North Potomac Yard Landbay F

Zero Carbon Analysis

DSUP #2020-10025 Condition #80
NPY Small Area Plan 2017

3575 Potomac Avenue
Alexandria, VA 22305

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Purpose

Sustainable Building Partners, along with JBG Smith and the larger project team, have studied the feasibility and path forward to the decarbonization of the built environment, striving for carbon neutrality for North Potomac Yard Landbay F (Phase 1) buildings by 2030 and site by 2040. The Zero Carbon Analysis addresses and is consistent with the language in the DSUP2020-100025 Potomac Yard Park Condition #80.

Carbon

80. Prior to release of the first building permit, the applicant shall conduct a zero-carbon analysis for the entire district to include the site. The zero-carbon analysis will be used as a benchmark for associated revisions to the ESMP toolkit and targets in future phases in order to improve performance towards achieving carbon neutrality by 2030. (P&Z) (T&ES)

Reference 1: DSUP #2020-10025, Condition #80

The goal of carbon neutrality is to neutralize the lifecycle carbon emissions for a development.

Key **criteria** for striving to achieve carbon neutrality includes:

- Implement strategies to reduce the energy consumption and peak demand of the site.
- Strive to minimize or eliminate on-site combustion.
- Offset operational and embodied carbon through on- and off-site strategies.

In addition to operational and embodied carbon, this study addresses the following additional emissions associated with the development:

- Sequestration
- Transportation
- Waste
- Refrigerant

The **intent** of the Zero Carbon Analysis is to help inform revisions to the ESMP toolkit, inclusive of feasible strategies that inform future phases of the development in order to improve performance toward carbon neutrality. Improvements in performance will attempt to close the gap of projected carbon emissions as it relates to a zero-carbon condition.

Note that this is a point in time analysis, or a snapshot in time. It is based on information available at the time of the analysis relative to the site and buildings designs and available technology.

Boundary and Elements

Existing Condition: North Potomac Yard is a redevelopment of a suburban-style shopping center located along Route 1 in the northeastern section of the City of Alexandria, just south of Four Mile Run. The existing site includes a surface-parked shopping center anchored by major retailers and restaurants along the western portion of the site and a surface-parked movie theater flanked by stormwater management ponds along the eastern portion of the site.

Proposed Condition: The North Potomac Yard redevelopment is comprised of 64 acres and is being developed in two phases. The development will transform the location into an urban, mixed-use, and transit-oriented area with office, residential, academic, hotel, entertainment, retail, and restaurant uses. New infrastructure, public parks, publicly-accessible open space, and a metro stop will anchor the buildings and connect them in meaningful and sustainable ways with the surrounding community.

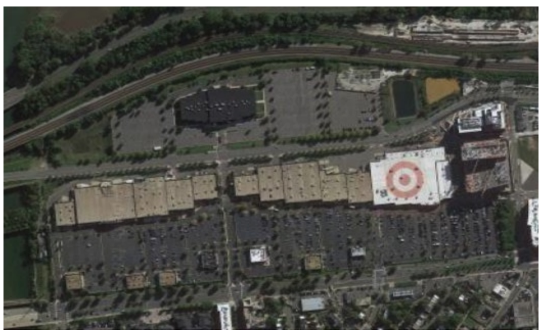


Figure 1: Existing Site Conditions

Figure 2: Proposed Phase 1 Site

The boundary of the site and project is Phase 1 as defined below:

- Located on east side of Potomac Ave
- Nineteen (19) Acre development area
- 1.8 million sf total building area
- Nine (9) Mixed-use blocks (academic, office, multifamily, retail)
- One (1) Pump Station
- Public parks and publicly accessible open space
- Home of Virginia Tech's Innovation Campus

The boundary of the study looks to address the carbon emissions for the following elements over a 20 year period:

- Site (hardscape and landscape emissions and sequestration)
- Buildings (structure, envelope, MEP systems, tenants and their contribution)
- Operations (transportation use, waste disposal, on-going refrigerant use and charge)

Carbon emissions associated with these elements are defined as follows:

- Embodied carbon represents the carbon emissions associated with the extraction, processing, manufacturing, transportation, use, and disposal of materials.
- Operational carbon represents the carbon emissions associated with site and source energy use and the carbon emissions avoided by renewable energy production.
- Carbon sequestration is the process of capturing and storing atmospheric carbon dioxide via plants and materials.

Framing the Challenge and Opportunities

Carbon emissions are quantified as carbon dioxide equivalency (CO2e) which normalizes the effects of various greenhouse gases in order to quantify and compare impacts of different elements, strategies, and activities. In the context of the built environment, whole building carbon encompasses embodied and operational carbon that occur within different life cycle stages including product and construction, in-use, end-of-life, and recovery.

Figure 3 represents the cumulative carbon emissions associated with a typical development over its life cycle. The anticipated carbon emissions are directly impacted by the following:

- Material choices
- Construction methodology
- Source energy
- Site energy

The goal of carbon neutrality is to reduce or neutralize the cumulative carbon emissions reflected in this figure. The toolkit includes strategies and mechanisms that can be implemented at various times throughout a project's life. The toolkit is directly impacted by market conditions, industry transition, project location, and technological advancements and therefore are unique to a specific project.

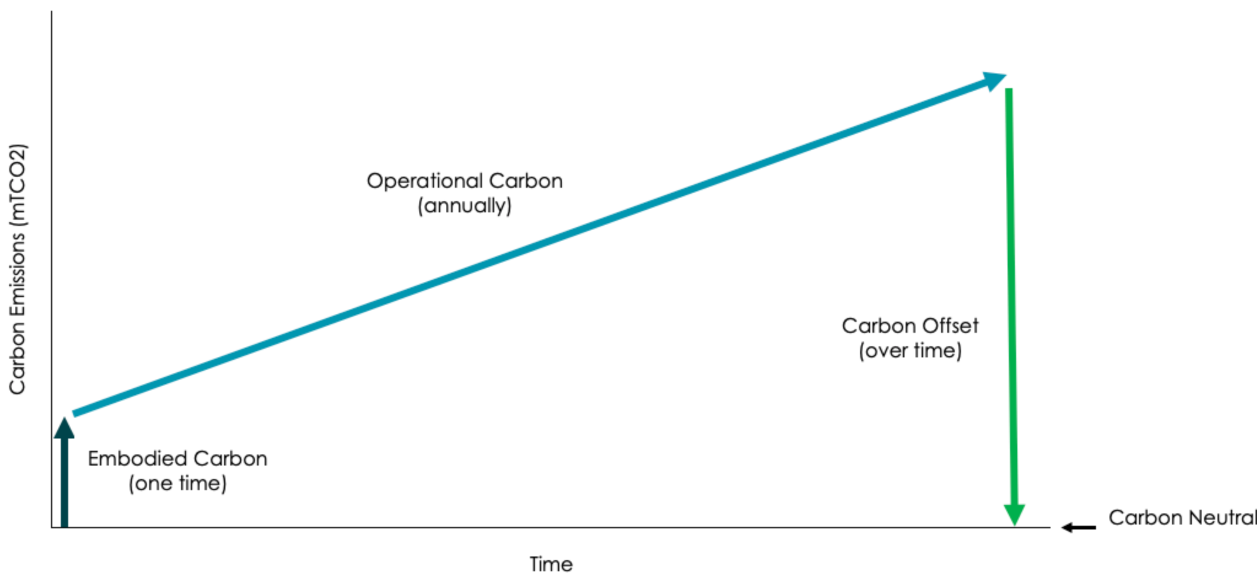


Figure 3: Typical Cumulative Carbon Emissions Over Development Life Cycle[1]

[1] Carbon sequestration, transportation, waste, and refrigerant impacts are not explicitly shown above, but represent important carbon impacts in the overall development schedule and path to carbon neutrality

Concept Level Carbon Impacts

For the purpose of this analysis, the total net carbon impact of the development is annualized starting at Year 0 of building operations. All embodied and operational carbon emissions evaluated as part of this analysis are represented from this base year. The anticipated carbon emissions associated with Phase 1 is **223,000 metric-tons (mT)** over 20 years, which equates to an estimated **reduction from industry benchmarks of 27%**. The carbon profile is shown in Figure 4.

