excess generation means that renewable energy technology is generating more energy than required. Excess generation is more common during the summer months, so credits can be carried forward for a consecutive 12-month period. This allows excess generation credits accrued in the summer to be used during the winter, where the power generation is lower.

Financial Model:

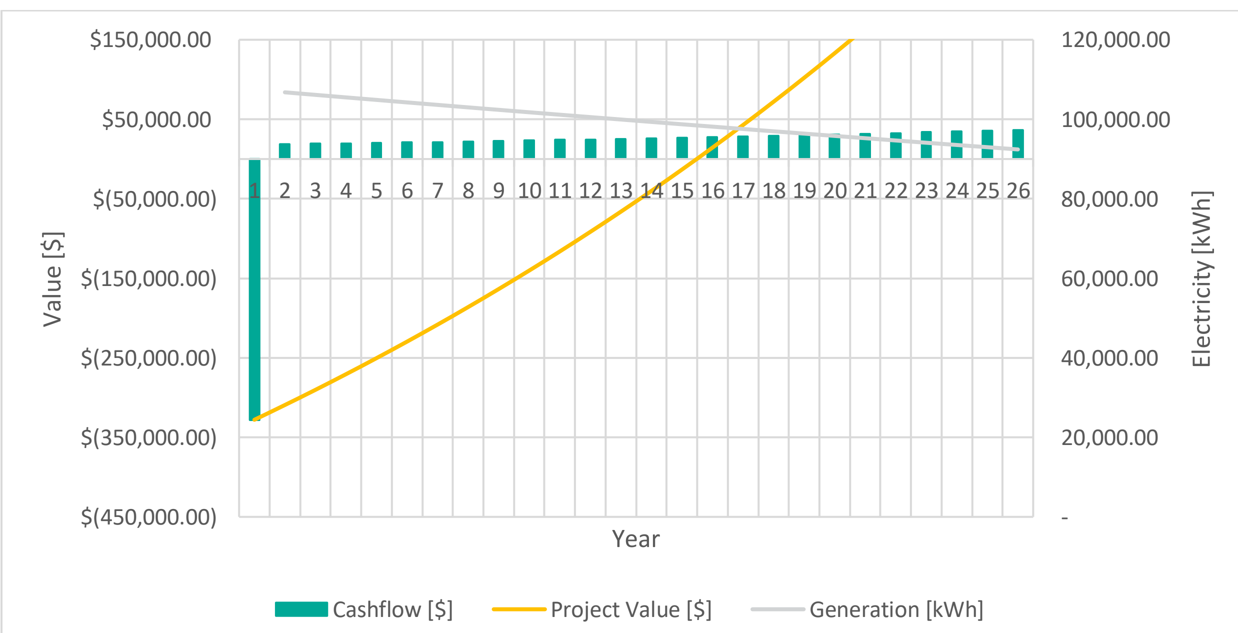
Return on Investment over the span of 26 years with respect to power generation.

North Wall:



Graph 6: ROI Graph North Wall

East Wall:



Graph 7: ROI Graph East Wall

Per Drawing Sheets A201, A202, A203 dated April 11th,2022.

Date: June 27th ,2023

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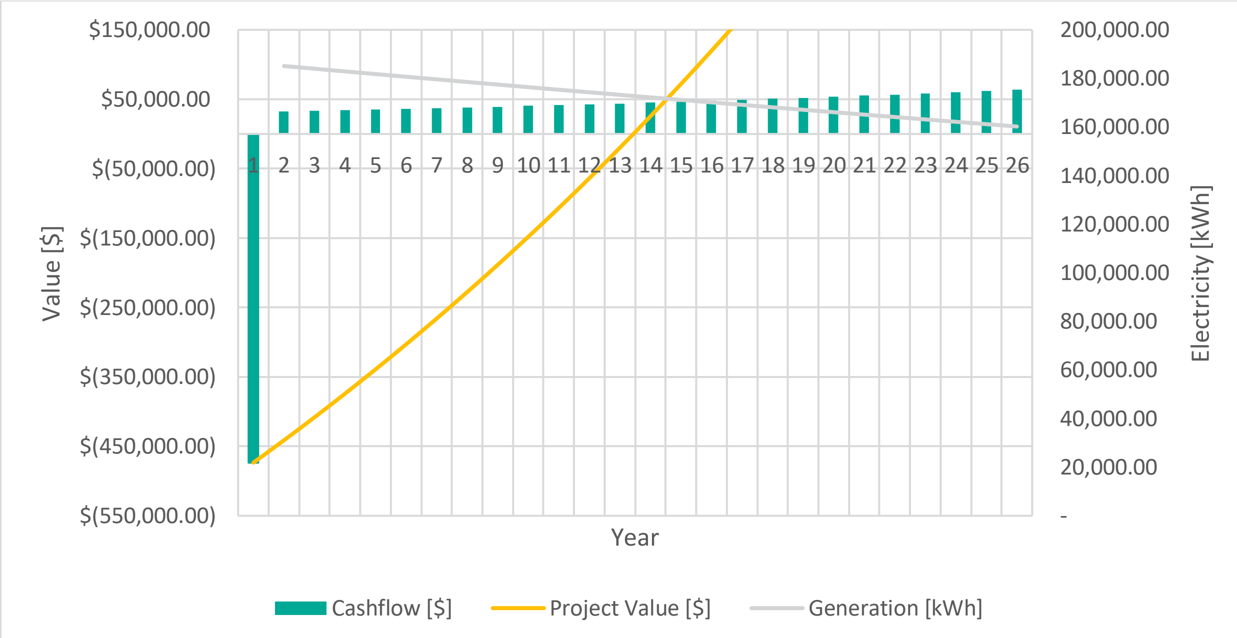
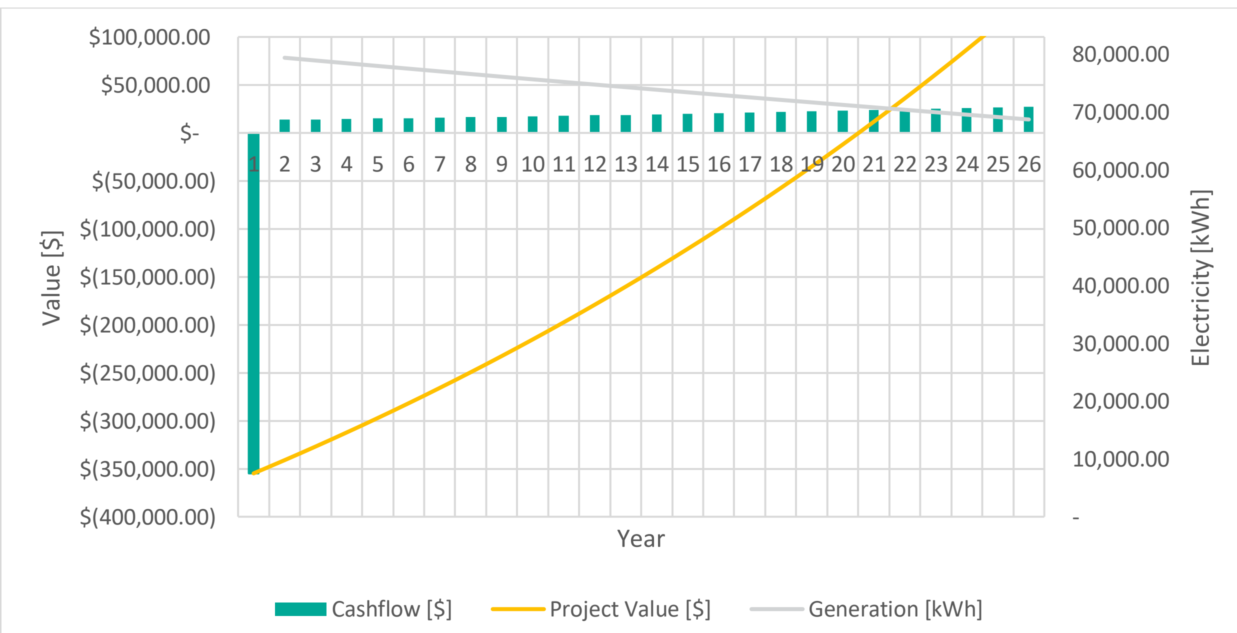
South Wall:



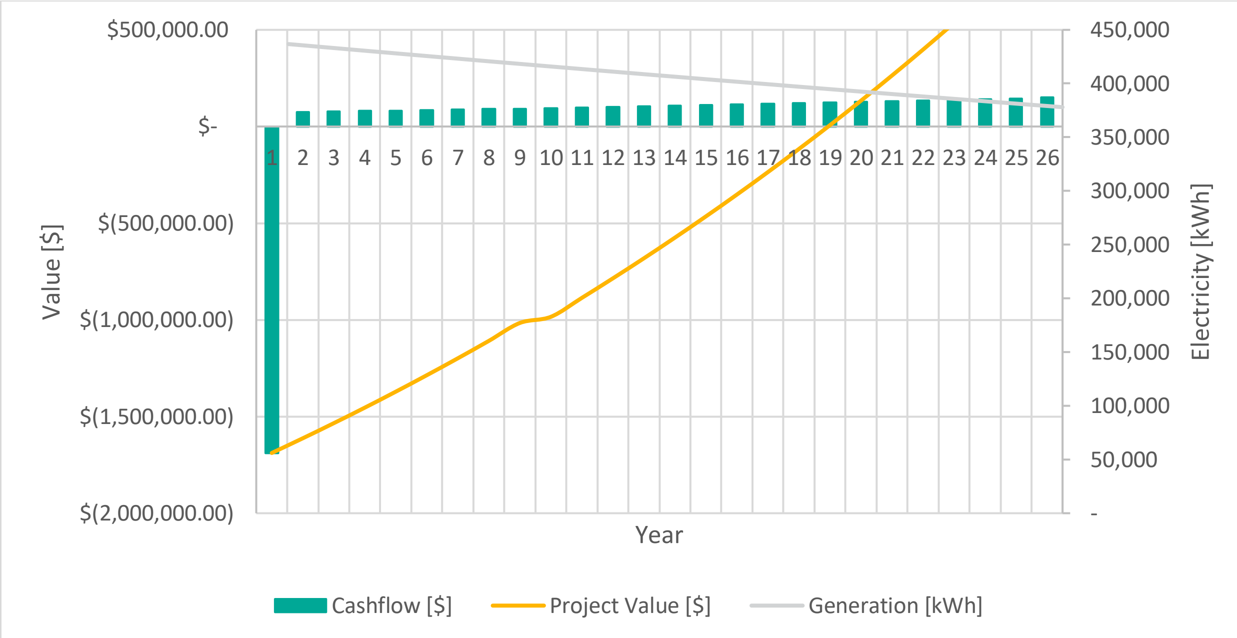
Graph 8: ROI Graph South Wall

West Wall:



Graph 9: ROI Graph West Wall

Entire Project:



Graph 10: ROI Graph on Entire Project

Assumptions:

- Solstex Budget number given as ($74.00/sf) approx. and the other wall panels, ACM panels priced at ($30.00/sf).
- Budget numbers are in USD.
- Inverter replacement in year 10

Generation decreases across the life of the project, due to panel degradation. Cashflows will increase across the life of the project as electrical prices increase.

Government Incentives:

Business Energy Investment Tax Credit

If a solar project is started in 2023, it is eligible for a tax credit that is equivalent to 30% of the total cost of the solar system. This tax credit was not part of the financial analysis above and can help project economics. Please consult your accountant/tax advisor for more information about the utilization of these credits.

ENVELOPE REVIEW

Process

SWA has evaluated the thermal performance of the facade anchor systems for proprietary BIPV systems from two manufacturers – Mitrex and Solstex by Elemex. The goals of this thermal analysis were:

- Quantify the true thermal performance of a typical SCA wall assembly with each BIPV system
- Evaluate what design modifications, if any, would needed to meet SCA's standard of R-30 walls.

SWA performed all thermal modeling in Heat3, a 3-dimensional steady state conductive heat flow modeling software commonly used to evaluate the performance of building envelope systems. The BPIV façade anchors were modeled according to manufacturer's specific details to their respective systems as well as additional clarifications provided directly from each manufacturer.

SWA used the results of this modeling in supplemental calculations to determine the true R-values of the modeled wall assemblies.

Modeling Assumptions

SWA assumed the following wall construction (from exterior to interior) for all thermal models:

- BIPV panel
- Air gap
- 4" of semi-rigid mineral wool insulation
- Exterior sheathing
- 6" steel stud cavity backup wall with semi-rigid mineral insulation cavity infill. Studs spaced at 16" o.c.
- Interior drywall

Anchor clips supporting the BIPV panels were spaced according to each manufacturer's standard spacing, defined below. Any increase in clip spacing compare to what was modeled for this study, whether it be vertically or horizontally, will result in better thermal performance than what SWA is reporting in this analysis.

Findings

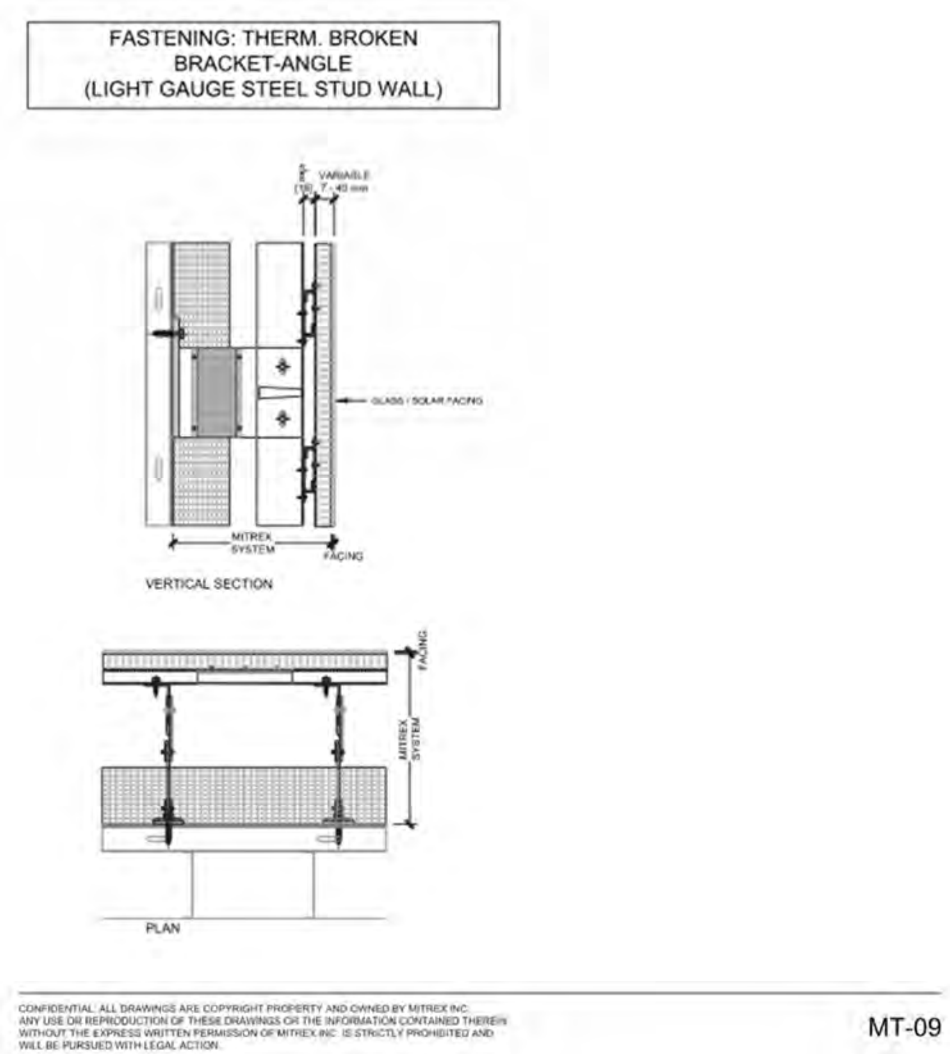
Mitrex BIPV System

The Mitrex BIPV panel anchor system is a clip and rail system. While clip spacing can vary depending on the wall construction, SWA modeled 16" on center horizontally and 16" on center vertically to align with the assumed steel stud back up spacing. The thermal break version of this system includes a pad made of glass reinforced fiber polyamide, circled in red in Figure 36 below. To better understand the impact of the thermal break pad on the wall's performance, SWA also modeled a separate case without the thermal break (using aluminum in lieu of glass reinforced fiber polyamide for this pad). Results of thermal modeling for this system can be found in the table below.

Figure 35: Mitrex thermal analysis results

	True Wall R-value	% De-Rate on Wall R-Value
Clear Field Assembly	31.0	-
Wall Assembly w/ Thermally Broken Clip	29.5	4%
Wall Assembly with Non-Thermally Broken Clip	15.5	50%

Figure 36: Mitrex typical details (in section and in plan) of thermally broken BIPV façade anchor system



Solstex by Elemex BIPV System

The Solstex BIPV panel anchor system is a clip and rail system. Every third clip is a gusseted version of the clip, having an extra reinforcement plate to enhance the system's overall structural capacity. typical thermally broken option. The thermal break option on this system includes two 1/8" thick pads made of cork, circled in red in Figure 38 below, on each clip. One is located between the clip and the back-up structure, and the other is located between the clip and the L-angle supporting the BIPV panel. To better understand the impact of the thermal break pads on the wall's performance, SWA also modeled a separate case without the thermal break (by simply removing both 1/8" cork pads). Results of thermal modeling for this system are below in Figure 37.