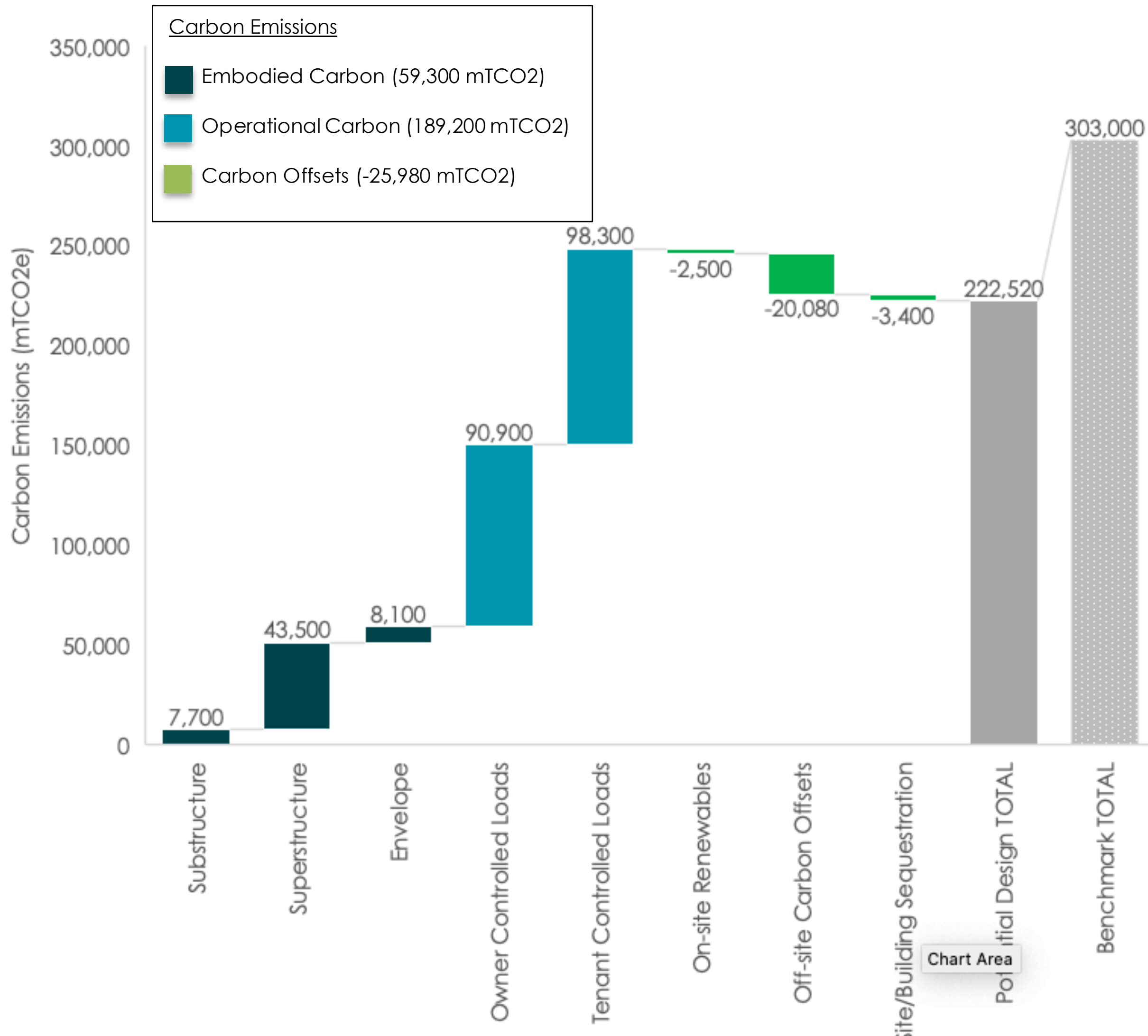


Figure 4: Lifecycle Carbon Emissions (20 Years)

The benchmarks for which this analysis is being compared to are listed below. These benchmarks represent intensities and therefore the totals in Figure 4 are based on the total development area.

- Embodied carbon – International carbon intensity data (ECI-kgCO2/m2). The most robust data set is from the Carbon Leadership Forum.
- Operational carbon – Regional energy use intensity data (EUI-kBTU/sf). The most robust regional data set available is from the DC's Building Energy Performance Standard (BEPS).
- Carbon sequestration – An industry benchmark is not available. For the purpose of this analysis, zero mTCO2/sf is used.

Embodied carbon is anticipated to be 59,300 mT CO2 and is primarily fixed at the point of construction completion. For context, the carbon emission profile of a typical building located in our area is 55-64 lbCO2/sf (Reference Figure 5). Predicted carbon emissions represent a 27% reduction from available industry benchmark data. Carbon offsets would have to be purchased to neutralize embodied carbon emissions. Key considerations and drivers relative to embodied carbon include:

- The industry is still in its infancy relative to embodied carbon. However, there is heightened focus around a more consistent methodology for benchmarking. Increased disclosure and reporting by the industry is required for a better comparative analysis.
- Approximately 90% of the emissions are "locked in" and occur before the building is constructed. Whereas strategies can be deployed over time to realize continuous operational carbon emission reductions, similar strategies cannot be deployed to achieve embodied carbon reductions.
- Embodied carbon represents 6.2 years of total operational energy use for this development.
- Concrete is a carbon intensive material. Cement management is currently a key strategy for reducing the embodied carbon of buildings in our area.
- Selecting materials with Environmental Product Declarations (EPDs) will drive transformation and deep carbon emissions within the industry.
- Carbon sequestering materials and mass timber are opportunities in the near future. Advancements in carbon sequestration technology and adoption of 2021 IBC codes for large-scale mass timber construction are current hurdles.

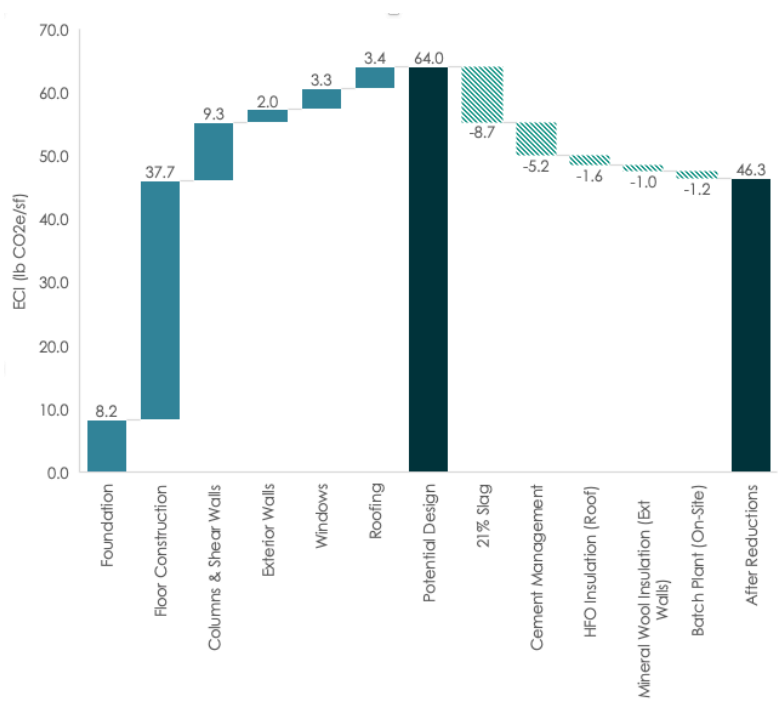


Figure 5: Embodied Carbon Intensity

Operational carbon emissions are anticipated to be 8,400 mT CO2/year by implementing energy efficiency strategies, minimizing on-site combustion, installing on-site renewables, and purchasing RECs and carbon offsets that meet LEED v4.1 Renewable Energy requirements.

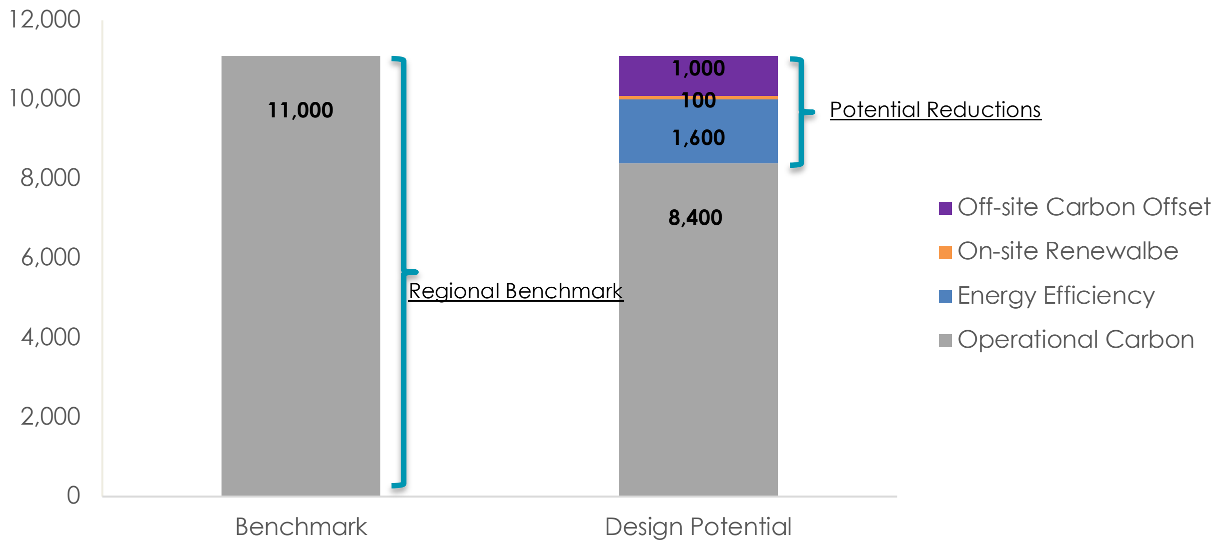


Figure 6: Annual Operational Carbon Emissions

Operational carbon is impacted by the energy efficiency of a building, the decarbonization of the electric grid, the deployment of on-site renewables, and the purchase of off-site renewables. Key considerations and drivers relative to these items include:

Energy efficiency

- Reducing energy demand first is critical to progressing carbon neutrality as it allows the electric utility meet growing energy demands with carbon-free solutions.