Figure 37: Solstex thermal analysis results

	True Wall R-value	% De-Rate on Wall R-Value
Clear Field Assembly	31.0	-
Wall Assembly w/ Thermally Broken Clip	22.8	27%
Wall Assembly with Non-Thermally Broken Clip	21.7	30%

As shown in Figure 37, the modeled wall does not achieve the SCA's design standard of an R-30 wall. SWA evaluated alternative options in order to achieve an R-30 wall with the thermally broken Solstex system. The most viable alternative is to change the exterior insulation layer from 4" mineral wool to 5" of rigid polyiso insulation.

Figure 38: Solstex Typical Detail at horizontal joint (in section) of thermally broken BIPV façade anchor system

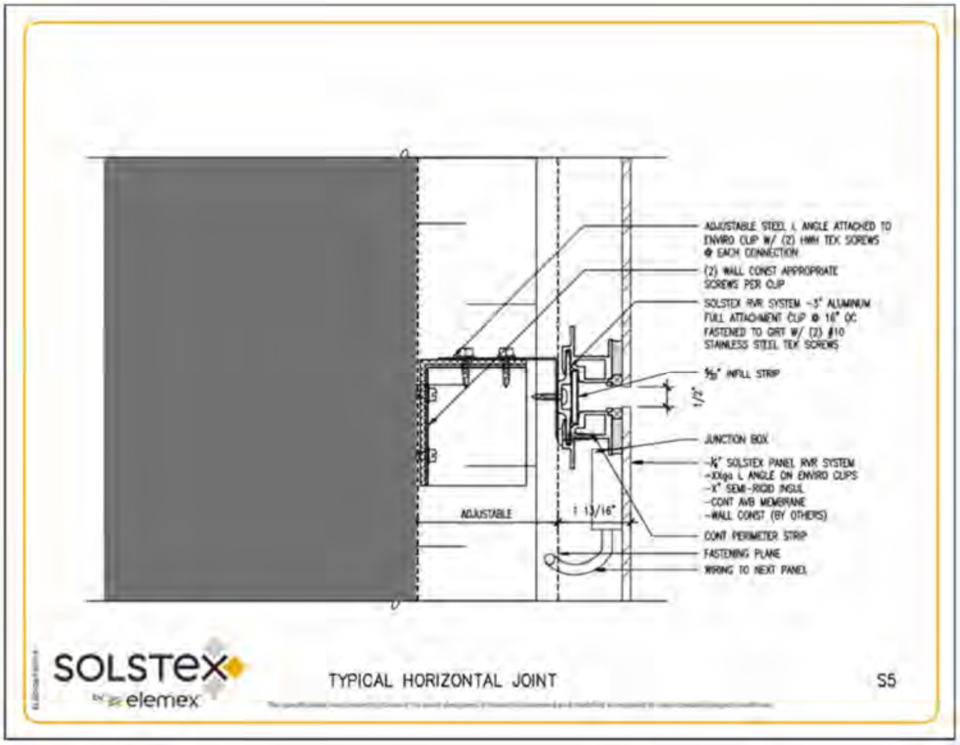
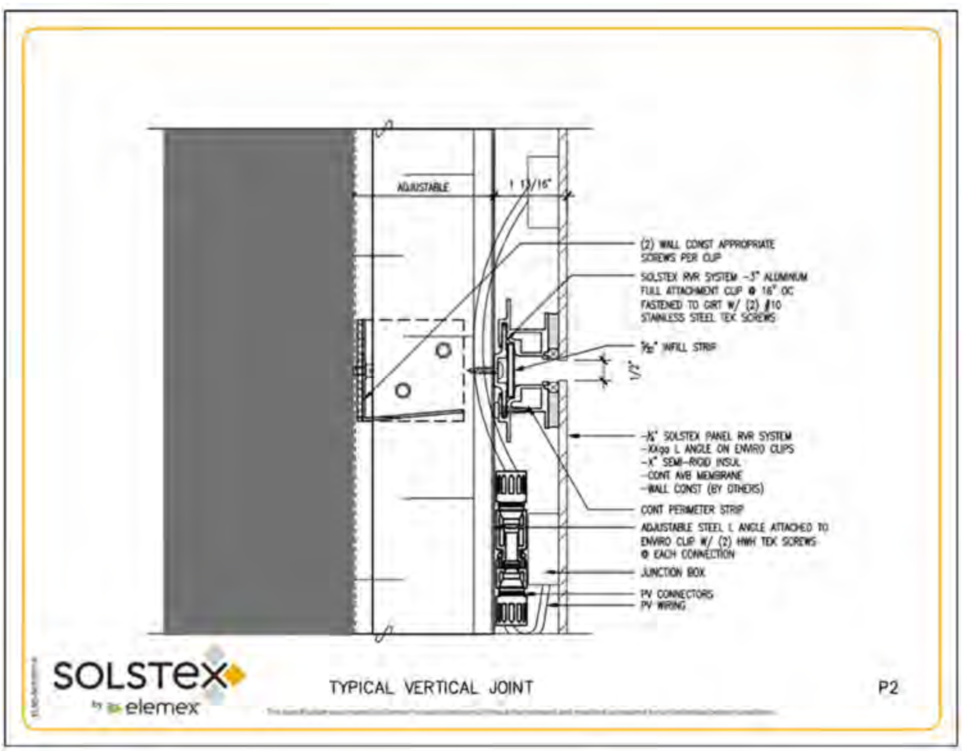


Figure 39. Solstex Typical Detail at vertical joint (in plan) of thermally broken BIPV façade anchor system



ENERGY REVIEW

Process

SWA utilized two case study projects to evaluate energy performance. A total of three scenarios were developed for each of the case study projects (Basecase, Mitrex, Elemex) in order to evaluate impact on the building's net energy use intensity due to change in thermal performance of the wall system and PV energy generation.

The model was constructed using eQUEST version 3.65, which is an acceptable simulation tool for LEED certification program and code compliance requirements of ASHRAE Standard 90.1. The software uses annual weather data to calculate various energy flows into and out of each zone, including solar gains, occupancy and equipment gains, energy stored within the building fabric, and the temperature diluting effect of natural ventilation. The energy model can calculate variations of temperature in each control zone for every hour of the year.

A brief description of the two SCA projects has been included below:

<u>Project Name: NYC School Building B</u>

Project Conditioned Area: 129,349 SF

Vintage/ Program: New Construction

Climate Zone: ASHRAE Climate Zone 4A

Simulation Weather File: USA_NY_New.York-Kennedy.Intl.AP.744860_TMYx.2004-2018.bin

<u>Project Name: NYC School Building A</u>

Project Conditioned Area: 106,540 SF

Vintage: Retrofit

Climate Zone: ASHRAE Climate Zone 4A

Simulation Weather File: USA_NY_New.York-Kennedy.Intl.AP.744860_TMYx.2004-2018.bin

Using energy models developed for previous energy studies (GSG compliance, capital improvement evaluation, etc), SWA developed three scenarios.

a. Basecase : Reflecting as-designed building with wall performance at current SCA standard of R-30 effective (U-0.033) Wall system. No renewable offset
b. Mitrex: As-designed building with Mitrex wall performance at R- 29 (U-0.034) & renewable offset*.
c. Elemex: As-designed building with Elemex wall performance at R- 22.8 (U-0.034) & renewable offset*.

Please note that the renewable offset is based on manufacturer estimates. The Elemex system estimate (renewable offset) does not include impact of shading by neighboring building.

Findings

Both the Mitrex system and Elemex system are seen to have a range of 15%-26% overall energy use savings over the base case scenarios.

Energy use without renewable energy generation offset is slightly higher in Elemex due to reduced wall performance over basecase scenario. Renewable energy generation accounts for higher savings in Elemex system compared to Mitrex, however, further evaluation for shading by neighboring building is expected to result in a reduced estimated energy production.

Figure 40. Percent Savings Over Basecase

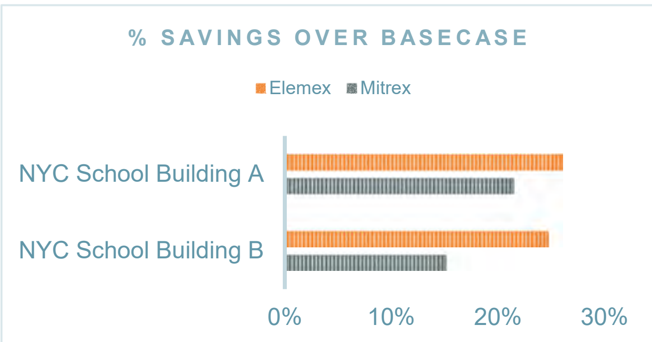


Figure 41. Net Energy Use Intensity

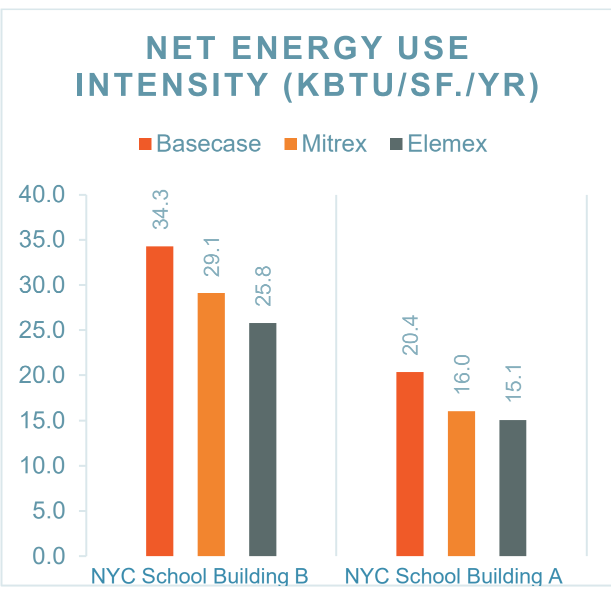
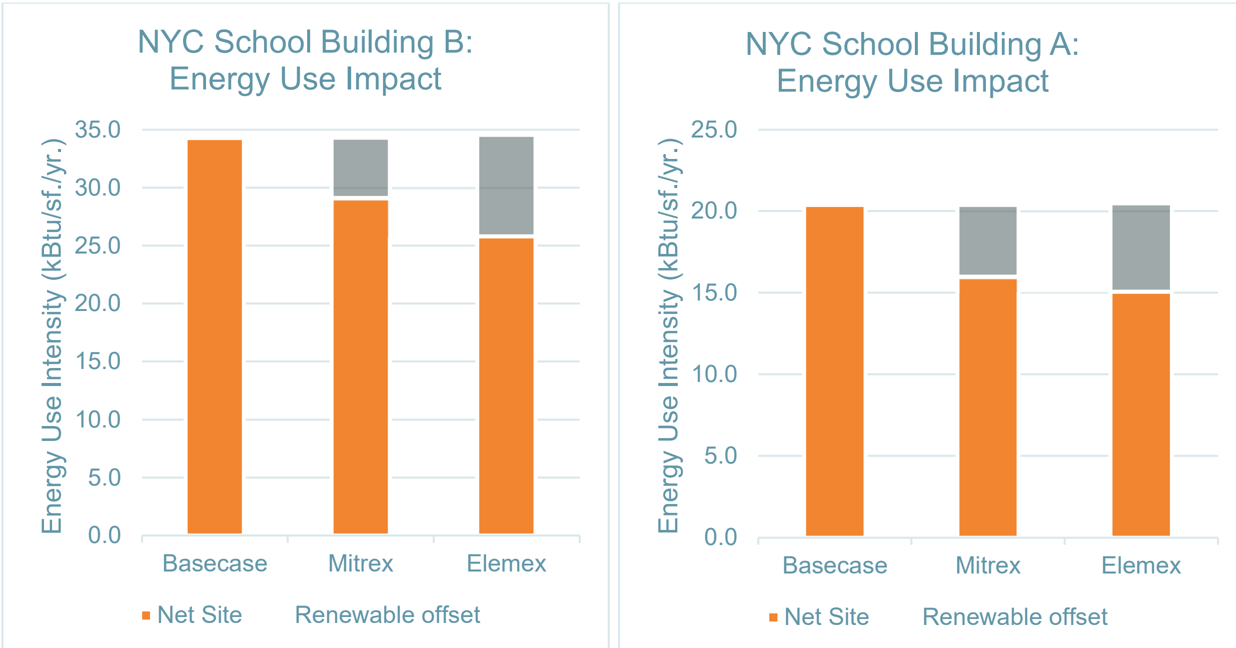


Figure 42: Site Energy use & Renewable offset comparison



COST REVIEW

SWA worked with Arch Energy, a division of Consigli construction that specializes in renewable energy installations to appropriately estimate the real cost implications of installing BIPV technology on SCA buildings. While the individual product manufacturers that participated in the case studies provided cost estimates for the design and installation of BIPV systems, Arch Energy utilized a more detailed approach to factor in additional costs associated with the various BIPV products proposed. All cost estimating is based on the designs proposed and outlined in the 2 case study buildings.

Process

In order to price this scope appropriately an understanding of the material cost and installation method for each solar façade system was needed. Meetings with each solar façade manufacturer were held to review installation methods and receive material pricing. Both façade systems were then leveled to ensure consistent scope and quantity. This ensured that the comparison was held true for each option. The [SCA] basis of design façade system was also then priced for comparison based upon our familiarity with the product and installation requirements. The electrical requirements for the solar façade systems were reviewed with the manufacturers and the cost to install the electrical components was included based on experience installing PV systems and understating of the NYC market.

Findings

Arch Energy compared the cost of the proposed design for each case study building for the Mitrex and Elemex products against the standard SCA design to understand the potential additional cost associated with BIPV technology. The analysis shows a range of findings depending on the design and product manufacturer. In one instance, the cost of the BIPV technology was lower than the standard design, while in others, the additive cost of BIPV is over $1,000,000. However, the study did not compare the cost of the BIPV technology to standard rooftop PV. When those costs are factored in, the additive cost of the BIPV products is significantly reduced.

Tax Credits

This cost study did not factor any potential tax credits that can be claimed for investment in new clean energy technologies. It is advised that there may be additional cost benefits for the SCA that can be claimed if installing BIPV or any other clean energy production technology, even as a non-taxable entity.

RECOMMENDATION FOR BIPV IMPLEMENTATION

Suitable Project Types / Recommended Project Characteristics

The Consultant Team has identified the following project building characteristics as those that most contribute toward the feasibility of BIPV implementation:

- Solar exposure / access
  - It is recommended that an insolation analysis be performed for each individual project site to confirm the total potential amount of solar radiation available annually. This analysis should take into account the effects of the project site's context, including neighboring buildings and structures, trees, and any other objects that may shade the project site throughout the year. The findings of this analysis should be used to determine the feasibility of installing BIPV components at the project site. If it is determined that a sufficient amount of solar radiation would be available at the project site, the insolation analysis findings should then be used to locate BIPV components on building surfaces that receive the greatest amount of solar radiation annually.
- Suitable building façade surfaces, components for BIPV application
  - It is recommended that project teams evaluate the feasibility of implementing BIPV components for individual projects based on the following criteria related to building design and construction type:
    - Confirm project has adequate amount of exterior building surface area (façade and roof area) and/or glazing area to accommodate the amount of BIPV components needed to achieve PV generation goal.
    - Confirm that project's selected construction types for façade and roof are compatible with proposed BIPV component types (rainscreen panel, spandrel panel, roof paver, shading elements, balustrades, canopies).
    - Confirm that proposed BIPV components meet the design and performance requirements for the respective façade and roof products they will be replacing.
    - Confirm that proposed BIPV glazing components meet the project's glazing and window design and performance requirements.