- Tenant and user-controlled loads represent approximately almost half (50%) of the total building energy use. This poses unique challenges for multifamily buildings specifically, where loads are primarily tenant driven (estimated at 21 kBTU/sf).

- Ventilation loads are unique for our area and represent approximately 75% of the total owner-controlled loads. It can be mitigated but not completely removed.

- Advancements in heat pump technology for large-scale applications is essential and has the potential to reduce energy consumption 30-40%.

The carbon emission profile of a multifamily building with an EUI of 40 is shown in Figure 7. This represents a potential design that can be built today with available strategies and technology that achieve a reduction in energy demand and carbon emissions from regional benchmark conditions. Operational carbon is quantified based on anticipated operational energy use. Although the buildings in the Phase 1 development will include a combination of electricity and natural gas, the predominant fuel type will be electric based on development conditions. Operational carbon emissions have then been estimated based on the carbon intensity of the SRVC subregion grid which is currently 675.42 lbCO2/MWh of energy use. (Reference Figure 4, 6, and 7).

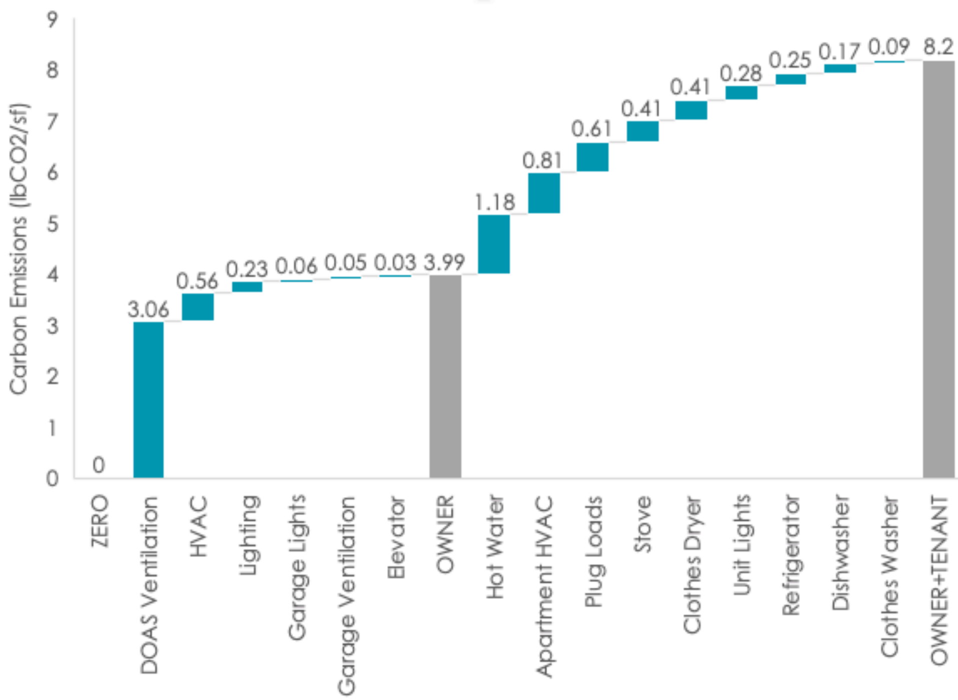


Figure 7: Multifamily Building Carbon Emissions

Electrification

- Electric resistance should not be used to meet electrification goals. Electric resistance heating is an extremely inefficient use of a unit of energy (kWh), using three times more energy than it's natural gas counterpart which results in more carbon emissions.

- Utilizing electric resistance for heating air and water would drastically increase the energy demands of a building and, as a result, the source energy from the grid. This would require the utility to use non-renewable based energy sources to meet an accelerated demand.

- Heat pump technology, specifically for heating outside air and hot water in our region, is necessary as an alternative to electric resistance and/or more commonly natural gas. However, scalable technology is currently not available for these systems.

Table 1: Source Carbon Emission Scenarios[2]

Source Energy		Site Heat Energy		Carbon Emissions (lbCO2/MMBtu)	Reduction (%)	Building Electrification
Natural Gas	294 in	Elec. Resistance	100 out	627	--	electric
Natural Gas	125 in	NG Fired Boiler	100 out	203	67%	natural gas
Natural Gas	74 in	Heat Pump	100 out	158	74%	electric
Renewables	34 in	Heat Pump	100 out	0	100%	electric

- The Virginia Clean Economy Act (VCEA) requires Dominion Energy Virginia to be carbon-free by 2045. Therefore, operational carbon emission intensity will decrease over time. This trend is not represented in the Figures within this analysis since it is a point in time analysis, but it is an important driver and consideration when looking outward.

[2] Information within this table is partially referenced from the ASHRAE article "Gas-to-Electric Resistance" (ASHRAE Journal September 2021, pg 19)

- The SRVC subregion's carbon intensity is currently 675.42 pounds CO_2 per megawatt-hour (lbCO_2/MWh). A regression model based on past data projects a carbon-free grid in 2041.
- Mindful use of energy by avoiding electric resistance as well advancements in renewable energy technology and policy are key drivers that would allow the utility to meet the VCEA requirements while simultaneously meeting growing energy demands. Without these strategies and mechanisms, the electric utility will struggle to decarbonize.

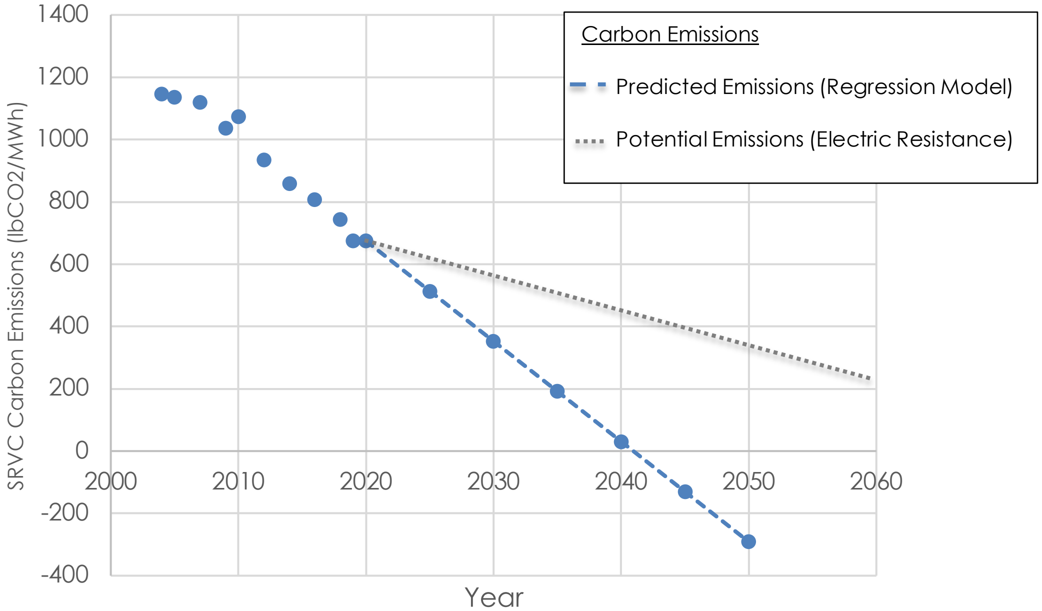


Figure 8: Predicted Carbon Emissions of the SRVC Grid

On-site renewables and off-site renewable purchases allow the project to achieve carbon neutrality. Figure 9 represents a feasible option for offsetting operational carbon emissions. Deploying an optimized on-site renewable strategy will offset a very small portion of the total carbon emissions.

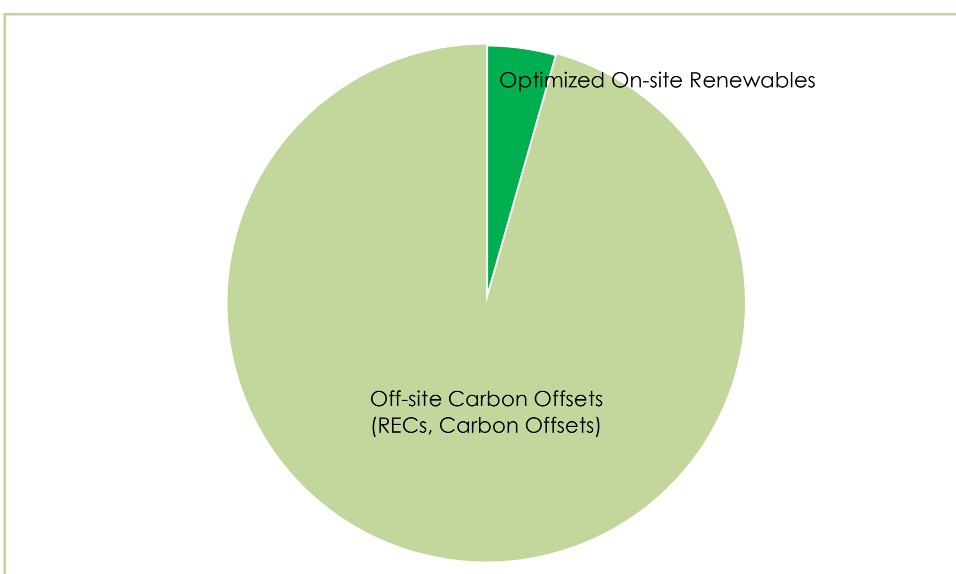


Figure 9: Carbon Emission Offset Potential (20 Years)

<u>On- and off-site renewables:</u>

- Photovoltaics (PV) will be installed on the Block 7 building, home of the Virginia Tech Innovation Campus. It is anticipated to generate ~370,000 kWH of energy per year. Other building rooftops within the development will be solar ready to support future PV.
- Optimized PV solutions for high density projects with limited roof area can offset a small percent of annual energy use, typically between 1-5%. An optimized PV solution for the Phase 1 development could offset 6% of annual energy use. This avoids carbon emissions annually for a total of 10,200 mTCO2 over 20 years. Additional mechanisms would be necessary to neutralize carbon emissions. (Reference Figure 9)
- On-site photovoltaics (PV) have become more cost-effective over the years, but are still significantly more compared to off-site purchases.
- Off-site renewable energy purchases, like RECs, drive renewable energy onto the grid. The price of RECs is currently very volatile due to increased demand as entities work to meet their carbon neutrality goals. It is a primary step for a carbon neutral future.
- Power purchase agreements (PPAs) are currently limited to large-scale projects and entities that use >10 MW of energy which this development is well short of.
- PPAs are currently not feasible for multifamily projects since each unit is individually metered. New mechanisms, like co-ops or aggregates, are needed to allow participation at an individual level.

Carbon sequestration is the process of capturing and storing atmospheric carbon dioxide and can occur in both plants and paving materials. The current Phase 1 development design is anticipated to be carbon neutral in 2043 as represented in Figure 10.

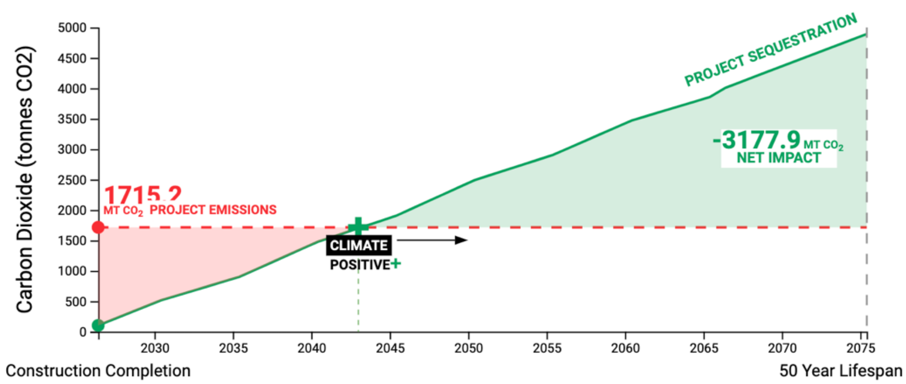


Figure 10: Site Carbon Sequestration Projections

- Potomac Yard Park is the largest contributor to the site's carbon sequestration effort.
- Large and moderate-sized trees sequester the most carbon per plant.
- Without consideration to stormwater management goals and requirements, the carbon emissions avoided by PVs increases exponentially more compared to green roof as roof coverage increases.

Additional carbon emission elements and considerations of the development include transportation, waste, and refrigerant impacts.

Transportation:

- Encouraging less single-occupancy vehicle use via mass transit, biking, demand management, and program implementation is key. The development will be adjacent to the Potomac Yard metro station and served by a Bus Rapid Transit Line, include bike lanes and shared-use paths, have Capitol bike share locations, an electric bus charging station, and implement garage demand management strategies.

- Market transition to electric vehicles (EVs) will result in deep carbon emissions. Decarbonization of the electric utility will results in deeper carbon emissions.

- But, balancing EV charging deployment with market demands, potential changes in modes of transportation, the building's ability to meet power demands, and the utility's ability to decarbonize during electrification are important considerations when planning for EV charging. The Phase 1 development will install 64 EV charging spaces and EV-ready infrastructure for 15% of parking spaces.

Waste:

- Recycling and composting can cut carbon emissions by one to two-thirds compared to landfill disposal. The convenience of the Phase 1 recycling drop-off center will contribute.

- Methane is a major byproduct in landfills and stores twenty to thirty five (20-35) times more heat in the atmosphere compared to carbon dioxide.

Refrigerant:

- Refrigerants are critical to refrigeration and air conditioning systems. When considering refrigerant types, there is often a tradeoff between the global warming potential and ozone depletion impacts.

- Natural refrigerants are available but come with their own challenges and limitations relative to safety and efficiency.

- New refrigerants are being developed that have a significantly lower GWP compared to HFCs and with better efficiency and safety compared to natural refrigerants.

The Zero Carbon Analysis performed for the North Potomac Yard – Landbay F **Phase 1 development anticipates a 27% reduction in carbon emissions compared to current industry benchmarks.** Given the proposed density, inclusive of critical open space and infrastructure, the remaining available surface area for on-site renewable energy will only offset the emissions associated with operational energy to a limited extent. A critical component of rapid decarbonization of the built environment requires the electric grid to move away from fossil fuel based resources while keeping up with the anticipated increase in electric demand that the grid will see in the foreseeable future. Smart electrification deployed at the site level is an important step in this process. Additionally, a consistent methodology for benchmarking embodied carbon is needed and under development. This repository of data will help quantify reductions consistently such that comparative analyses between low carbon material efficiencies and product selections can be done accurately. With heightened attention around carbon neutrality, the industry is responding and working to advance technology, mechanisms, and carbon metrics that result in cost-effective solutions and a more robust toolkit of strategies to meet collective carbon neutrality goals in the near future.

Appendix

Definitions and Boundaries

Carbon emissions are quantified as carbon dioxide equivalency (CO2e) which is a scientific measurement that is used to standardize the climate effects of various greenhouse gases. In addition to carbon dioxide, there are several other greenhouse gases, such as methane, nitrous oxide, water vapor, etc. The various gases are different in severity and remain in the atmosphere for different periods of time. CO2e normalizes the effects of greenhouse gases in terms of CO2 in order to compare the impacts of different contributors. CO2e is often reported as totals or carbon intensities, with intensity measured by dividing the total by area analyzed. Typical metrics include:

- Pounds CO2e (lbCO2 or lbCO2/sf)
- Metric tons CO2e (mTCO2 or mTCO2/sf)
- Kilograms CO2e (kgCO2 or kgCO2/m2)

Carbon emissions can occur in different stages of the life of a building or development. Whole life carbon in the context of the built environment encompasses operational and embodied carbon that occurs within distinct system boundaries (or life stages) of the project (Figure 12). These boundaries are often categorized and identified as “cradle to gate”, “cradle to grave”, and “cradle to cradle” impacts and cover one or more of the System A through D boundaries.