Feasible BIPV Applications

The Consultant Team has identified the following BIPV applications as the most feasible for implementation on SCA projects:

- **BIPV rainscreen panels**
  - Availability: product is available from at least three established manufacturers capable of serving NYC:
    - Mitrex
    - Elemex
    - Helios Façade
  - Efficiency/Output:
    - ~13-15 W/SF
    - ~8-10 kWh/SF/yr.
  - Carbon Reduction: ~4-6 kgCO2e/SF/yr.
  - Cost
    - Per manufacturer proposals:
      - ~$6-$8/W
      - ~$85-$95/SF (supply + installation)
- **PV window glazing**
  - Availability: product is available from at least two established manufacturers capable of serving NYC:
    - Mitrex
    - Onyx
    - Helios Façade
  - Efficiency/Output:
    - ~5-7 W/SF
    - ~3.5 kWh/SF/yr.
  - Carbon Reduction: ~1.5-2 kgCO2e/SF/yr.
  - Cost:
    - Per manufacturer proposals:
      - ~$7/W
      - ~$35/SF (supply)

The Consultant Team has determined that the following BIPV applications are less feasible for implementation on SCA projects:

- **BIPV rooftop pavers**
  - Availability: Product is available from one established manufacturer capable of serving NYC:
    - Onyx
  - Efficiency/output:
    - ~13 W/SF
    - ~16 kWh/SF/yr.
  - Carbon Reduction: ~8 kgCO2e/SF/yr.
  - Cost:
    - Per manufacturer proposals:
      - ~$3-$4/W

    - ~$45-48/SF

- **BIPV canopies**
  - Availability:
    - Fabric-based product is available from one manufacturer capable of serving NYC:
      - PVilion
    - PV glass-based product is available from at least two established manufacturers capable of serving NYC:
      - Mitrex
      - Onyx
  - Efficiency/output (fabric):
    - ~5.5 W/SF
    - ~7 kWh/SF/yr.
  - Carbon Reduction (fabric): ~4 kgCO2e/SF/yr.
  - Cost:
    - Per manufacturer proposals:
      - ~$7-$10/W installed (fabric, including canopy)
      - ~$50-$150/SF

BIPV Design Considerations

The Consultant Team has developed the following BIPV design considerations per guidance published by the **Whole Building Design Guide**, found here: https://www.wbdg.org/resources/building-integrated-photovoltaics-bipv#rcas

- Application of BIPV components should be considered only once the building's energy efficiency has been maximized through passive design techniques and high-efficiency equipment and systems have been selected to reduce the energy demand of the building. This will enable the BIPV systems applied to provide a greater contribution to the load.
- BIPV components should be evaluated in terms of life-cycle cost, and not just initial, first-cost. Overall cost should be reduced by the avoided costs of the building materials and labor that BIPV components replace.
- Analyze local climate conditions: Project teams should evaluate and understand the impacts of the climate on the output of BIPV components. Power output will be increased on cold, clear days. Output will be reduced on hot, overcast days.
  - Surfaces reflecting light onto the array, including snow, will increase output;
  - BIPV components must be designed for potential snow- and wind-loading conditions;
  - BIPV components on buildings in dry, dusty environments or environments with heavy industrial or traffic pollution will require regular claning washing to limit efficiency losses.
- Assess site and orientation: Early in the design phase, project teams should ensure that proposed BIPV components will receive maximum solar exposure and will not be shaded by site obstructions such as neighboring buildings or trees. BIPV components should ideally be completely unshaded during the peak solar collection period consisting of three hours on either side of solar noon.

- Evaluate orientation of BIPV components: Different orientation can have a significant impact on the annual energy output of a system, with tilted arrays generating 50%–70% more electricity than a vertical facade.
- Utility-interactive system versus stand-alone system:
    - BIPV systems tied to a utility grid use the grid as storage and backup. System should be sized to meet the goals of the project, based on budget and/or space constraints. The inverter must be selected to meet the specific requirements of the utility.
    - BIPV 'stand-alone' systems include on-site battery storage.
- Based on the project's peak load and the peak power output of the proposed BIPV system, it may be economically beneficial to incorporate batteries into grid-tied systems to help offset the most expensive power demand periods. Such a system could act as an uninterruptible power system.
- Provide adequate ventilation behind/below BIPV components as PV conversion efficiencies are reduced by elevated operating temperatures. The impact of elevated temperatures will be greater with crystalline silicon products compared to amorphous silicon thin-film products. To improve the conversion efficiency of each BIPV component, project design teams should ensure that there will be adequate ventilation behind/below the components to dissipate heat.
- Evaluate potential for hybrid PV-solar thermal: To optimize system efficiency, a project could opt to implement heat recovery to capture and utilize the solar thermal energy generated through the heating of the BIPV modules. Captured "waste" heat could be used to pre-heat incoming ventilation make-up air during winter months.
- Evaluate potential for integrating daylight design and PV generation: Projects could opt to use semi-transparent thin-film modules, or crystalline modules with custom-spaced cells in PV glass products, to create unique daylighting features in facade, roofing, or skylights. These BIPV elements would potentially help to reduce unwanted cooling load and mitigate glare associated with large glazing areas.
- Installation and maintenance professionals involved with the project should be properly trained, licensed, certified, and have experience with PV systems.
- Where possible, project teams should use pilot / demo projects to test actual performance of proposed BIPV products.

Proposed BIPV Implementation Process

The Consultant Team recommends that SCA establish standard BIPV evaluation and design process for inclusion in SCA Design Requirements and Green Schools Guide.

The Consultant Team proposes the following standard components of a BIPV design and implementation process for SCA projects:

1. During Conceptual / Schematic Design Phase, project design team should conduct site assessment and solar insolation study to determine solar exposure/access and to identify areas of roof and façade that receive a minimum required amount of solar radiation to make the application of BIPV feasible.
2. Project team should conduct early assessment of all building surfaces and components were BIPV components could be applied, based on solar access assessment and proposed building design. This exercise of identifying building surfaces and components

for BIPV application could start from an assessment of solar potential on all surfaces and then selecting those surfaces and components with the highest solar potential.

Project team should consider the following in determining feasibility of implementing BIPV components:

a. Building's use and electrical loads
b. Building location and orientation
c. Building and safety codes
d. Utility issues and costs

3. Coordinate with BIPV manufacturers to generate options for BIPV applications. Manufacturers should provide a feasibility assessment based on the project's drawings and/or BIM model. These assessments should include the following, at minimum:

    a. Predicted energy output
    b. Cost
    c. Installation details

    This preliminary analysis phase should result in a summary demonstration of the benefits and limitations of BIPV application on the project. Speed should be favored over accuracy during this phase to ensure that the greatest range of options can be explored in a time-efficient manner.

4. Once a BIPV application(s) has been selected, the project team should verify that proposed products have been or can be approved for use via OTCR process.
5. Project team should analyze the impact of proposed BIPV components on whole-building energy performance.
6. Project team should analyze the impact of proposed BIPV components on the building's thermal envelope performance.
7. Throughout Design Development and Construction Documents phases, the project design team should coordinate with selected manufacturer(s) to ensure that proposed BIPV applications are refined based on design changes to ensure maximum efficiency and output. (*A deviation process will be required in cases where it is desired that a BIPV manufacturer be involved during the design process. <u>Selection of manufacturers prior to the selection of General Contractor is not the standard SCA project process.</u>)
8. During the Construction Phase, the installation process of selected BIPV components should include the following:
    a. Scheduling
        i. Delivery and installation of BIPV components should be coordinated to avoid prolonged on-site storage.
    b. Installation training
        i. Installation of BIPV components should be completed by trained, qualified installers to ensure that all required occupational health and safety regulations are complied with and to prevent damage to components.
    c. Commissioning
        i. The following should be tested during the commissioning phase:
            1. Structural compliance
            2. Electrical safety

    3. Calibration of BIPV components to verify predicted output

9. During the Operations Phase, monitoring and ongoing maintenance are essential to ensuring that the installed BIPV components operate safely and optimally. The building's O+M Plan should include the periodic inspection of BIPV modules, connections, inverters, battery storage, etc. The output of the BIPV components should be monitored to ensure that optimal performance is ongoing.

Obstacles to Implementation

The Consultant Team has identified the following factors that may act as barriers to the implementation of BIPV components on SCA projects:

- Timely building code approvals for new BIPV products. Project teams may encounter delays in obtaining approval from DOB to use new BIPV technology. This could potentially disrupt the project schedule.
- There are currently only a limited number of completed BIPV projects in North America that can be referenced as demonstrating the technical performance and the potential economic and other benefits of installed BIPV applications. However, it is expected that in the near term the number of completed BIPV projects will rapidly increase as the industry continues to mature and the technology becomes more widely adopted.

KINETIC ENERGY

Overview

Kinetic energy refers to the energy that is associated with the movement of objects or systems. Kinetic energy generation in buildings involves capturing and converting the movement, vibrations, and other forms of kinetic energy within structures into usable electrical energy. This emerging field presents opportunities for sustainable energy production, increased energy efficiency, and reduced reliance on external power sources. However, it also faces certain limitations that require consideration. Understanding the potential opportunities, limitations, and future outlook of kinetic energy generation in buildings is crucial for its successful integration and adoption.

Kinetic Energy Options

While buildings are primarily known for their static structures, there are various instances where kinetic energy can be harnessed or considered for different purposes, including the following:

- Occupant Movement:
  - As occupants move within a building, their motion generates kinetic energy. This energy can be harvested and utilized in different ways, such as through kinetic flooring systems that convert footsteps into electrical energy. This technology can power low-energy devices or contribute to the building's overall energy needs.
- Vibrations and Structural Movements:
  - Buildings experience vibrations and movements due to environmental factors such as wind, earthquakes, or human activities. Innovations in building materials and design can harness these vibrations and convert them into usable energy. For example, piezoelectric materials can generate electricity from mechanical stress, allowing for the capture of kinetic energy from building vibrations.
- Energy Recovery Systems:
  - Certain building systems, such as HVAC (Heating, Ventilation, and Air Conditioning) systems, generate waste heat during operation. This waste heat can be converted into kinetic energy using technologies like heat recovery wheels or heat exchangers. The kinetic energy produced can be used to power other systems within the building or offset additional energy requirements.
- Energy-Generating Systems:
  - There are emerging technologies that utilize kinetic energy directly for power generation within buildings. For instance, piezoelectric materials embedded in the building structure can generate electricity from external forces like wind or vibrations. These systems can contribute to the overall energy needs of the building and reduce reliance on external power sources.

Products

Figure 43: Product Information

Product	Manufacturer	Description
Pavegen	Pavegen	Carpet tiles that convert kinetic energy generated by footsteps, are available with a mobile app for measurement and engagement.

		<u>Benefits & Limitations</u> • Great engagement product for citizens and can help create brand identity, consumer engagement and awareness. Most case studies for the project include education, smart city initiatives and brand campaigns. • No quantifiable data is available for the products. https://www.pavegen.com/
Sustainable Dance Floor	Energy Floor	Each tile – measuring 75x75x20cm – can produce up to 35 watts of energy which can then be fed into the venue's system. <u>Benefits & Limitations</u> The business model proved unsustainable, so the company shifted its focus toward using dance floors to raise awareness of energy usage. https://energy-floors.com/products/the-dancer/kinetic-dancefloor/
Bodyheat	Townrock Energy	Uses the concept of geothermal energy. The system works by capturing the heat generated while people are moving and transfers it to the rock surrounded by boreholes which are drilled to a depth of 15-200m for storage. This stored energy is later retrieved as and when required with the help of heat pumps. <u>Benefits & Limitations</u> There is insufficient energy data to provide an analysis, however this product can be used to create awareness among the public. https://townrockenergy.com/2021/12/15/bodyheat-a-world-first/
Pedal a watt	Pedal a watt	The Pedal-A-Watt stand allows you to drop your bicycle into the stand, pedal and create electricity. <u>Benefits & Limitations</u> Generating electricity with pedal powered bikes is inefficient, making them unsustainable, less robust and more costly in comparison to the alternatives in the market. https://www.econvergence.net/
Power Box 50	K-tor	This is a pedal generator that can be used with your legs or arms. It generates electricity as you pedal, like on a stationary bicycle. Charge the batteries of a full range of portable electronics. Or charge external batteries to power laptops and all kinds of appliances — either directly from the batteries or through an inverter. The Power Box has a 12-volt automotive like outlet. It allows you to plug in devices

		designed to plug into an automotive outlet like 12-volt to USB converters and with the 12 volts to alligator slip cable included to direct charge 12-volt batteries. Benefits & Limitations Generating electricity with pedal powered bikes is inefficient, making them unsustainable, less robust and more costly in comparison to the alternatives in the market. https://www.k-tor.com/pedal-powered-generator/
Pedal/Hand generators	Electric pedals	Various products are available on the market. Provides Power Generators (Bikes/Hand-cranks etc) to generate electricity and a Power Management System to manage and give feedback to the audience. Benefits & Limitations Generating electricity with pedal powered bikes is inefficient, making them unsustainable, less robust and more costly in comparison to the alternatives in the market. https://www.electricpedals.com/modular-systems-products
Elevator KERS	Skeleton Technologies	The manufacturer uses their supercapacitors to power ElevatorKERS (Kinetic Energy Recuperation System). It is based on the concept that elevators generate energy which is mostly dissipated aimlessly in elevator drives but could be captured and reused from one trip to another. This system captures the energy created by electric traction elevators and re-uses it to power the elevator. Benefits & Limitations The system aims to provide energy efficiency and seamless integration with existing elevator systems; however the initial cost of investment can be a barrier. The system may also require additional space for the necessary equipment, which can be a limitation for the existing building. https://www.skeletontech.com/skeleton-blog/elevator-kers

Case studies

Figure 44: Case Study Projects

Project	Location	Description
Crowne Plaza Copenhagen Towers	Copenhagen, Denmark	The hotel installed electricity generating bikes in the gym for all hotel guests. The bikes have iPhones mounted on the handlebars which monitor how much power is being produced and fed into the mains supply of the hotel. Any guest producing 10-watt hours or more will be rewarded with a free meal. Benefits

		It serves as a valuable lesson and tool for public engagement. By allowing individuals to experience firsthand the effort required to generate a small amount of electricity, it helps raise awareness about the challenges of energy production and encourages energy conservation. <u>Limitations</u> According to the calculations provided by the hotel, one hour of cycling at 30kmph only produces around 100 watt hours of electricity. This amount of energy is sufficient to power a single 100-watt bulb for just one hour. Therefore, the energy output from this technology is relatively low and not practical for generating a significant or useful amount of energy. The above scheme was planned for one year, and if successful – it would be rolled out to other hotels under the group. No information is available if the above initiative was sustainable long term. Product Information: Not Available
Simon Langton Grammar	Kent, UK	The installation consists of 24 kinetic tiles spanning a distance of over 5 meters in a corridor of the school. These tiles are designed to harness the energy generated by footsteps and use it to power on-demand lighting. Additionally, the tiles are equipped with wireless technology that enables the collection of real-time footfall data. Constructed from a thin layer of recycled rubber sourced from old lorry tires, the Pavegen tiles feature an embedded pressure pad. With each footstep, these tiles convert the kinetic energy into approximately four watts of power. <u>Benefits</u> The 24 tiles now installed in the school are expected to generate enough energy to power LED lighting along the corridor as well as a series of mobile phone chargers, producing 100 watts at peak times. <u>Limitations</u> The energy generation provided by the system is inadequate for practical use. Product Information: Pavegen
Club Watt	Rotterdam, Netherlands	The installation "Sustainable Dance Floor" produces up to 25 watts per module, this generated energy is used to power the lighting and DJ booth. <u>Benefits</u> The implementation of these interactive technologies fosters an inclusive and engaging environment where dancers can actively participate in a sustainable experience. <u>Limitations</u> One limitation is the insufficient energy generation capacity of the system. Despite a significant investment of $257,000 in the floor, it is unlikely to recoup the cost through energy

		savings due to its relative inefficiency as a first-generation model. Product Information: Sustainable Dance Floor
SW3	Glasgow, UK	The installation of the "Bodyheat" system harnesses the body heat generated by energetic dancers to produce renewable energy. This energy can be stored and used later to provide heating or cooling for the venue, resulting in an estimated annual reduction of approximately 70 tons of CO_2 emissions. By capturing and storing body heat in the surrounding rocks, the system acts as a heat battery. During non-club times when the venue is used as an office or arts space, the stored heat can be retrieved from the rocks, reducing the need for additional heating and improving energy efficiency. Product Information: BODYHEAT <u>Benefits</u> The system utilizes body heat generated as a source of renewable energy reducing reliance on traditional energy sources and helps to mitigate the venue's carbon footprint. <u>Limitations</u> The effectiveness of this system is directly linked to the presence of active dancers generating body heat. During periods of low dance activity, such as non-club times, the energy generation potential may be limited. Additionally, this system may involve a significant initial investment.
Tent City Jail	Phoenix, Arizona	A customized stationary bike has been implemented in the prison to allow inmates to earn TV privileges through pedaling. The bike generates 12 Volts of electricity which is sufficient to power a 19-inch TV. For every hour spent pedaling, inmates earn an hour of TV time. Product Information: Not Available <u>Benefits</u> The implementation of these bikes incentivizes the inmates to engage in physical activity by connecting it to TV privileges. The bike's ability to generate electricity reduces reliance on conventional energy sources and contributes to a more sustainable prison environment. <u>Limitations</u> The energy output may not be sufficient for powering ither electrical devices or meeting higher energy demands.

Technology Limitations

As discussed in the previous sections, kinetic energy has the potential to be harnessed and utilized in buildings, however there are several technological limitations that can impact its adoption and integration into the building:

1. Energy Density and Output: The amount of kinetic energy available for generation within a building is limited. It may not be sufficient to meet all energy demands, especially for larger buildings or high-power applications. Supplementary energy sources may still be required, depending on the building's energy requirements.
2. Variability and Unpredictability: The availability of kinetic energy within a building can vary significantly based on occupancy, usage patterns, and environmental factors. This variability poses challenges for maintaining a stable and consistent power supply, requiring additional energy storage or backup systems.
3. Retrofitting Challenges: Integrating kinetic energy generation into existing buildings can be challenging. Retrofitting structures with the necessary technologies may require significant modifications, including the installation of new components and systems. This can impact the feasibility and cost-effectiveness of implementing kinetic energy generation in older buildings.
4. Cost Considerations: The cost of implementing kinetic energy generation technologies in buildings is an important consideration. Currently, many kinetic energy solutions are still in the development stage, and their deployment may involve higher initial investments. However, as technology matures and economies of scale are achieved, the costs are expected to decrease.
5. Maintenance and Durability: Although there is limited information available on the durability of the kinetic energy systems, it is without doubt that they would require regular maintenance and monitoring to ensure optimal performance. These systems, many of which are made of piezoelectric materials, may be prone to wear and tear, reducing their lifespan and efficiency over time.