- System Boundary A - product extraction, manufacturing (cradle to gate), & construction
- System Boundary B - in-use including maintenance, repair, replacement and operations
- System Boundary C - end of life including disposal (cradle to grave)
- System Boundary D - recovery (cradle to cradle)

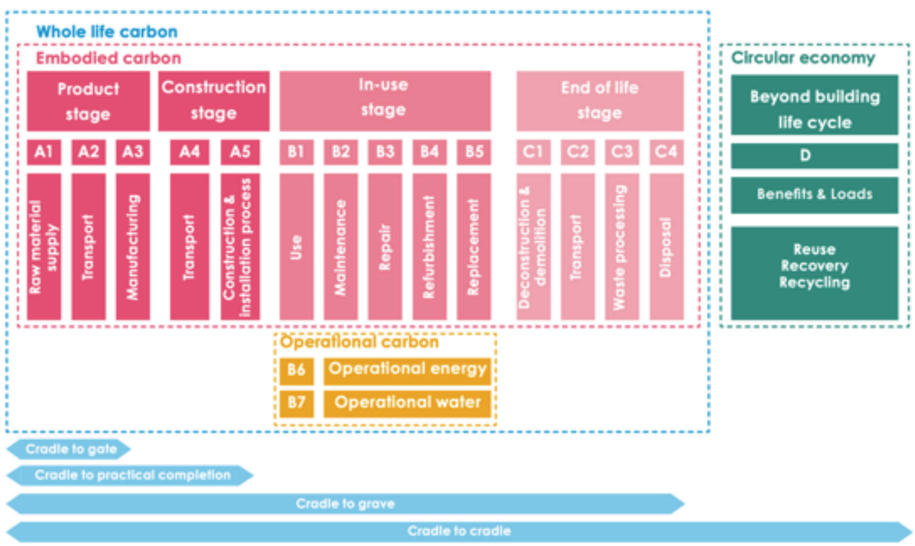
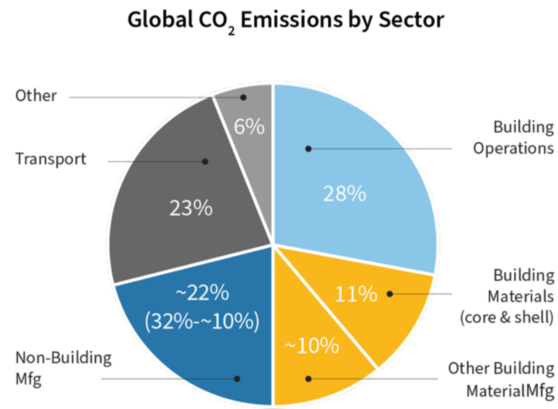


Figure 12: Carbon Impact System Boundaries

Carbon sequestration, transportation, waste, and refrigerant impacts are not explicitly shown or in the above system boundaries, but represent important carbon impacts in the overall development schedule and path to carbon neutrality. These carbon impacts would fit into System Boundary B, or the in-use stage of the development.

Embodied Carbon

Embodied carbon represents the upfront carbon emission impacts of building construction materials. The 2019 Global Status Report has quantified these impacts at 21% of total global CO2 emissions, almost half of the total building and construction sector impact (49%).



Reference 1: Global CO2 Emissions by Sector (from *Carbon Leadership Forum*)

Although embodied carbon emissions span cradle to grave, around 90% of the total impact occurs from extraction, processing, manufacturing, and transportation of building materials before it becomes operational (Year 0), meaning embodied carbon emissions are generally "locked in" with little opportunity to significantly reduce impact throughout the building's life. When considering the timeline of embodied carbon impacts and the opportunity for increased energy efficiency of buildings over time, it becomes apparent that we must also address embodied carbon.

A whole building life cycle assessment (LCA) is the most comprehensive way to evaluate embodied carbon. LCAs are similar to energy models and quantify the relative performance of elements and strategies. Whereas energy models analyze the operational carbon of the building while it is in use, LCAs analyze the embodied carbon of construction materials used to create the building. LCAs can include all materials and equipment that are installed as part of the project, but for the purpose of this analysis, the LEED v4 framework has been used to identify materials and elements for evaluation, which include the structure (foundations, columns/shear walls, beams, floor construction) and enclosure (façade finish, sheathing, insulation, framing, drywall, windows, roof).

Since most of the embodied carbon impact is cradle to gate (System Boundary A), key details for quantifying the impact are based on material quantities, choices, and sourcing locations.

- Material quantity: Design efficiency and material quantity reduction will have substantial impacts on the overall embodied carbon performance of a building.
- Material choice: Using products with environmental product declarations (EPDs) communicates and quantifies comparable life cycle impact of individual materials. Both industry-wide and product-specific EPDs are available.
- Material sourcing location: Sourcing products from regional manufacturers can reduce carbon emissions from transporting products to site.

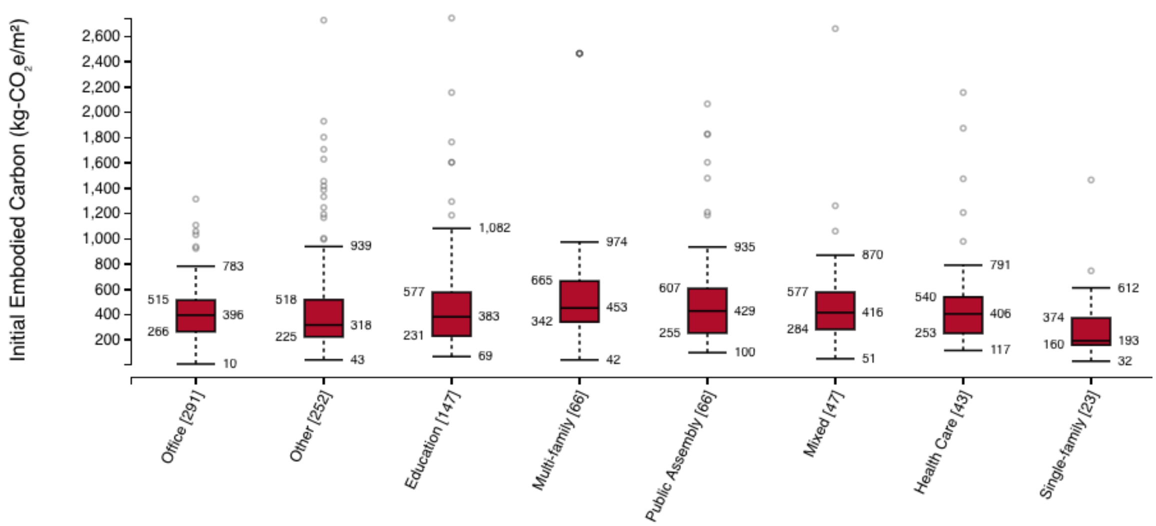
In combination, multiplying a bill of materials or material take-off by impacts disclosed in EPDs quantifies the whole-building impacts.

Figure 12: Methodology for quantifying whole-building embodied carbon

Limitations in setting benchmarks stem from tracking and reporting embodied carbon still being in its infancy in North America. European countries have been quantifying, tracking, and reporting this data longer. Even so, the industry as a whole has a relatively small data set available and inconsistent assessment methodology for establishing benchmarks and comparing buildings, introducing uncertainty in reported values. This is apparent when comparing to operational energy data sets, which is based on a robust data and consistent methodology for determining energy use intensity (EUI) from years of analysis performed by ENERGY STAR.

The industry is making strides to quantify and track embodied carbon emissions with the goal of creating a sufficient data set for which useful and accurate benchmarks can be established to measure relative performance. The industry's prioritization of encouraging project teams to quantify and disclose embodied carbon results is a critical step in setting benchmarks and continuing to move the industry forward to decarbonization. The following initiatives and tools are working toward this goal:

> Carbon Leadership Forum (CLF) aims to "accelerate the transformation of the building sector to radically reduce the embodied carbon in building materials and construction through collective action." (from CLF webpage) The CLF recently published the *CLF Embodied Carbon Benchmark Study* which aims to establish benchmarks and create an LCA practice guide. The results of the study found a need for standardization of assessments and data collection as well as the development of a larger data set. The study did publish embodied carbon results for cradle to gate (Boundary A) impacts which can be viewed online. Note, the figure below is not specific to the United States, or even North America, and instead represents all contributing projects across the world.



Reference 2: Embodied Carbon Benchmark Results[3]

> Building Transparency's EC3, One Click LCA's Carbon Heroes, and the Structural Engineering Institute (SEI)'s SE 2050 programs aim to collect data to build a meaningful data set for the industry. These tools and programs collect data by setting conditions for entering verified completed projects created within their software or by having design firms commit to reporting data to them annually. Once these databases grow, users will be able to conduct useful comparative assessments of their buildings against other similar designs.

[3] Reference 2 is from the *CLF Embodied Carbon Benchmark Study*

Furthermore, the industry is working toward developing a process and methodology for creating a baseline which is used to compare different design scenarios for a specific building or project. Currently, the baseline can be an industry standard and/or early design and/or existing building. It is often a combination of an industry standard building of similar type, size, thermal performance, and location as well as an early design iteration. Clarity in defining the baseline by both the industry and jurisdiction will help to ensure consistency between comparative results. Note that the LEED rating system quantifies a reduction in impact as compared to a baseline building, for both energy and material impact. This baseline is fundamentally different than a benchmark.

The primary metric for evaluating embodied carbon performance is embodied carbon intensity (ECI), measured in kgCO2/m2 (or mTCO2/sf), which is a parallel metric to energy use intensity (EUI). Note that the industry often uses kgCO2/m2 considering LCAs have been more prominent in European countries. ECI is considered the benchmark from which the North Potomac Yard Phase 1 buildings are being evaluated.

Table 2: CLF Benchmark Data for Boundary A (cradle-to-gate)

Building Type	**CLF** (kgCO2/m2)	**CLF** (lbCO2/sf)
Multifamily	453	93
Lodging	357	73
Office	396	81
Mixed Use	488	100
Education	383	78

*Data set represents 1,191 results throughout the world and are median values

Potential embodied carbon impact has been evaluated for the North Potomac Yard Phase 1 development. Results are quantified as lbCO2/sf for ease in comparing them to other emission sectors, like operational carbon. SBP used OneClick LCA's Carbon Designer tool in order to complete the analysis. This tool creates a box model of the project and is typically used early in the design process to understand the magnitude of impact of different design strategies and elements. In the case of this analysis, the tool was used to represent an average building within the development and one that would be typical in the DC-Maryland-Virginia location of recent years. The analysis has evaluated opportunities and limitations of structure, envelope, and material elements considering code requirements, thermal and moisture performance, and material advancements. The approach was additive, meaning anticipated intensities were derived by adding embodied carbon up from a zero condition. Opportunities in today's market are shown in the same graphic providing a picture of the impact of implementing these strategies within the Phase 1 development.

Major characteristics of this average building from which the Box Model was created include the following:

- 300,000 GSF
- Residential building
- Concrete structure
- Industry average EPDs
- Eastern Region NRMCA Concrete Mix Design (21% slag content)

Based on these characteristics, the anticipated embodied carbon intensity of Phase 1 buildings is around 64 lbCO2/sf, depending on the timeline of construction and can be reasonably reduced to approximately to 46 - 55 lbCO2/sf using strategies and materials currently available in the market.

Table 3: Estimated Embodied Carbon Sources and Strategies to Reduce Impact

Contributor	ECI (lb CO2/sf)	Basis of Design
Elements Contributing to Embodied Carbon Emissions		
Foundation	8.2	Concrete, Spread footings
Floor Construction	37.7	Concrete, post-tensioned slab
Columns & Shear Walls	9.3	Concrete, typical
Exterior Walls	2.0	Brick construction, typical
Windows	3.3	Aluminum-framed storefront/fixed, typical
Roof	3.4	HFC XPS Insulation
TOTAL Anticipated ECI	**64.0**	
Strategies Contributing to Embodied Carbon Emissions Reductions		
Cement Management Practices	14.0	Avoid winter pour, increase slag (30-50%), Type IL cement
HFO Insulation (Roof)	1.6	HFC 134a-free rigid insulation
Mineral Wool Insulation (Ext Walls)	1.0	Mineral wool board, typical
Batch Plant (On-Site)	1.2	On-site concrete mixing, reduced transport
TOTAL Anticipated ECI (After Reductions)	**46.3**	**27.5% Reduction**

For comparison, embodied carbon will represent 88% of the total embodied and operational carbon emissions of the building at Year 1 of operations. It will take 6.2 years of operations before operational carbon emissions equal embodied carbon emissions.

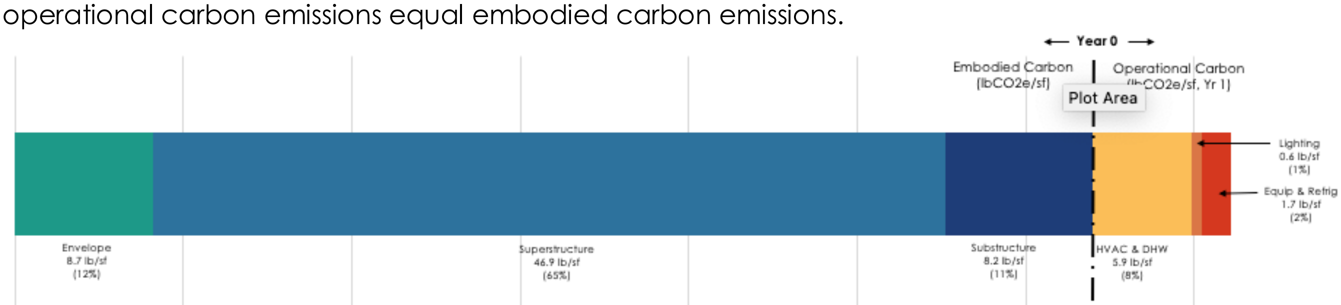


Figure 13: Carbon Emissions at Initial Occupancy

Concrete is a carbon intensive material that results in around 8% of global CO2 emissions annually. The material is a major contributor to a building's total embodied carbon impact and its use is common in local construction. The structural and concrete industry is urgently responding to the material's impact and exploring strategies and technologies that significantly reduce the carbon missions associated with the use and manufacture of concrete. For reference and an important consideration when evaluating the impact of concrete, the cement (an

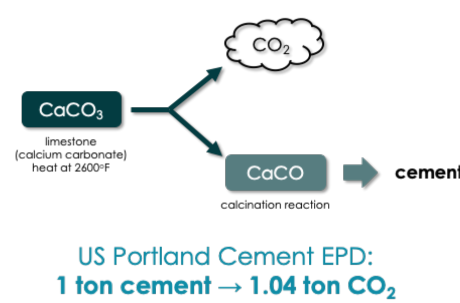


Figure 14: Concrete and Cement Emissions

ingredient within concrete) is the carbon intensive component. While it only represents up to 15% of the total composition of the concrete, it is responsible for 90% of the emissions.

Cement management is the primary tool for reducing embodied carbon of concrete. The following are key strategies that can be deployed to reduce the embodied carbon of concrete:

- Increase cement replacements (slag or other supplementary cementitious materials)
- Use alternative cementitious materials and aggregates (portland limestone cement)
- Use carbon sequestration (CarbonCure)
- Limit early strength requirements
- Optimize aggregate size
- Decrease transportation distance

Table 3 quantifies and estimates a reduction in total embodied carbon of approximately 14.0 lbCO2/sf using the following cement management strategies:

- Avoid winter pour, which results in SCM restrictions to meet cure time requirements
- Increase in slag above the 21% eastern benchmark (50% in foundations / 30% all other)
- Use of portland limestone (Type IL) cement in lieu of portland cement (Type I and II)

New technologies to reduced embodied carbon in the industry are under development:

Low Embodied Carbon Products

Manufacturers are starting to understand the importance of embodied carbon and their role in reducing emissions in the industry. Many have released Environmental Product Declarations (EPDs) disclosing the environmental impacts of their products. Some have even improved upon older products to further reduce impact. Owens Corning's Foamular NGX XPS insulation is a great example of a product that was updated in 2021 to drastically reduce GWP by about 83% compared to the original product. As the industry continues to move toward providing lower impact material options, project teams will be able to choose the products that result in lower associated carbon emissions. Incorporating embodied carbon as part of the material decision process can be done now and throughout the design and construction of Phases 1 & 2. Online resources such as Building Transparency's EC3 Tool and the Sustainable Minds' Transparency Catalog can be used to compare products based on their embodied carbon.

Mass Timber Design

Mass timber is becoming increasingly viable in the industry as a structural opportunity to reduce embodied carbon. Due to its ability to store carbon, mass timber is a competitive material when it comes to low-carbon construction. Trees remove CO2 from the atmosphere through the process of photosynthesis and store it as carbon (C) within plant tissues. Carbon is sequestered in the wood throughout its life until the material is burned or decomposes. Available products include cross-laminated (CLT), nail-laminated (NLT), and glue-laminated (Glulam) timber that can be used to meet all structural needs and performance as other structural materials, as set out in the International Building Code (IBC). Additionally, there are many benefits to mass timber structures due to the prefabricated nature of the products: reduced labor, schedule savings, and a lighter structure with reduced foundations, which all contribute to making the material cost competitive.

Reusing mass timber products increases the environmental benefits by keeping the wood products from releasing their stored biogenic carbon at the end of life. Due to their prefabricated and modular nature, mass timber products can be reasonably deconstructed and reused.

Current codes (IBC 2015 & 2018) allow mass timber buildings up to 6 stories. New code (IBC 2021) will allow a maximum of 9 stories fully exposed, up to 12 stories partially encapsulated, and up to 18 stories fully encapsulated. There are already some early adopters of the IBC 2021 code designing and constructing mass timber buildings, making mass timber design and construction a notable option to be considered for current and future projects.