Conclusion

Utilizing kinetic energy in buildings presents an opportunity for energy conservation and sustainability. By capturing and harnessing the energy associated with movement and vibrations within a building, it is possible to reduce energy consumption, improve efficiency, and contribute to renewable energy generation. Continued research and development in this field holds the potential for further advancements and integration of kinetic energy harvesting in building design and operation.

INSOLATION REVIEW PROCESS

Overview

A solar insolation study is a comprehensive analysis that delves into the intricate details of solar radiation and its availability at a specific location. By examining the amount of sunlight received over a given period, this study aims to assess the solar energy potential of the site and provide crucial information for a wide range of applications, including solar power generation, architectural design, and urban planning.

Solar insolation refers to the solar radiation that reaches the Earth's surface. It is a measure of the power per unit area received from the sun. The two common units used to express solar insolation are watts per square meter (W/m^2) or kilowatt-hours per square meter per day ($kWh/m^2/day$).

For the purpose of this report, a solar insolation study was carried out to analyze the solar radiation potential of BIPV in public school buildings across New York City. It is important to understand how the data results of this study can form a key baseline for future analysis:

- Energy Generation Potential: Solar radiation is the primary source of energy for PV systems. The amount of solar radiation received by a building directly affects the potential energy generation from its PV panels. By understanding the solar radiation levels at the building's location, it becomes possible to estimate the amount of electricity that can be produced by the PV system.
- System Sizing: The solar radiation data helps determine the appropriate size and capacity of the PV system required to meet the building's energy needs. Higher solar radiation levels generally indicate a greater potential for electricity generation, allowing for the selection of an adequately sized PV system to maximize energy production and optimize the return on investment.
- Energy Production Estimation: Solar radiation data enables accurate estimation of the energy production from a PV system over a given period. By considering the specific solar radiation values for each month or day, the expected energy output can be projected. This estimation is valuable for assessing the system's performance, evaluating its economic feasibility, and understanding its impact on energy costs and carbon footprint reduction.
- Shading Analysis: Solar radiation analysis helps identify potential shading issues that may affect PV system performance. Obstructions such as nearby buildings, trees, or structures can cast shadows on the PV panels, reducing the amount of solar radiation they receive. By understanding the shading patterns and their impact on solar radiation, appropriate measures can be taken to mitigate or minimize shading effects, optimizing the PV system's performance.
- System Orientation and Tilt: Solar radiation data assists in determining the optimal orientation and tilt angle for the PV panels. The orientation refers to the direction the panels face, while the tilt angle determines their angle of inclination. By considering solar radiation patterns throughout the year, the PV system can be oriented and tilted in a way that maximizes solar radiation capture, thus optimizing energy production.
- Economic Viability and ROI Analysis: Solar radiation analysis is essential for evaluating the economic viability of a PV system installation. By estimating the energy production based on solar radiation levels, the potential savings in electricity costs can be

determined. This information helps assess the financial feasibility of the PV project, calculate the return on investment (ROI), and make informed decisions regarding the installation of PV systems on the building.

Solar insolation studies play a vital role in planning and implementing solar energy projects effectively. They provide a detailed understanding of solar resource availability, allowing stakeholders to make informed decisions and maximize the benefits of solar energy for their buildings, and overall project feasibility.

Software

For this study, the software used was “Rhino” along with different plug-ins on its visual programming interface called “Grasshopper”. A brief description of the software has been provided below for further reference:

- Rhino

Rhino, also known as Rhinoceros or Rhino 3D, is a powerful 3D computer-aided design (CAD) software application commonly used in industrial design, architecture, automotive design, product design, and other fields that require precise 3D modeling and visualization. It is developed by Robert McNeel & Associates.

Rhino software provides a versatile platform for creating, editing, analyzing, and rendering complex 3D models. Rhino has an extensive ecosystem of plugins and add-ons that enhance its functionality and extend its capabilities. These plugins provide specialized tools for specific industries or advanced workflows, allowing users to tailor Rhino to their specific needs.

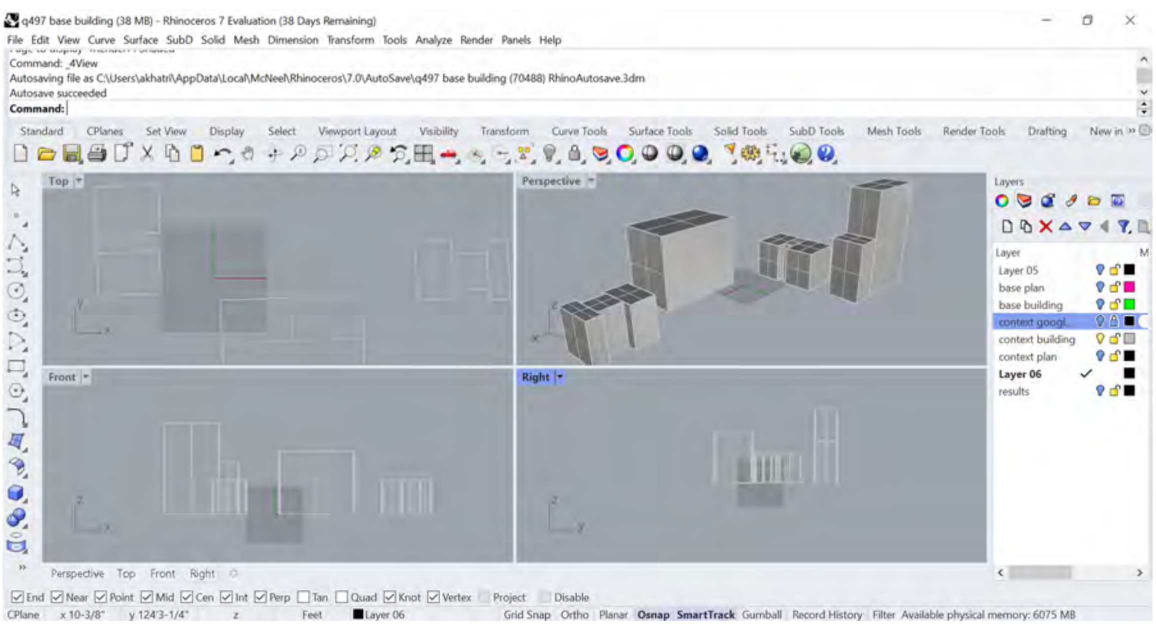


Figure 45: Rhino Interface

- Grasshopper

Rhino includes a visual programming interface called Grasshopper. It allows users to create parametric designs and generative workflows by connecting different components and algorithms. Grasshopper provides a flexible and intuitive way to automate design processes and explore design variations. Grasshopper provides a user-friendly and intuitive interface for creating, editing, and manipulating geometry and data in Rhino.

Grasshopper has a vibrant ecosystem of plugins and extensions developed by third-party developers. These plugins expand Grasshopper's capabilities by introducing new nodes and components, integrating with external software, and providing specialized tools for various design and engineering disciplines.

One of the key features of Grasshopper is that it supports the management and manipulation of data, including geometry, numbers, text, and more. It provides tools for organizing and filtering data, visualizing results through interactive previews, and exporting data to other software applications for further analysis or fabrication.

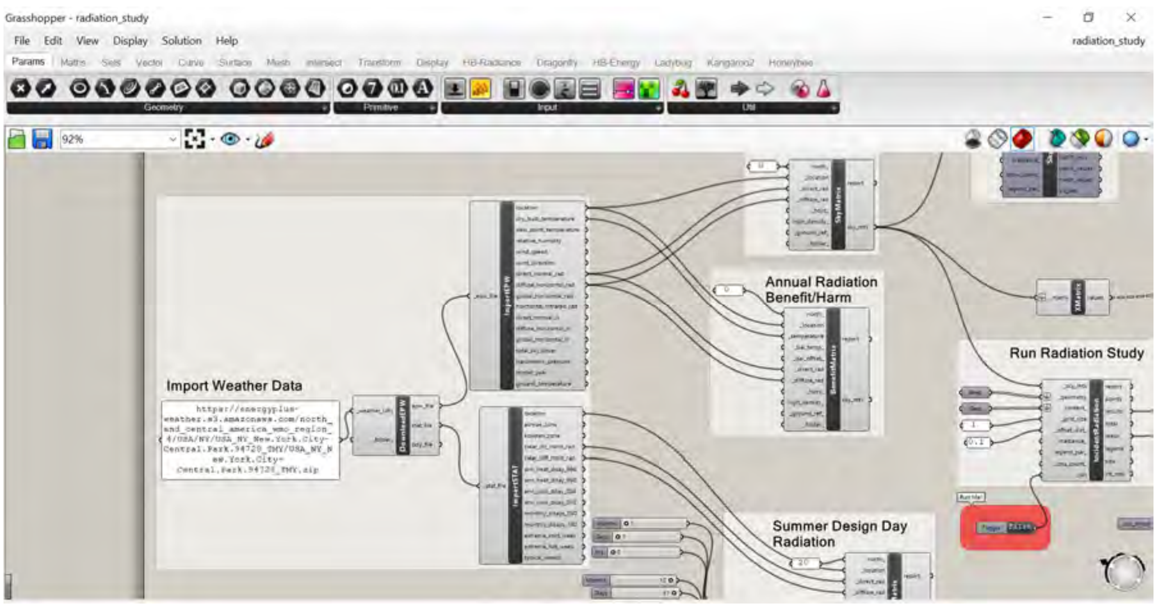


Figure 46: Grasshopper Interface

Simulation Tools

Honeybee and Ladybug are free, open-source environmental plugins for Grasshopper and form part of a larger package of environmental tools, known as Ladybug Tools.

- Ladybug

  Ladybug is a plugin for the Grasshopper visual programming language in Rhino 3D software. It provides tools and components for environmental analysis and simulation in the field of building performance and design. Ladybug allows architects, engineers, and designers to evaluate and optimize the environmental impact and energy performance of buildings by incorporating climate data and analysis directly into the design process.

  Some key features and functionalities of Ladybug include:

    - Climate Analysis: Ladybug enables users to import weather data from various sources and analyze climate conditions such as temperature, solar radiation, wind speed, humidity, and more. This information is critical for understanding the environmental context and potential energy implications for a specific location.

- Solar Analysis: Ladybug includes components for solar analysis, which allow users to assess the solar exposure and shading conditions of a building or site. It can calculate the sun's position throughout the year, analyze shadow casting from surrounding objects, and evaluate the potential for solar energy generation and daylighting.
- Energy Analysis: Ladybug supports energy analysis by integrating with building energy simulation engines such as EnergyPlus and Radiance. It enables users to model and simulate the energy performance of buildings, assess energy consumption, estimate heating and cooling loads, and evaluate the effectiveness of various design strategies.
- Daylight Analysis: Ladybug provides tools for daylight analysis, allowing users to study natural light levels and distribution within a building. It can simulate daylight penetration, analyze glare potential, and assess the quality of indoor lighting conditions based on building geometry, window placement, and shading devices.
- Comfort Analysis: Ladybug includes components for evaluating thermal comfort in indoor spaces. It can analyze factors such as indoor air temperature, humidity, and air movement to assess occupant comfort levels based on established comfort standards and metrics.
- Visualization and Reporting: Ladybug offers visualization tools to represent analysis results through graphs, diagrams, and interactive visualizations. It also allows users to generate reports summarizing the findings of the environmental analysis, aiding in communication and decision-making processes.

Ladybug enhances the capabilities of Grasshopper and Rhino by providing a comprehensive set of tools for environmental analysis and simulation. It enables designers to incorporate data-driven analysis into the design process, assess building performance, optimize energy efficiency, and make informed decisions to create more sustainable and environmentally responsive designs.

- Honeybee

Honeybee is a plugin for the Grasshopper visual programming language in Rhino 3D software. It is designed to facilitate building performance simulation and analysis, particularly in the field of energy modeling and daylighting studies. Honeybee allows architects, engineers, and designers to assess and optimize the energy efficiency and environmental performance of buildings by integrating building physics simulations into the design process.

Key features and functionalities of Honeybee include:

- Energy Modeling: Honeybee provides tools for creating and simulating building energy models. It allows users to define building geometry, construction materials, HVAC systems, occupancy profiles, and other parameters required for energy analysis. With this information, it can simulate energy consumption, estimate heating and cooling loads, and evaluate the energy performance of a building under different scenarios.

- Daylighting Analysis: Honeybee supports daylighting analysis, enabling users to assess natural light distribution and quality within a building. It can calculate daylight factors, illuminance levels, and daylight autonomy, helping designers optimize window sizes, placement, and shading strategies for efficient use of natural light while minimizing glare and energy consumption.
- HVAC System Analysis: Honeybee incorporates HVAC system analysis capabilities, allowing users to evaluate the performance and energy consumption of various heating, ventilation, and air conditioning (HVAC) systems. It helps assess different system configurations, energy-saving measures, and the impact of HVAC strategies on overall building energy consumption.
- Renewable Energy Integration: Honeybee provides tools to integrate renewable energy systems into building energy models. Users can incorporate solar photovoltaic (PV) panels, wind turbines, geothermal systems, or other renewable energy technologies to evaluate their impact on energy generation and consumption.
- Building Code Compliance: Honeybee includes features to assess building code compliance and energy performance certification requirements. It can simulate energy performance metrics, such as energy use intensity (EUI), energy cost analysis, and carbon emissions, to ensure compliance with local regulations and sustainability standards.
- Parametric Analysis: Honeybee supports parametric studies and optimization workflows. Users can explore multiple design options, iterate through various building configurations, and analyze the impact of design changes on energy consumption, daylighting performance, and other environmental factors.

Honeybee extends the capabilities of Grasshopper and Rhino by enabling users to perform detailed energy modeling, daylighting analysis, and HVAC system evaluation within a visual programming environment. It empowers designers to make data-driven decisions, optimize building performance, and create more sustainable and energy-efficient designs

- EPW file

An EPW (EnergyPlus Weather) file is a standardized weather data file format used by the building energy simulation software called EnergyPlus. It contains a comprehensive set of weather data that represents the meteorological conditions of a specific location over a period of time, typically spanning a year. EPW files are widely used in building energy analysis and modeling to simulate the energy performance of buildings under various climatic conditions.

EPW files typically include the following weather parameters:

- Date and Time: The EPW file contains a timestamp for each weather data entry, indicating the specific date and time for which the meteorological conditions are recorded.
- Dry-Bulb Temperature: The dry-bulb temperature represents the ambient air temperature, measured in degrees Celsius or Fahrenheit. It indicates the overall temperature of the air without accounting for moisture content.
- Dew Point Temperature: The dew point temperature represents the temperature at which the air becomes saturated with water vapor, causing dew or

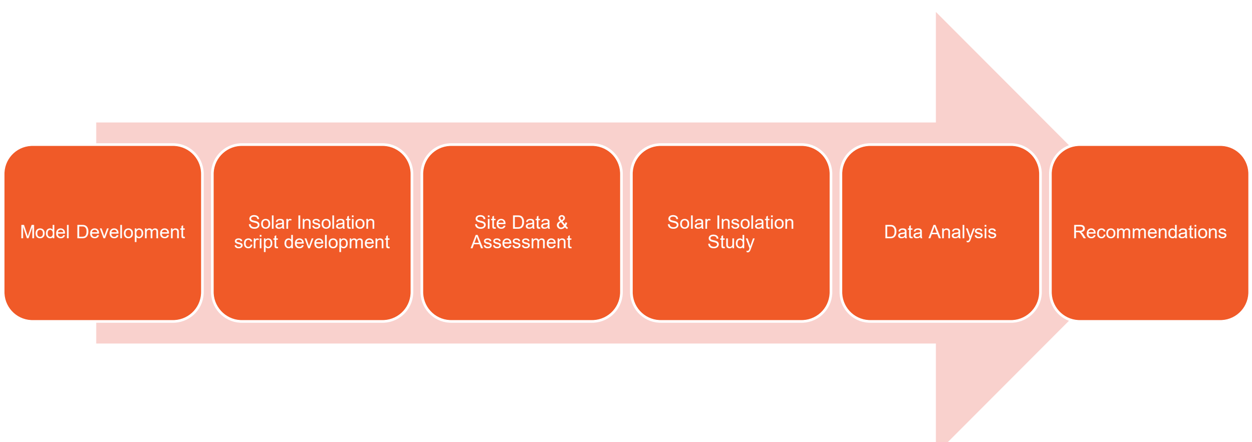
condensation to form. It indicates the moisture content of the air and helps assess the potential for moisture-related issues.

- Relative Humidity: Relative humidity is a measure of the amount of moisture present in the air relative to the maximum amount of moisture the air can hold at a specific temperature. It is expressed as a percentage.
- Solar Radiation: EPW files provide information about solar radiation, including direct normal irradiance (DNI), diffuse horizontal irradiance (DHI), and global horizontal irradiance (GHI). Solar radiation data is essential for assessing the availability of solar energy and for daylighting and solar energy system design.
- Wind Speed and Direction: EPW files include data on wind speed, usually measured at a standard height, and wind direction, which represents the compass direction from which the wind is blowing.
- Precipitation: EPW files provide data on precipitation, including rainfall, snowfall, or other forms of precipitation, typically measured in millimeters or inches.
- Atmospheric Pressure: The atmospheric pressure indicates the pressure exerted by the Earth's atmosphere at a specific location and is usually measured in hectopascals (hPa) or inches of mercury (inHg).