Carbon Capture Concrete

Concrete is responsible for roughly 7-8% of the world's carbon emissions (Carbon180). Due to concrete's high carbon impact, many manufacturers are working to create a scalable process of Carbon Capture, Utilization, and Storage (CCUS) to use emissions from the manufacturing process by injecting it back into the cement. Carbon utilization in concrete can reduce cement content and increase strength while mineralizing and storing carbon in precast and ready-mix concrete. Lehigh Hanson has partnered with Fortera, a Silicon Valley-based Material Technology Company, to utilize carbon capture technology at their Redding, California cement plant. This technology is likely soon to be available on the East Coast, making it a potential option for concrete products used in future projects.

Operational Carbon

As part of the Environmental Sustainable Master Plan (ESMP) 2020, the project team identified a potential process for exploring and addressing Carbon Neutrality for the development. This process focuses on reducing operational carbon emissions.

First: Conduct Zero-Carbon feasibility studies.

A critical element to completing the first step includes analyzing and understanding whole building energy performance. Whole building energy modeling works to address and reduce total energy use and demand and considers site and source energy use. Understanding site and source energy use and the associated carbon emissions is the first critical step toward achieving carbon neutrality goals. It ensures project strategies do not have unintended impacts, such as increasing source energy use and placing larger energy demands on the utility which would make it challenging for the utility to convert to renewables and completely decarbonize.

Whole building energy modeling evaluates architectural, mechanical, electrical, plumbing, and renewable energy concepts. The process is iterative and can be used as a design tool, allowing the project team to make better informed decisions that are more comprehensive and consider the energy performance impacts. All projects within Phase 1 will be completing a whole building in support of these efforts. Energy efficiency opportunities are being explored throughout the design process with a heightened focus around enclosure optimization, internal load optimization, ventilation control and design, and occupancy conditions where there is still significant opportunity for fine-tuning designs based on current industry practice and available technology. Strategies include, but are not limited to, the following:

- Enclosure optimization (minimize external loads)
- Internal loads optimization (minimize internal loads)
- Domestic hot water (optimize for energy use)
- Effective ventilation control and design (optimize for energy use & occupant health)
- Occupancy conditions (optimize controls)
- Electrification-ready to accommodate future technologies
- Electrification-ready to accommodate future technologies:
- On-site renewable energy (offset electric consumption):
- Off-site renewable energy (offset carbon impacts from electricity and natural gas)

Industry standards for understanding and comparing building energy performance have included the use of ASHRAE 90.1 energy cost savings, energy use intensity (EUI), and ENERGY STAR Scores. These metrics are used by government agencies, jurisdictions, green building rating systems, and other entities and institutions.

ASHRAE 90.1 energy cost savings: ASHRAE 90.1 has been a benchmark for the development of building energy codes and entitlement conditions, much like the International Energy Conversation Code (IECC), within the United States. It sets minimum energy efficiency requirements that evolve and are updated every three years. It is typically referenced in green building rating systems, like LEED, and within surrounding jurisdiction policies, codes, and conditions. As such, a comparison against ASHRAE 90.1 throughout design provides the design team a reference point that can inform design decisions to ensure the project will hit anticipated targets.

Energy Use Intensity (EUI): ENERGY STAR Portfolio Manager allows properties to benchmark their operational energy use relative to the energy use of similar properties within the nation. The *Energy Use Intensity by Property Type* technical reference lists national median site and source energy use intensities (EUI). Although source EUI is the recommended benchmark, normalizing on-site combustion and on-site electric use, site EUI is typically referred to. The national median site EUIs for anticipated property types are listed in Table 2 for comparison.

ENERGY STAR Score: Using the benchmark data in ENERGY STAR Portfolio Manager, projects can achieve an ENERGY STAR Score. This score is based on real energy usage data and is calculated by an algorithm that estimates the energy use of the actual building if it was a high-performer, average-performer, or worst-performer based on the building's peers. A minimum Score of 75 (or 75th percentile) must be achieved.

Operational Carbon (mTCO2e, metric tons of carbon dioxide equivalent): Operational carbon is calculated by converting the total energy use of the building (kWh, therms, kBtu) into a carbon equivalency. The conversion factor is based on the emissions associated with the combustion and transfer of energy, which can be either directly on site or from the utility to the project site. As a result, it takes into account the energy make-up of the grid and decarbonization of the utility.

The analysis uses EUI as the main reference point for energy performance, with the goal of reducing energy intensity and demand first. Other reference points, like ASHRAE energy costs savings, are useful in evaluating the same goal. The Phase 1 blocks are all at different design development stages with varying levels and refinement of information; therefore, EUI is used as the predominant metric since relative performance can be calculated. The development team has evaluated potential EUIs for each building type. The values are based on data from SBP's large portfolio of completed energy models and verified operational performance results within the DC-Maryland-Virginia region. The values take into account opportunities and limitations of technology currently available on the market, best practices and opportunities for fine-tuning the design, and real-world occupancy and operational characteristics. Our approach was additive, meaning the EUIs were derived by adding building energy consumption up from a zero condition, to include all owner and tenant-controlled elements. Operational carbon emissions were then derived and quantified using source carbon emission intensities, which considers carbon emissions of the electric grid. Source carbon emissions were used to accurately represent the carbon impact of various end-uses and strategies and to understand the required offset to decarbonize the project.

Table 4 summarize the potential EUIs for each building type within the North Potomac Yard development and compares them to median regional and the median US EUIs.

- *Median regional EUIs* are based on the Building Energy Performance Standard (BEPS) program in the District of Columbia. This program is a database of actual reported energy use of buildings in DC, grouped by building type. It is comprised of 18,750 buildings.
- *Median US EUIs* are derived from ENERGY STAR Portfolio Manager's *U.S. Energy Use Intensity by Property Type* Technical Reference which uses nationally representative data that is primarily derived from the Commercial Building Energy Consumption Survey (CBECS) data source.

Table 4: Site EUI Summary by Building Type*[4]

Building Type	Potential EUI	Median Regional EUI	Median US EUI
Office	40		
	(14% less)	47	
	(25% less)		53
Multifamily**	40		
	(28% less)	56	
	(33% less)		60
Academic	75		
	(6% less)	80	
	(11% less)		85
Retail***	75		
	(-7% less)	70	
	(45% less)		137

The following tables show the additive derivation of the potential EUIs and equivalent source carbon emissions. Both building types assume predominantly electric buildings, and therefore the carbon emissions are based on the carbon intensity of the electric grid, which currently stands at 675.42 lb/MWh.

[4] *Traditional Townhomes are not included in the Table since Median US EUI information is not available. Target EUIs don't include EV charging stations.
**Multifamily excludes retail.
***Retail energy intensity can vary greatly based on the type of business, with a range of median US EUIs between 52 – 325 kBTU/sf.

Table 5: Estimated Energy Demands and Source Carbon Emissions for Multifamily Buildings

End-Use	EUI kBtu/sf-yr	Source Carbon Emissions lbCO2/sf-yr	Basis of Design
Owner Controlled			
DOAS Ventilation	15.4	3.06	Direct to unit, dehumidified neutral temp air, DX cooling, electric heat
Common Area HVAC	2.81	0.56	Variable Frequency Drive System
Common Area Lighting	1.15	0.23	All LED
Garage Lights	0.33	0.06	LED with occupancy sensors
Garage Ventilation	0.28	0.05	CO/NOx control with VFD
Elevator	0.17	0.03	Typical high efficiency elevator
SUBTOTAL	20.14 kBtu/sf	3.99 lbCO2/sf	
Tenant/Occupant Controlled			
Hot Water	5.97	1.18	Electric water heater with low flow fixtures
Apartment HVAC	4.1	0.81	VRF System with cycling fans
Plug Loads	3.07	0.61	Typical, not under influence of project team
Stove	2.06	0.41	Electric
Clothes Dryer	2.05	0.41	Energy Star, electric
Unit Lights	1.4	0.28	All LED
Refrigerator	1.28	0.25	Energy Star
Dishwasher	0.87	0.17	Energy Star, includes water heating
Clothes Washer	0.43	0.09	Energy Star, includes water heating
SUBTOTAL	21.23 kBtu/sf	4.21 lbCO2/sf	
TOTAL	41.4 kBtu/sf	8.2 lbCO2/sf	

Table 6: Estimated Energy Demands and Source Carbon Emissions for Office Buildings

End-Use	EUI kBtu/sf-yr	Source Carbon Emissions lbCO2/sf-yr	Basis of Design
Owner Controlled			
HVAC & Ventilation	15.36	3.04	
Owner Lights	0.88	0.17	LED with occupancy sensors
Garage Ventilation	0.77	0.15	Reduced cfm/sf with CO/Nox controls
Garage Lights	0.74	0.15	LED with occupancy sensors
Owner Miscellaneous	0.68	0.14	Trash compactors, booster pumps, etc
Elevator	0.37	0.07	Regenerative elevators
Hot Water	0.15	0.03	Electric water heater with low flow fixtures
SUBTOTAL	18.94 kBtu/sf	3.75 lbCO2/sf	
Tenant/Occupant Controlled			
Tenant Data & Support	8	1.58	Typical
Tenant Plug Loads	7.47	1.48	
Tenant Lights	5.42	1.07	LED with occupancy sensors
SUBTOTAL	20.89 kBtu/sf	4.13 lbCO2/sf	
TOTAL	39.84 kBtu/sf	7.88 lbCO2/sf	

Key conclusions and points of note from the analysis that have informed the potential EUIs are listed below. These points emphasize the level of accuracy and likelihood that operational performance will be realized that corresponds to modeled performance.