EPW files are essential for accurate building energy simulations as they provide the necessary input data to model the building's energy consumption, heating and cooling loads, and other performance parameters. They allow designers, architects, and engineers to evaluate the energy efficiency and environmental impact of buildings under different climate conditions and to make informed decisions regarding building design, systems selection, and energy optimization strategies.

Working Methodology

To conduct a solar insolation study, there are several steps involved.



1. Model Development on Rhino

Using Rhino, create a detailed shoe-box model of the building or site you want to analyze for solar insolation. This model includes accurate geometry, such as building shape, roof configuration and any surrounding structures or features that may cast shadows.

2. Script Development on Grasshopper

In Grasshopper, develop a script that will drive the solar insolation study. The script uses Ladybug and Honeybee components. It allows various inputs such as the location, orientation, site context, etc along with other desired analysis parameters. The script also defines the radiation context and the result outputs.

3. Site Data Analysis and EPW File Import

Prior to running the study, perform a site data analysis to gather information specific to the location. This may include latitude, longitude, altitude, and other relevant climate data. Obtain EPW file, which contains weather data for the chosen location, typically obtained from reputable sources or meteorological agencies.

4. Define Parameters

With the Grasshopper script and EPW file in hand, initiate the solar insolation study. The script uses the EPW file as input, extracting the solar radiation data for various timeframes throughout the year. It is important to set the time frame for radiation analysis, for this study it is annual. The script calculates the solar insolation on various surfaces of the building based on their orientation and tilt angles.

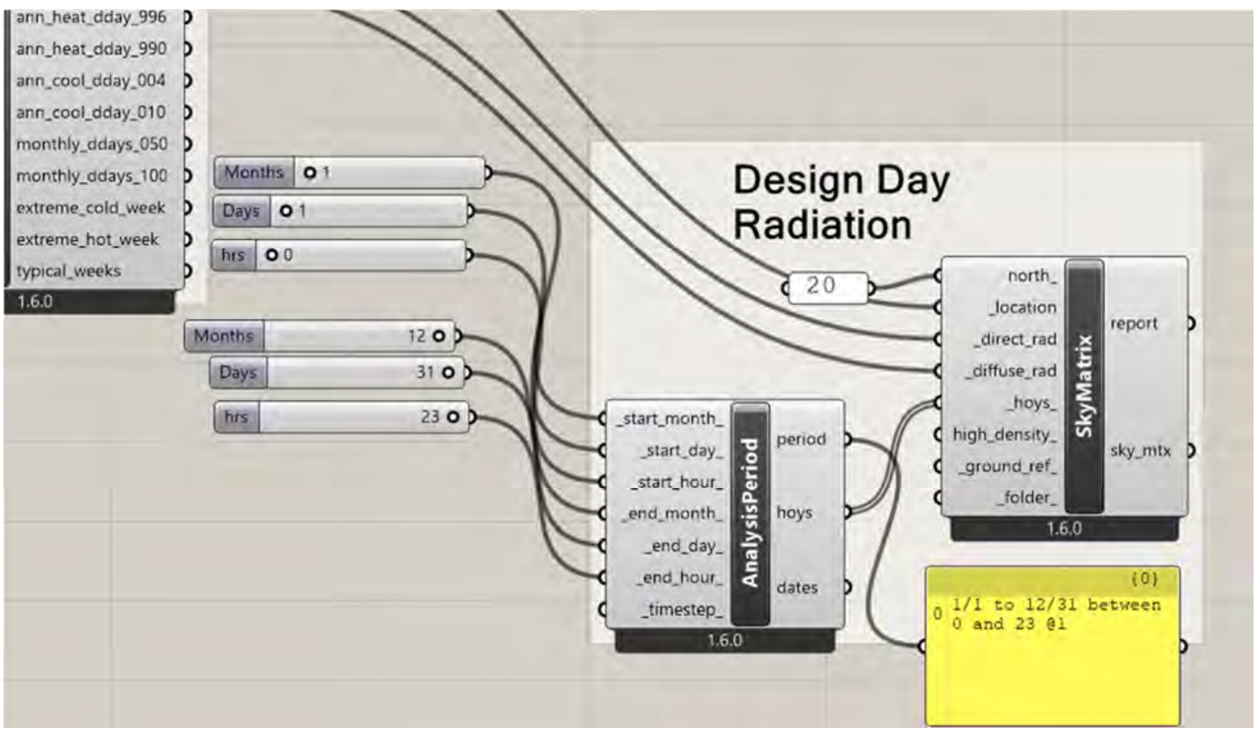


Figure 47: Setting time frame parameters in Grasshopper

5. Obtaining Results

After running the study, retrieve the results generated by the Grasshopper script. These results may include metrics such as solar radiation values, cumulative solar exposure, shading analysis, and potential energy generation. The results can be visualized through diagrams, charts, or 3D models to provide a clear understanding of the solar insolation patterns and variations across the building or site.

By following this methodology, the solar insolation study helps evaluate the potential solar energy availability, optimize building design for passive solar strategies, assess shading impacts, and inform decisions related to solar energy system sizing, orientation, and overall energy efficiency of the building.

Recommendations

The recommendations from a solar insolation study can vary depending on the specific objectives and context of the project. For the purpose of this report, the following recommendations may arise for discussing the BIPV feasibility on projects:

- Optimal Building Orientation: The study can identify the most favorable building orientations in terms of solar insolation. Recommendations may include aligning the building's major surfaces (such as roofs or facades) to maximize solar exposure for passive solar heating, daylighting, or solar energy generation.
- Solar Resource Assessment: Solar insolation data obtained from the study provides valuable information about the solar energy potential at the site. Assess the average annual solar radiation levels and the availability of sunlight throughout the year. High solar insolation values indicate a favorable solar resource, which increases the feasibility of BIPV integration.
- System Sizing and Energy Generation: Analyze the solar insolation data to determine the optimal sizing of the PV system. Consider the available space area for BIPV panel installation and the estimated energy demand of the building. Calculate the potential energy generation based on the solar insolation data and compare it with the building's energy needs to assess feasibility.
- Site Suitability: Consider the physical characteristics of the site, such as available space, shading obstructions (identified through the solar insolation study), and the orientation of the building. Assess whether these factors align with the requirements for efficient BIPV system operation. A site with ample unshaded building surface area, proper orientation, and minimal obstructions is more feasible for BIPV integration.
- Shading Strategies: The study can highlight areas or objects that cast shadows on the building surfaces throughout the year. Recommendations may involve incorporating shading devices, adjusting the height or position of nearby structures or trees, or designing efficient shading systems to minimize unwanted solar heat gain or glare.
- Daylighting Optimization: For daylighting design, the study can help identify areas within the building that receive adequate natural light and those that require additional artificial lighting. Recommendations may include adjusting window sizes, positions, or glazing properties to enhance daylight penetration and reduce reliance on artificial lighting, leading to energy savings and improved occupant comfort.
- Microclimate Considerations: The study may reveal microclimate variations within the site or building footprint. Recommendations may involve designing microclimate mitigation strategies, such as incorporating green spaces, optimizing ventilation patterns, or using thermal mass to moderate temperature fluctuations and enhance occupant comfort.

- Sustainable Design Integration: The solar insolation study can align with broader sustainable design principles. Recommendations may involve considering passive solar design techniques, incorporating renewable energy systems, exploring energy storage solutions, and adopting sustainable materials to reduce the building's environmental impact and enhance overall sustainability.

It's important to note that these recommendations should be interpreted in conjunction with other project requirements, budgets, local regulations, and design priorities.

RELEVANT EXISTING STUDIES

LOCATIONS AND CONTACT INFORMATION OF OWNER INSTALLED TECHNOLOGY

Mitrex Case Studies:

The Kingston Box

- Overview:
  - Solar Facade project on the penthouse of a building that incorporates active and non-active modules on all four orientations (South, West, East, and North)
- Location: Kingston, Ontario
- Completion Date: February 1, 2023
- BIPV Product Installed: Solar Façade
- System Size
  - Total Active BIPV Area: 957 SF
  - 44 total modules (of M265-SD08F612) installed:
    - 6 panels are facing South
    - 16 panels are facing West
    - 15 panels are facing East
    - 7 panels are facing North
  - Total DC system size: 11.66 kW
- Module Types: Brown-1217S 265W (Solar Solid Colors line)

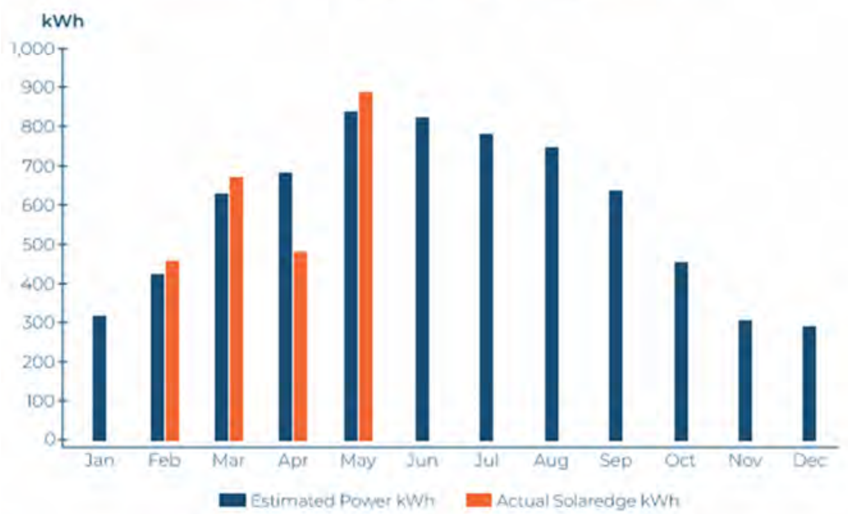
MODULE CODE	Pmax (W)	Voc (V)	Isc (A)	Vmp (V)	Imp (A)	TOLERANCE (%)
M265-SD08F612	265	48.4	6.84	40.5	6.55	+/- 5

- Electrical Equipment Used:
  - Solaredge SE9KUS (9 kW) with 44 (two strings of 22 optimizers each) S440 optimizer to convert the energy from BIPV modules to 208V AC power
- Performance:
  - Solaredge designer tool used to estimate the generation.
  - Annual energy production after inverter and optimizer losses is 6.91 MWh.
  - 593 kWh/KWp/Year
  - Estimated monthly generation:

COMPARATIVE TABLE BETWEEN ESTIMATED POWER VS ACTUAL POWER

MONTH	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Estimation (kWh)	316	424	627	679	837	821	779	747	637	453	302	286
Actual (kWh)	-	457	668	479	888	-	-	-	-	-	-	

COMPARATIVE GRAPHIC BETWEEN ESTIMATED POWER VS ACTUAL POWER



Monitoring of this project is available through Solaredge monitoring website or appTechnical drawings and documents are attached.

Industrial Wall

- Overview:
    - Solar Facade project on the west wall of an industrial building that incorporates active and non-active modules featuring 5 different black and white color shades to create a gradient effect throughout the entire wall
- Location: Toronto, Ontario
- Completion Date: December 2022
- BIPV Product Installed: Solar Façade
- System Size
    - Total Active BIPV Area: 3,597 SF
    - 166 total modules installed:
        - 58 panels of M330-SD051F
        - 8 panels of M225-SD061F
        - 37 panels of M185-SD011F
        - 41 panels of M155-SD011F
        - 22 panels of M085-SD021F
    - Total DC system size: 36 kW
- Module Types:

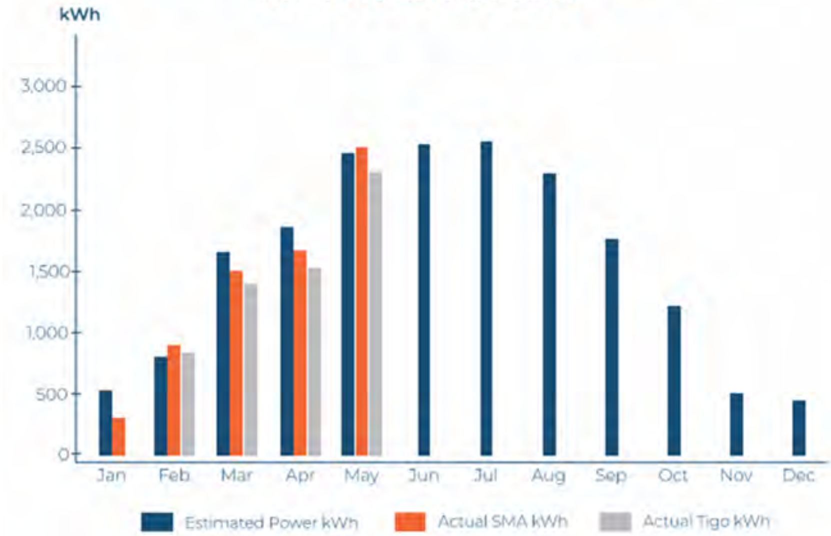
MODULE CODE	Pmax (W)	Voc (V)	Isc (A)	Vmp (V)	Imp (A)	TOLERANCE (%)
M330-SD051F	330	48.7	8.55	40.4	8.17	+/- 5
M225-SD061F	225	48.1	5.84	40.6	5.54	+/- 5
M185-SD011F	185	47.7	4.83	41.1	4.50	+/- 5
M155-SD011F	155	47.4	4.04	40.8	3.80	+/- 5
M085-SD021F	85	46.4	2.41	40.0	2.13	+/- 5

- Electrical Equipment Used:
    - SMA Core 1 33.3kW Inverter with 166 Tigo TS4-A-O to convert the energy production BIPV modules to 3 Phase 480V AC power
    - Tigo TS4-A-O PV Module Advanced Add-On for module-level optimization and monitoring for energy production tracking and system management
- Performance:
    - Pvsyst software has been used to estimate the generation
    - Annual energy production after inverter and optimizer losses is 18.53 MWh.
    - 513 kWh/KWp/Year
    - Estimated monthly generation:

COMPARATIVE TABLE BETWEEN ESTIMATED POWER VS ACTUAL POWER

MONTH	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Estimation (kWh)	519	795	1648	1855	2448	2529	2552	2285	1757	1204	498	442
Actual SMA (kWh)	304	896	1493	1655	2504	-	-	-	-	-	-	-
Actual Tigo (kWh)	-	836	1390	1520	2300	-	-	-	-	-	-	-

COMPARATIVE GRAPHIC BETWEEN ESTIMATED POWER VS ACTUAL POWER



- Monitoring of this project is available through SMA Sunny Portal powered by ennexOS website and app.
- The Tigo system monitors the performance of each individual module:
  - Link to Access: https://ei.tigoenergy.com/p/41RacineWestWall/

Technical drawings and documents are attached.

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https://www.nyc.gov/site/buildings/codes/solar-panels.page

- NYC Buildings, Solar Installation Frequently Asked Questions
https://www.nyc.gov/site/buildings/codes/solar-faq.page

- NYC DCAS, Clean Energy Generation
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ADDENDA

SolarLab Case Studies:
School Building A Existing Building Envelope Retrofit School
School Building B New Construction

SolarLab Case Study Report

SolarLab

Solar Facade Simulation

Project: NYC, NY. NYCSCA
Architect:

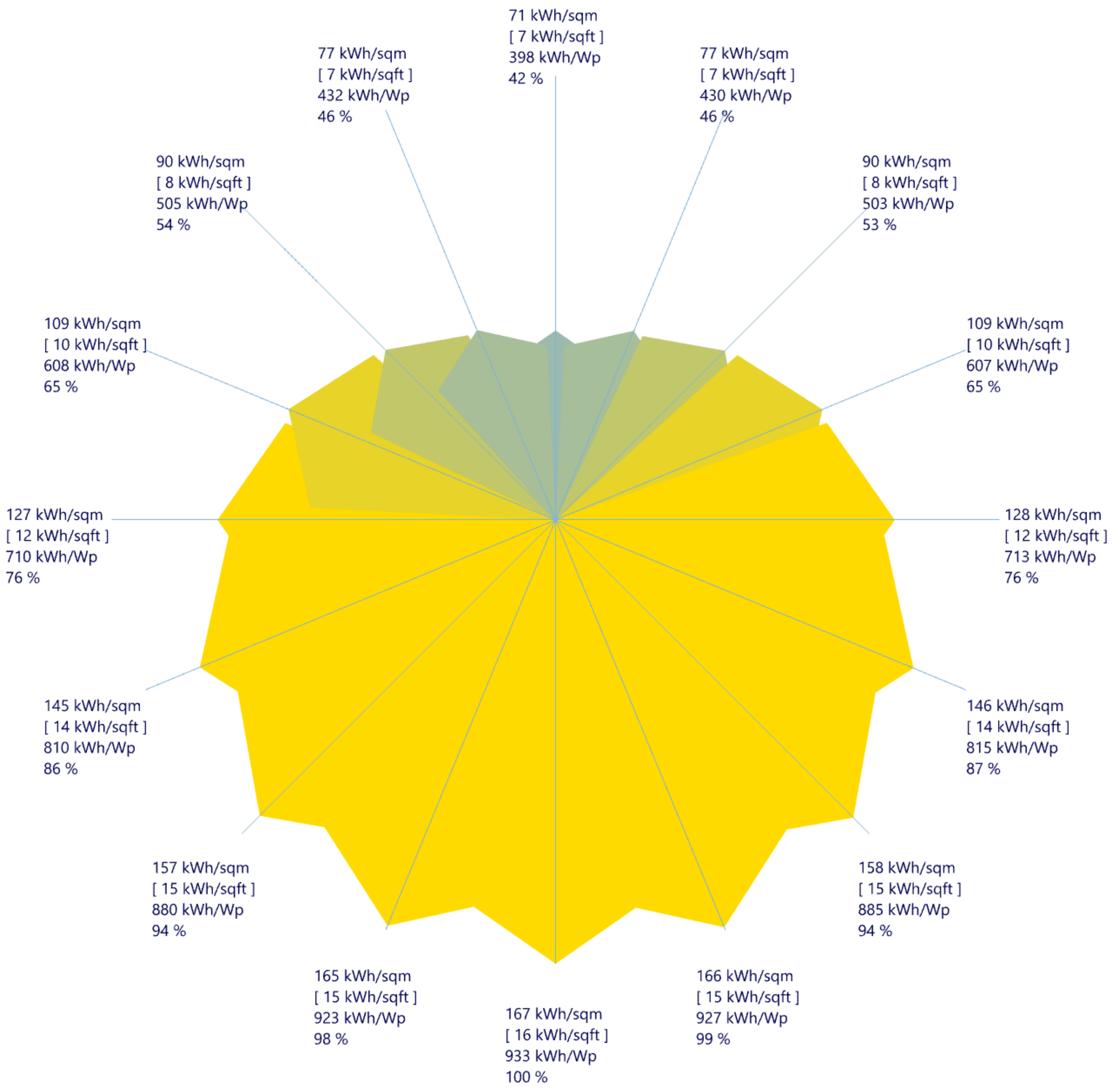
anders smith | as@solarlab.global | +45 3028 1162 | © 2025.04.024

Location: NYC, NY
Weather file: USA_NY_NewYork-Central.Park.Observatory-Belvedere.Castle.725053_TMY3.epw

SolarLab

Potential in New York

How much electricity can one square meter or square foot of mat black solar wall cladding produce in the different orientations



SolarLab

Without trees

Total solar facade area: 1,877 sqm (20,197 sqft) | Estimated yearly electricity production: 146,000 kWh

SolarLab

Looking North East

Total solar facade area: 1,877 sqm (20,197 sqft)
Estimated yearly electricity production: 146,000 kWh, without trees!

SolarLab

Looking South East

Total solar facade area: 1,877 sqm (20,197 sqft)
Estimated yearly electricity production: 146,000 kWh, without trees!

SolarLab

Simulations and production numbers presented are informational estimates only and SolarLab can not guarantee any future performance or be held liable for any performance deviations from the estimates presented

Looking South West

Total solar facade area: 1,877 sqm (20,197 sqft)
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SolarLab

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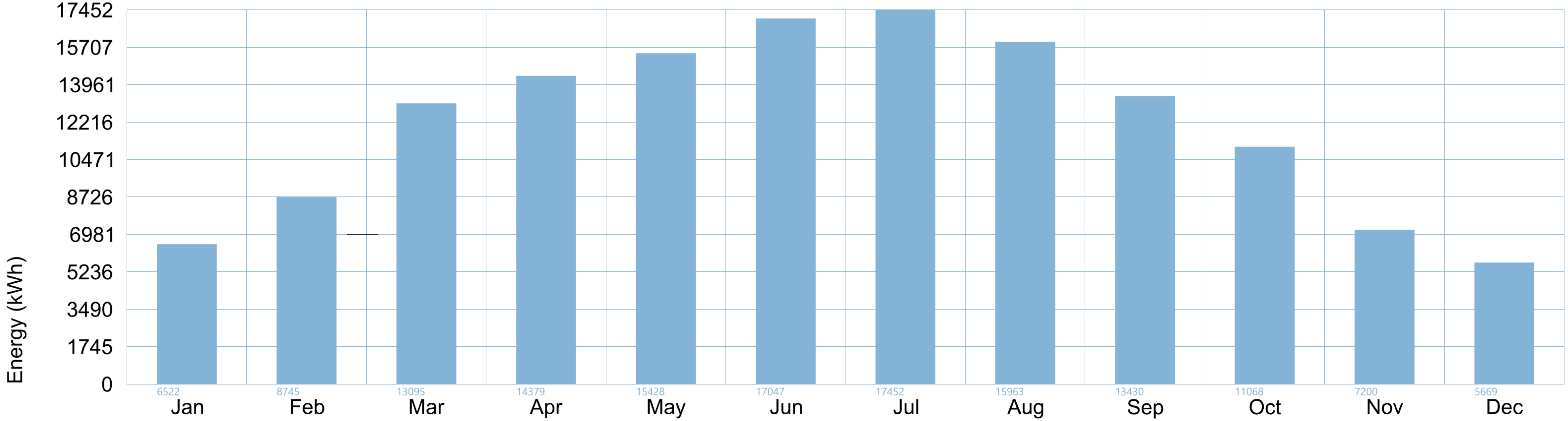
Monthly production

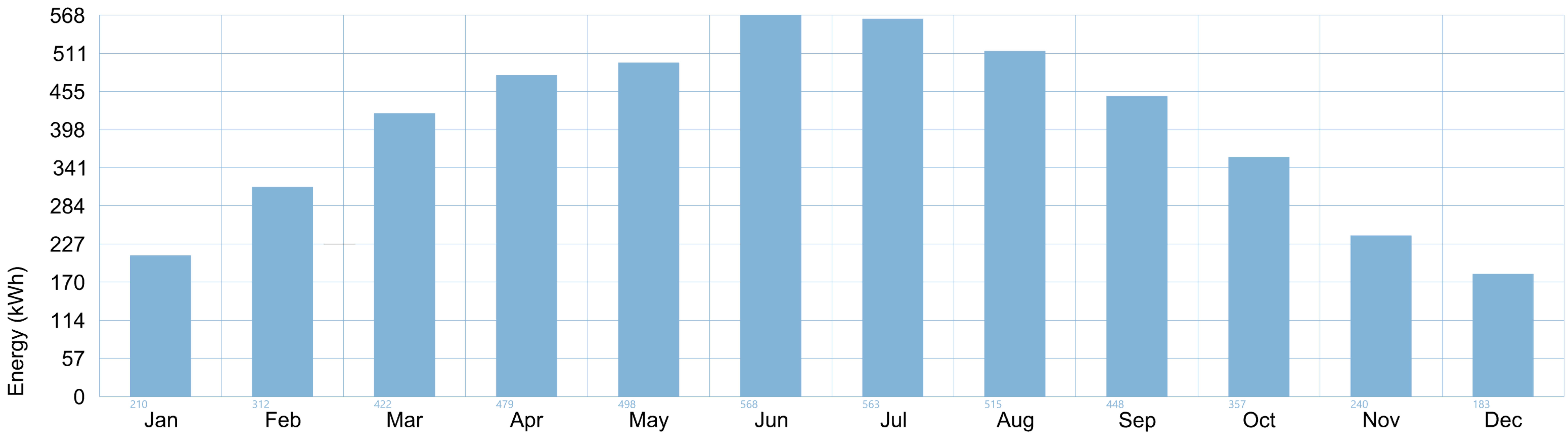
Total solar facade area: 1,877 sqm (20,197 sqft)
Estimated yearly electricity production: 146,000 kWh, without trees!



SolarLab

Average daily production

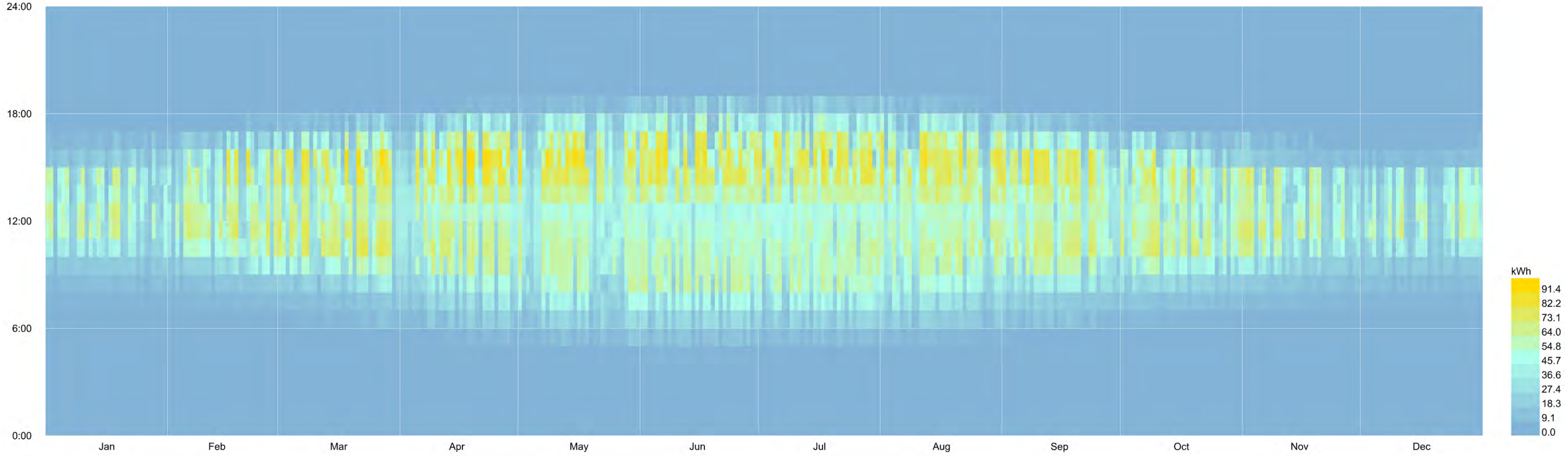
Total solar facade area: 1,877 sqm (20,197 sqft)
Estimated yearly electricity production: 146,000 kWh, without trees!



SolarLab

Yearly production Hour by Hour (8760)

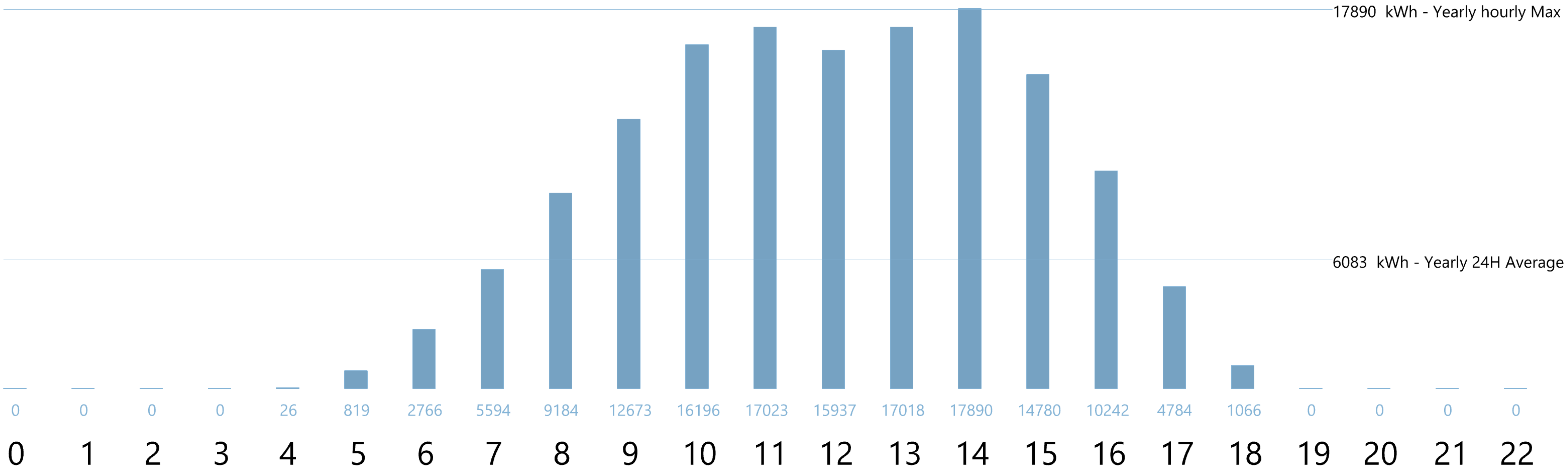
Total solar facade area: 1,877 sqm (20,197 sqft)
Estimated yearly electricity production: 146,000 kWh, without trees!



SolarLab

Yearly production Aggregated hourly

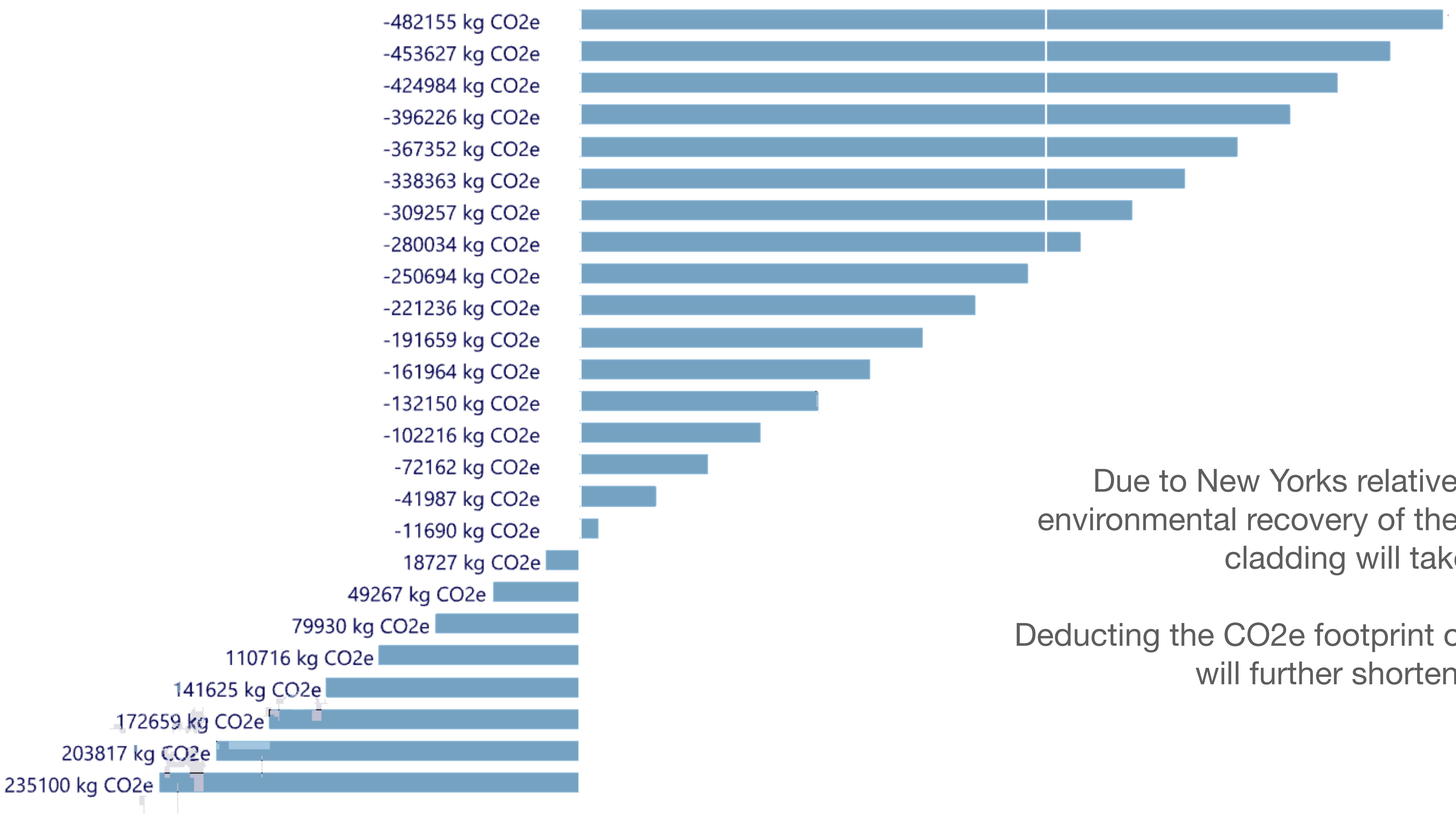
Total solar facade area: 1,877 sqm (20,197 sqft)
Estimated yearly electricity production: 146,000 kWh, without trees!



SolarLab

Carbon offset ROI on invested CO_2

Based on electricity production of 146,000 kWh/year, 216 g CO2/kWh in NYC & A1-A3 investment of 142kg CO2/sqm of SolarLab facade



Due to New Yorks relatively clean electrical supply the environmental recovery of the total invested CO2e in the solar cladding will take less than 9 years.

Deducting the CO2e footprint of the traditional cladding replaced will further shorten the time of recovery.

SolarLab

Simulations and production numbers presented are informational estimates only and SolarLab can not guarantee any future performance or be held liable for any performance deviations from the estimates presented

With trees

Total solar facade area: 1,877 sqm (20,197 sqft) | Estimated yearly electricity production: 105,000 kWh

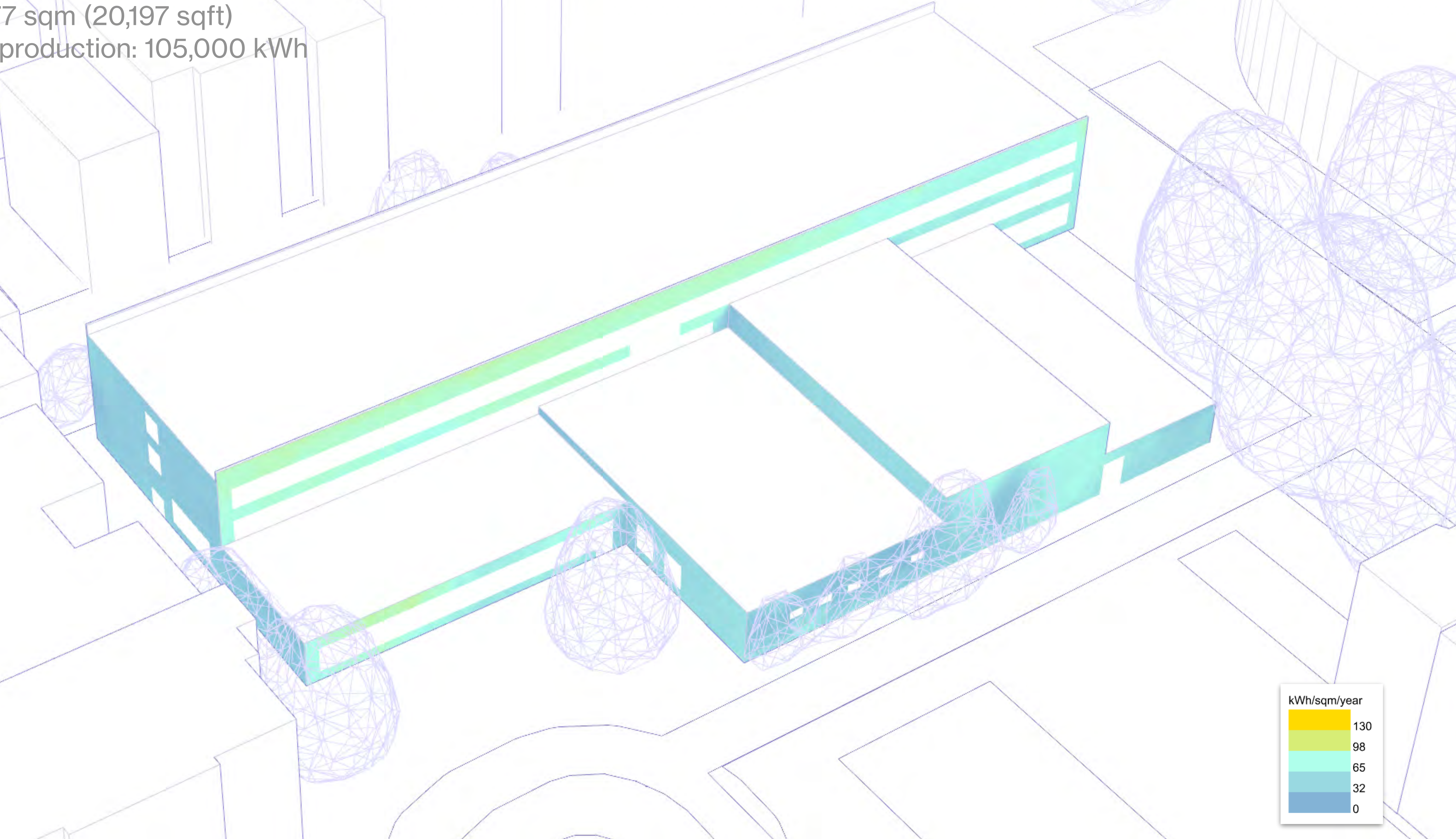
Looking North East

Total solar facade area: 1,877 sqm (20,197 sqft)
Estimated yearly electricity production: 105,000 kWh

SolarLab

Looking South East

Total solar facade area: 1,877 sqm (20,197 sqft)
Estimated yearly electricity production: 105,000 kWh



SolarLab

Simulations and production numbers presented are informational estimates only and SolarLab can not guarantee any future performance or be held liable for any performance deviations from the estimates presented

Looking South West

Total solar facade area: 1,877 sqm (20,197 sqft)
Estimated yearly electricity production: 105,000 kWh

SolarLab

Simulations and production numbers presented are informational estimates only and SolarLab can not guarantee any future performance or be held liable for any performance deviations from the estimates presented

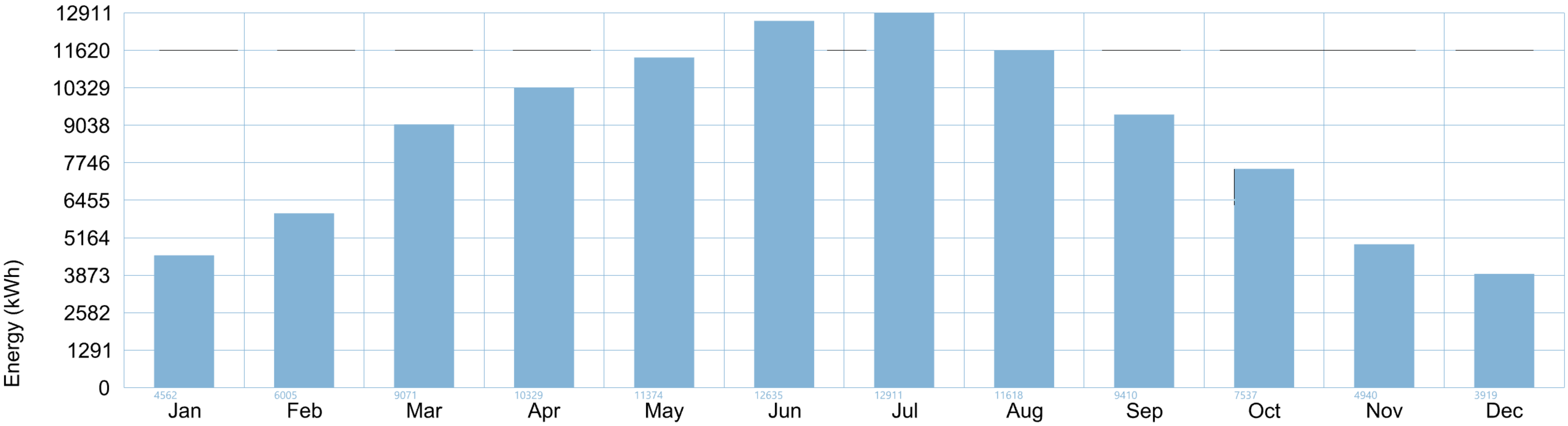
Looking North West

Total solar facade area: 1,877 sqm (20,197 sqft)
Estimated yearly electricity production: 105,000 kWh

SolarLab

Monthly production

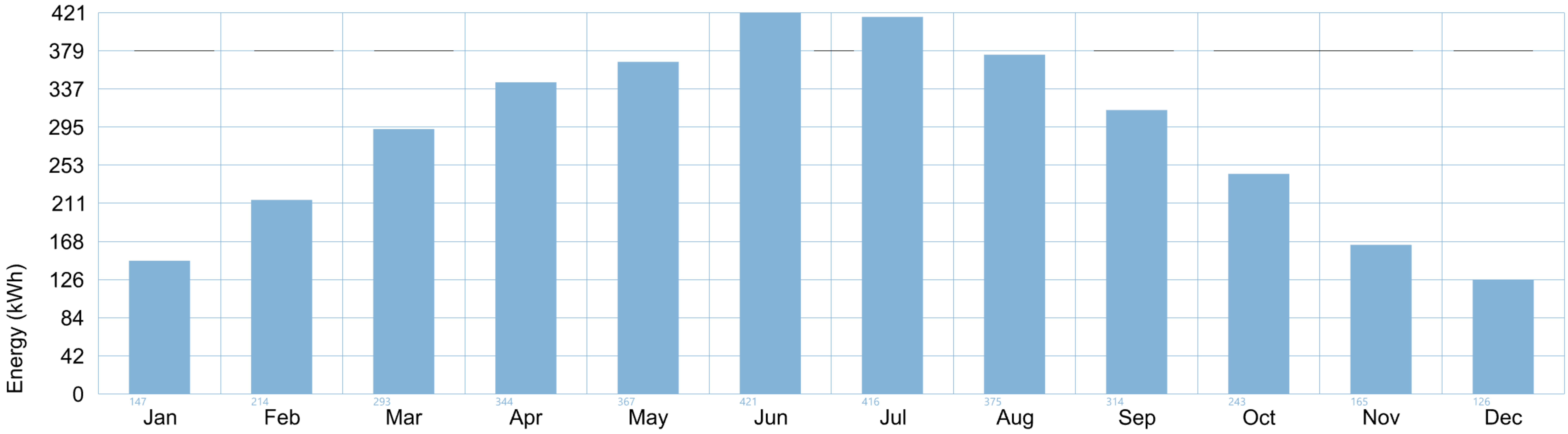
Total solar facade area: 1,877 sqm (20,197 sqft)
Estimated yearly electricity production: 105,000 kWh



SolarLab

Average daily production

Total solar facade area: 1,877 sqm (20,197 sqft)
Estimated yearly electricity production: 105,000 kWh



SolarLab

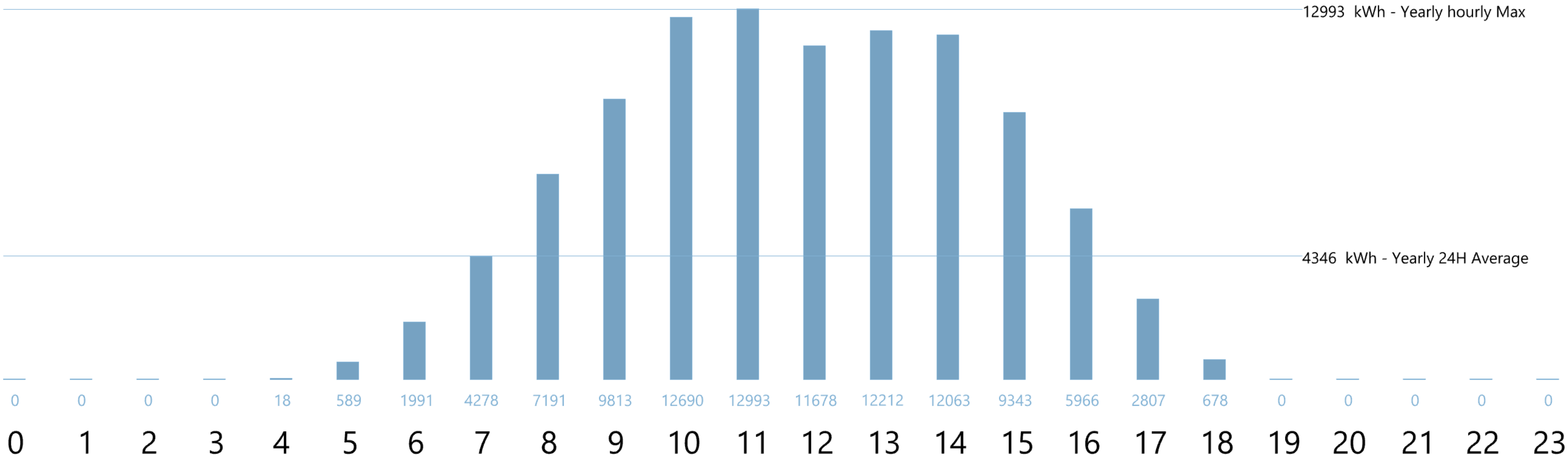
Yearly production Hour by Hour (8760)

Total solar facade area: 1,877 sqm (20,197 sqft)
Estimated yearly electricity production: 105,000 kWh

SolarLab

Yearly production Aggregated hourly

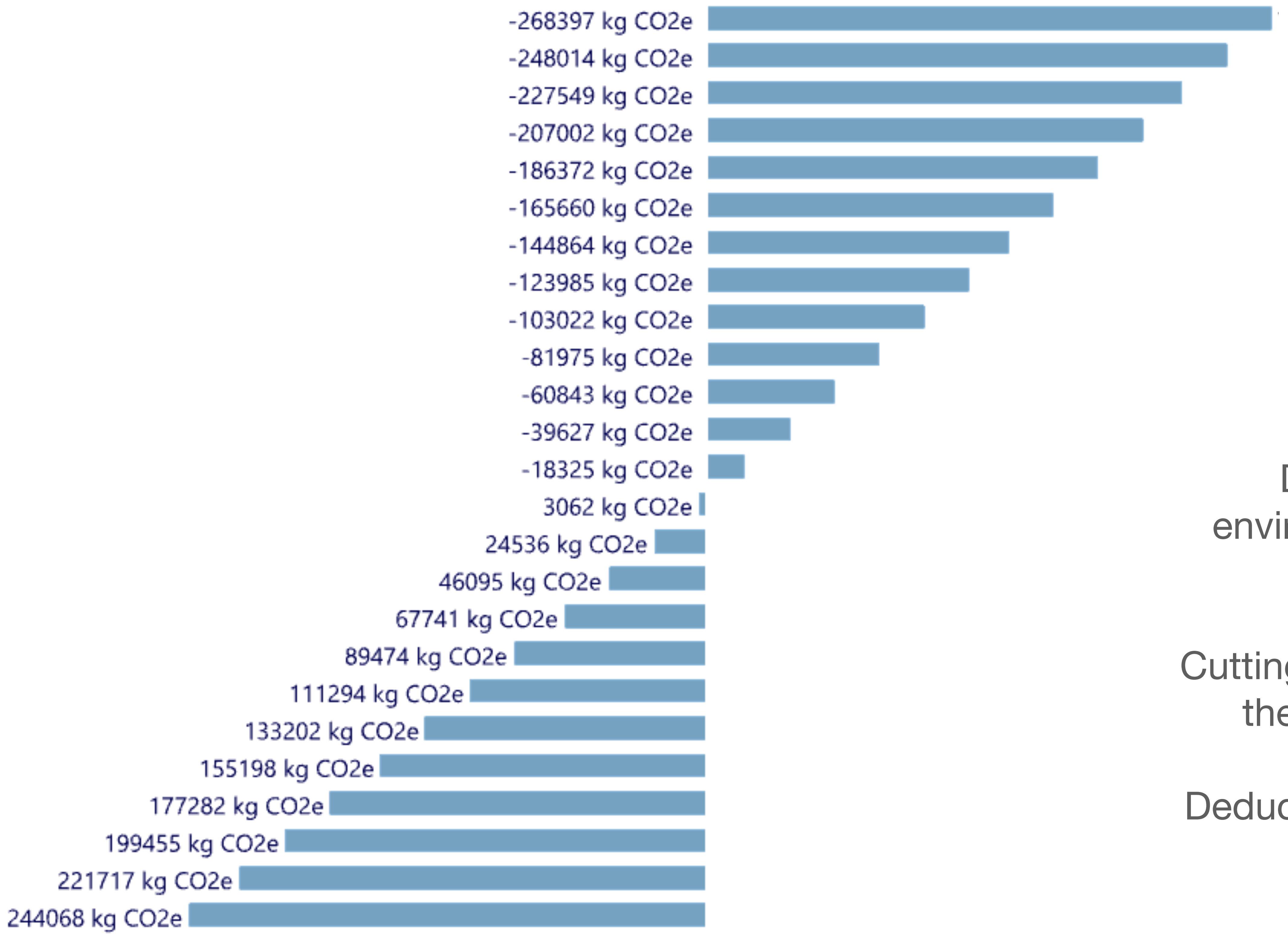
Total solar facade area: 1,877 sqm (20,197 sqft)
Estimated yearly electricity production: 105,000 kWh



SolarLab

Carbon offset ROI on invested CO_2

Based on electricity production of 105,000 kWh/year, 216 g CO2/kWh in NYC & A1-A3 investment of 142kg CO2/sqm of SolarLab facade



Due to New Yorks relatively clean electrical supply the environmental recovery of the total invested CO2e in the solar cladding will take less than 11 years.

Cutting the trees back could reduce payback time by 2 years, but they also add cooling benefits inside and out…and beauty

Deducting the CO2e footprint of the traditional cladding replaced will further shorten the time of recovery.

SolarLab

Assumptions & Estimates

Total solar facade area: 1,877 sqm (20,197 sqft)
Estimated yearly electricity production: 146,000 kWh, without trees!

- Simulations based on mat black ventilated rain-screen for optimal production. If a metallic or ceramic like structural color coating is desired the expected production will be reduced from 146,000kWh/year to around 131,000 kWh/year, but other design choices can also have an impact.

- The surrounding vegetation also has a large impact and the trees we can see in Google street view and East are quite substantial, so we estimate that they could reduce production to 105,000 kWh/year for a black facade and to 95,000 kWh/year for a coloured facade

- Cost is estimated for the mat black ventilated rain-screen system including customised panels and mounting system, 3-phase power system with panel level safety and power management as well as web based monitoring system. The 20,197 sqft active facade will cost 475 €/sqm or 50 USD/sqft, or around 1,010,000 USD at todays exchange rate, excluding potential tariffs, taxes or duties.

- In case a metallic or ceramic like color coating required, the cost will be 570 €/sqm or 60 USD/sqft, or a total of around 1,212,000 USD.

- Installation is not included, but typically takes about 1 man-hour/sqm or 6 minutes per sqft for an experienced local facade installer incl. both mechanical and electrical labour. SolarLab will provide installation manuals and support, as well as mock-ups and prototypes if needed.

- Typical lead time is 6 months from Architectural Design-Freeze, and requires that all design and any project specific testing is completed in advance.

- There are areas on the North side where it may be beneficial to replace the active solar cladding with passive cladding that offers around 15% lower cost, but retain the material and constructional qualities to insure a uniform architectural expression. The 3D visualisations are included to better understand the shading impact of surroundings and the building itself, and select areas for passive cladding.

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Solar Facade Simulation

Project: NYC, NY. USA. NYCSCA
Architect:

anders smith | as@solarlab.global | +45 3028 1162 | © 2025.04.24

Location: NYC, New York
Weather file: USA_NY_New.York-Central.Park.Observatory-Belvedere.Castle.725053_TMY3.epw

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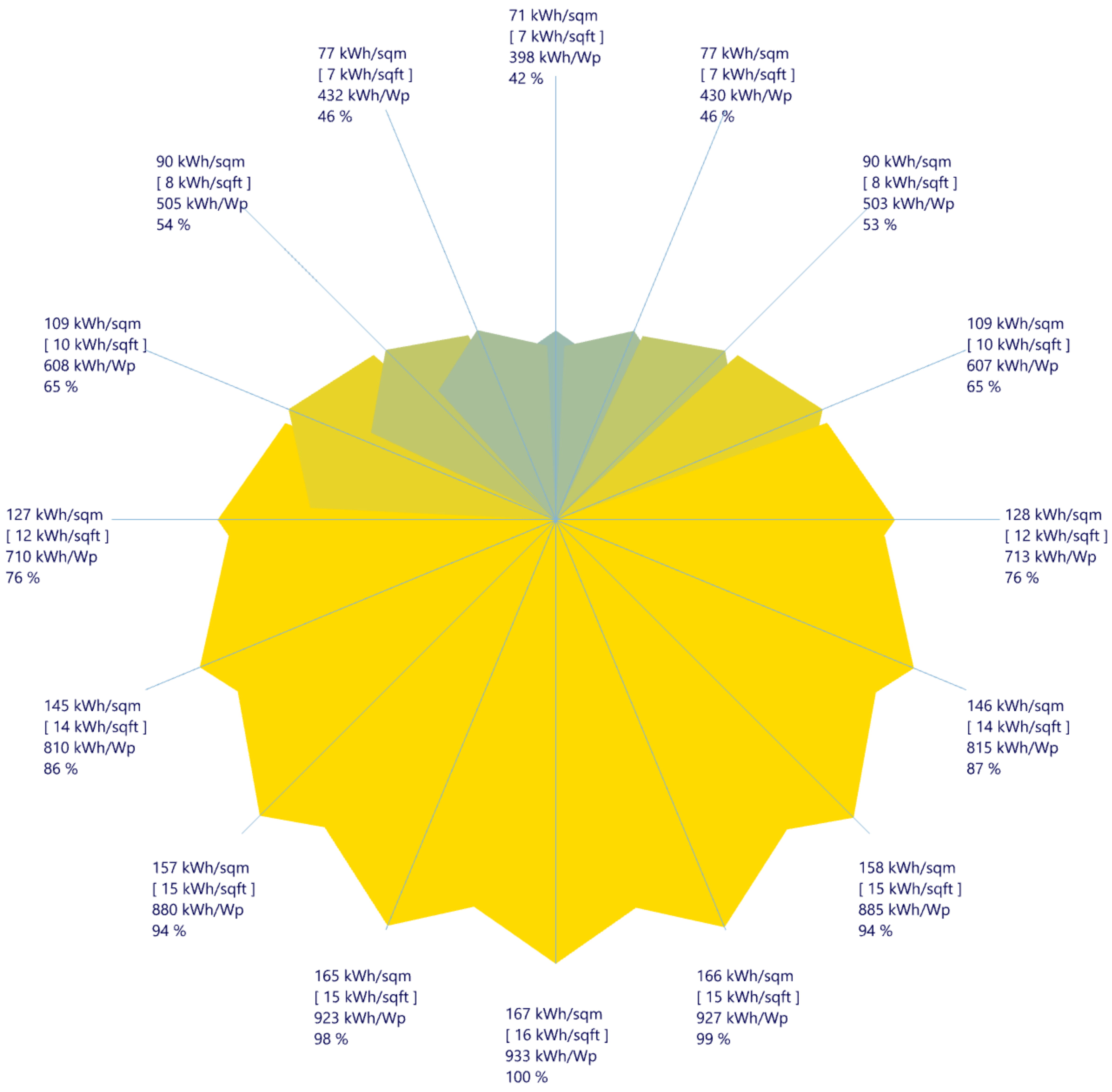
Potential in New York

How much electricity can one square meter or square foot of mat black solar wall cladding produce in the different orientations



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Looking North East

Total solar facade area: 3,876 sqm (41,673 sqft)
Estimated yearly electricity production: 296,000 kWh

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Simulations and production numbers presented are informational estimates only and SolarLab can not guarantee any future performance or be held liable for any performance deviations from the estimates presented

Looking South East

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Monthly production

Total solar facade area: 3,876 sqm (41,673 sqft)
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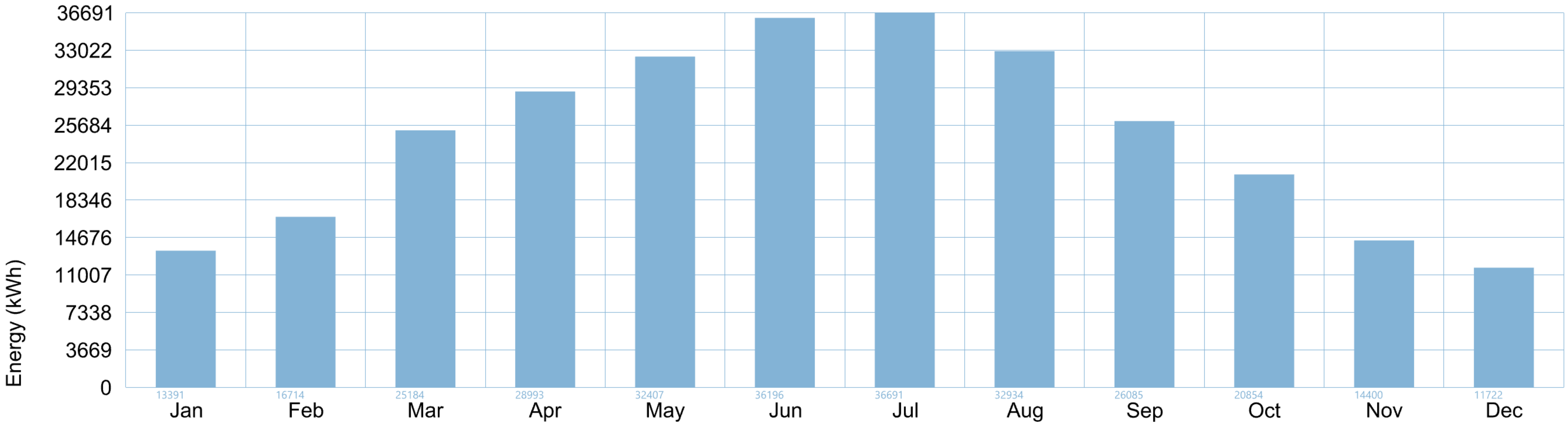

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Average daily production

Total solar facade area: 3,876 sqm (41,673 sqft)
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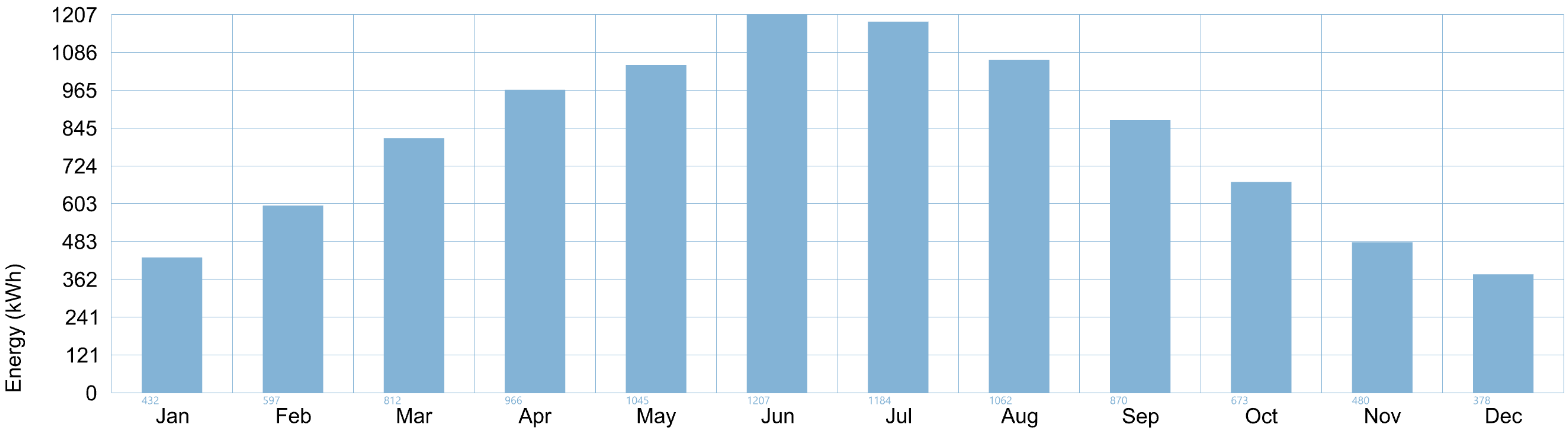

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Yearly production Hour by Hour (8760)

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Yearly production Aggregated hourly

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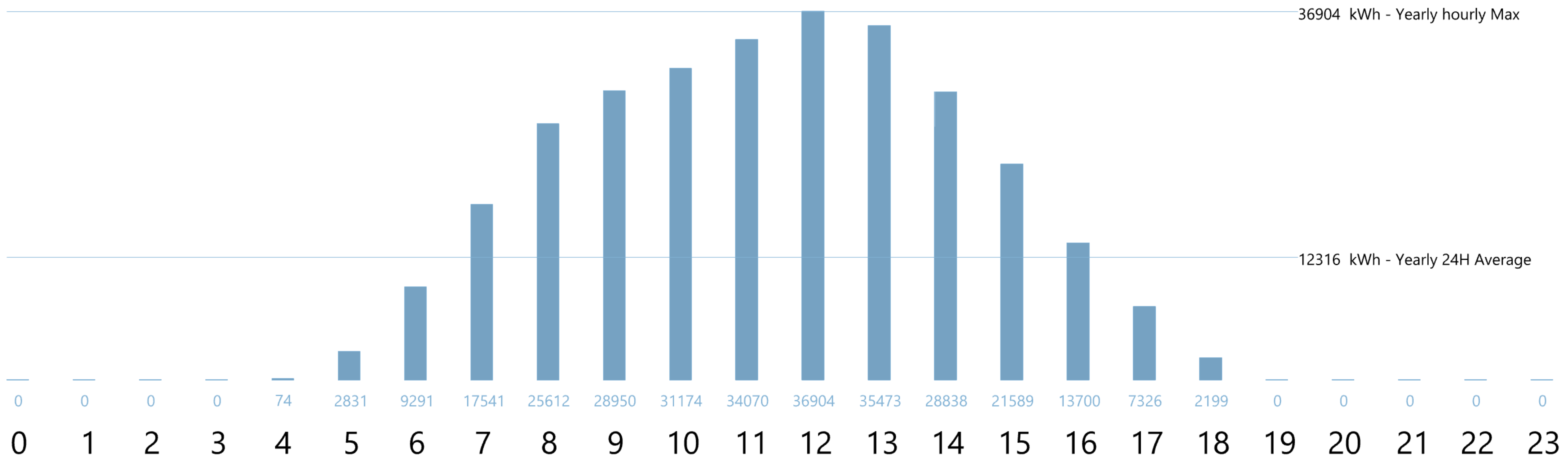

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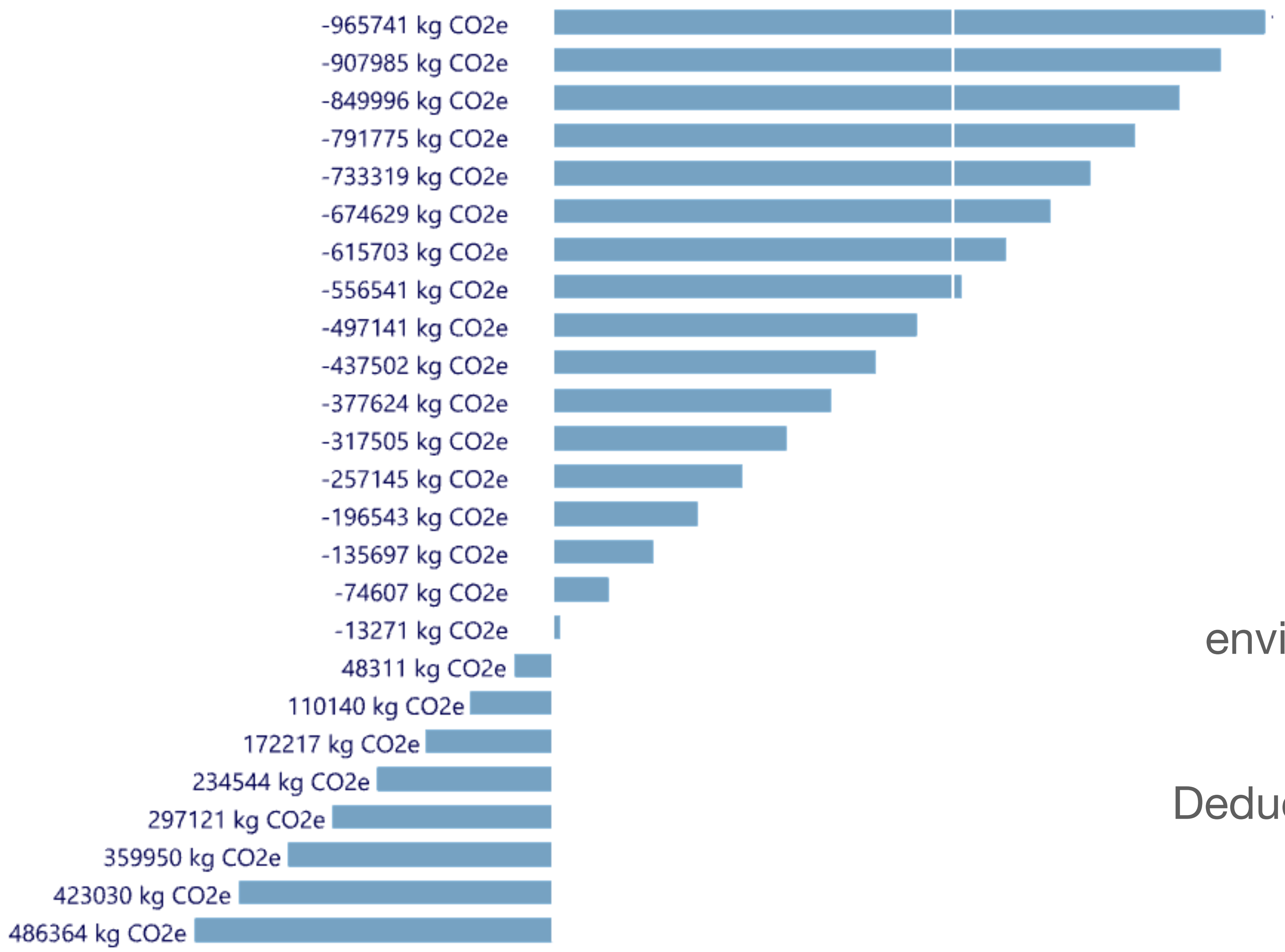
Carbon offset ROI on invested CO_2

Based on electricity production of 296,000 kWh/year, 216 g CO2/kWh in NYC & A1-A3 investment of 142kg CO2/sqm of SolarLab facade



Due to New Yorks relatively clean electrical supply the environmental recovery of the total invested CO2e in the solar cladding will take less than 9 years.

Deducting the CO2e footprint of the traditional cladding replaced will further shorten the time of recovery.

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Assumptions & Estimates

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Estimated yearly electricity production: 296,000 kWh

- Simulations based on mat black ventilated rain-screen for optimal production. If a metallic or ceramic like structural color coating is desired the expected production will be reduced from 296,000kWh/year to around 266,000 kWh/year, but other design choices can also have an impact.

- Cost is estimated for the mat black ventilated rain-screen system including customised panels and mounting system, 3-phase power system with panel level safety and power management as well as web based monitoring system. The 41,673 sqft active facade will cost 475 €/sqm or 50 USD/sqft, or around 2,100,000 USD at todays exchange rate, excluding potential tariffs, taxes or duties.

- In case a metallic or ceramic like color coating required, the cost will be 570 €/sqm or 60 USD/sqft, or a total of around 2,500,000 USD.

- Installation is not included, but typically takes about 1 man-hour/sqm or 6 minutes per sqft for an experienced local facade installer incl. both mechanical and electrical labour. SolarLab will provide installation manuals and support, as well as mock-ups and prototypes if needed.

- Typical lead time is 6 months from Architectural Design-Freeze, and requires that all design and any project specific testing is completed in advance.

- There are areas on the North side where it may be beneficial to replace the active solar cladding with passive cladding that offers around 15% lower cost, but retain the material and constructional qualities to insure a uniform architectural expression. The 3D visualisations are included to better understand the shading impact of surroundings and the building itself, and select areas for passive cladding.

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