1. Ventilation Loads – Ventilation loads represent a significant portion of the overall building loads. Ventilation is required under building code and the LEED rating system, ensuring that quality air is provided throughout the space for the health and wellbeing of the

occupants. Our region is also unique in that we see a wide range and high variability of temperature and high humidity levels that requires a sufficient amount of energy to take that air from an outdoor to neutral condition before it enters the space. This ensures buildings do not experience moisture issues that could lead to indoor air quality issues. There are strategies available to mitigate the high energy use of ventilation systems through set point controls, etc but the ventilation load cannot be completely removed from the building.

2. Ventilation strategy – A centralized apartment ventilation strategy was included as part of this analysis, which decouples the apartment ventilation and HVAC equipment. There is an option to ventilate apartments locally, ducting outdoor air horizontally to the HVAC unit. HVAC equipment energy use for the apartments would increase under this scenario if the fan operates continuously. To mitigate fan energy use a time-averaged or occupancy-based control of the HVAC equipment is suggested.

3. Owner vs Tenant Loads – The owner has the ability to influence the energy usage of a select number of systems and elements within the building. There are many end uses that are directly under the influence of the tenant. For example, residential unit level plug loads, lighting, hot water, and appliances (all of which are assumed to use high efficiency technology) are occupant driven and require approximately 15-20+ kBtu/sf-yr, about half of the total energy consumption, before adding in additional energy end uses like ventilation and heating/cooling in the multifamily example above. One strategy to incentivize tenants to reduce occupant driven energy consumption is through tenant metering.

4. Variability in Energy Use by Project Type – A wide range of retail and hotel project types exist that can result in a wide range of reported EUIs. Simple motels or small hotels consisting primarily of guest rooms can achieve very low EUIs. Larger hotels with banquet/conference space have significant additional loads. It is anticipated that a hotel within this development would have banquet/conference space; therefore, the target EUI reported herein is approximately the same as the median US EUI. Retail energy intensity can also vary greatly based on the type of business which is apparent in the Median US EUI. Considering anticipated location and size of retail in the development (multiple spaces on the 1st floor) and scope of retail fit-out (mechanical, electrical, plumbing by retail tenant), maintaining flexibility in target is appropriate.

5. Measured Performance - Many energy models use unrealistic assumptions related to occupant behavior and building performance and as such significantly under-predict operational EUI.

6. Timely and Relevant: Accuracy - SBP has compared multifamily models to recently constructed buildings benchmarked as part of DC's BEPS law. SBP generally sees actual performance within 10% of modeled performance which is in line with International Performance Measurement and Verification Protocol (IPMPVP) standard for measurement of accuracy.

Second: Design all-electric buildings

This section focuses on the decarbonization of the electric grid and its impact on the decarbonization of the North Potomac Yard Landbay F Phase 1 development. It considers the impacts of strategies during this transitional period to all-electric buildings.

For reference, the EPA quantifies and communicates the carbon emissions relative to grid electricity generation in the Emissions and Generation Resource Integrated Database (eGRID). eGRID breaks the United States into 26 subregions based on the unique make-up of fuel sources within the region, plant and parent company ownership and affiliations, and grid configurations in order to calculate emissions factors. Virginia is located within the SRVC subregion. The predominant fuel types in 2018 within the SRVC subregion include gas, coal, and nuclear representing 91.5% of the total generation fuel sources. In comparison, these fuel sources represent 82% of the total national generation types. As of 2019, the SRVC grid's carbon emission intensity is 675.42 lb/MWh of energy generated.

Electrification of demand-side assets is a key component to the overall decarbonization of the built environment. This transfers consumption and emissions from the demand sectors to the power sectors. NREL indicates that electrification will result in system-wide energy and carbon emission reductions in both sectors. However, generation capacity is anticipated to double between 2018 and 2050 to meet future energy demands. The overall impact and contribution of electrification to decarbonization is highly dependent on market conditions, technology advancement, and policy implementation[5]. A combined approach will yield the best results in a shorter timeline. Considerations relative to these three driving forces include:

> <u>Non-electric resistance solutions:</u> The overall demand on the power sector will influence its ability to deploy power generating solutions that do not emit carbon. Specifically, equipment and appliances that use electric resistance to heat air and water is an extremely inefficient use of a unit of energy (kWh), using three times more energy than it's natural gas counterpart. The overall impact on the utility is apparent and heightened if the industry relies on electric resistance technology to decarbonize the built environment. As such, technological advances and alternative solutions to electric resistance that can be implemented for both small and large-scale projects ensures the grid can react and scale to meet an increase in energy demands using non-carbon emitting power generating sources.

> <u>Decarbonization through policy:</u> Specific to Virginia, The Virginia Clean Economy Act (VCEA) was passed April 2020 which promotes and requires energy efficiency standards and clean energy solutions. Notably, the law requires Dominion Energy Virginia to be 100% carbon-free by 2045 by retiring facilities that emit carbon to produce electricity and constructing, acquiring, or entering into agreements to purchase generating facilities that use renewable energy. As such, the law implements a mandatory Renewable Portfolio Standard (RPS) program within the Commonwealth. Other notable requirements and provisions include construction of energy storage capacity, implementing net metering programs, building offshore wind, and reducing the minimum thresholds for power purchase agreements (PPAs).

Limiting factors in the goal toward advancing non-electric resistance based solutions at scale include the following:

- <u>Heat pump technology for central ventilation</u> – Dedicated outside air (DOAS) units typically use gas for reheat, which is the most energy efficient but not the most low carbon way to condition outside air. A current alternative would be an all-electric DOAS; however it is generally limited to electric-resistance heating since large-capacity heat pumps are not commercially available above 70-tons. A large electric resistance heating coil will yield a significant increase in peak electric demand (kW), energy cost, source greenhouse gas emissions, and a net reduction in overall ASHRAE energy cost savings as compared to the gas or heat pump counterpart. Additionally, the significant increase in peak electric demand associated with electric resistance heating would likely require added electric capacity at the

[5] NREL's *<u>Electrification Futures Study: Scenarios of Power System Evolution and Infrastructure Development for the United States</u>*

building and could cause strain on the local electric grid's stability. It would also increase the size of the unit potentially infringing on other sustainable roof elements. Heat pump technology at the DOAS could result in a ~5.1 COP providing a low carbon option that outperforms both options currently available on the market (gas and electric-resistance). This technology is not widely available but manufacturers are working to address this challenge.

- Heat pump hot water heater – A potential air-cooled domestic hot water heat pump for a multifamily project would entail a centralized domestic hot water plant equipped with a series of 120-gallon heat pump water heaters designed at ~4.2 COP. HP water heaters are similar in configuration to a standard electric resistance storage heater, but significantly outperform them by using a heat pump system. The limiting factor is that these units are only available at residential scale (120-gal max) so a significant amount of these units would be required to satisfy the building DHW load and they must be housed in an enclosed and ventilated mechanical room to properly convert the ambient air conditions to water heating. Currently, these systems have been found to be feasible for small-scale multifamily buildings but are generally not feasible for large-scale multifamily buildings. This technology may be available in the relatively near future; however, a timeframe for market viable technology is unknown right now as manufacturers work to develop their future product lines.

Third: Research and incorporate renewables to the extent feasible

On site renewable energy reduces the energy demand of the building and on the utility and is a key element to the decarbonization of the built environment. Several renewable energy strategies are available including solar photovoltaic (PV), solar thermal, wind, hydropower, and geothermal[6]. Solar PV is the only feasible and promising renewable energy technology for integration in to the overall development scheme when considering FAA regulations, proximity to hydropower resources, and surface area.

The project team has engaged a PV company to evaluate theoretical layouts for on-site PV. The potential layouts maximize PV potential using a ballasted and/or canopy structure which are the simplest in terms of attachment and integration into the current building design. These layouts were used to evaluate the ability of PV to meet the requirements and goals of the development.

Potential layouts for each block are similar to Figure 15, with pink areas representing ballasted PV on roof or green roof and blue areas representing PV on a canopy structure. A canopy option has limited feasibility for this project in this location.

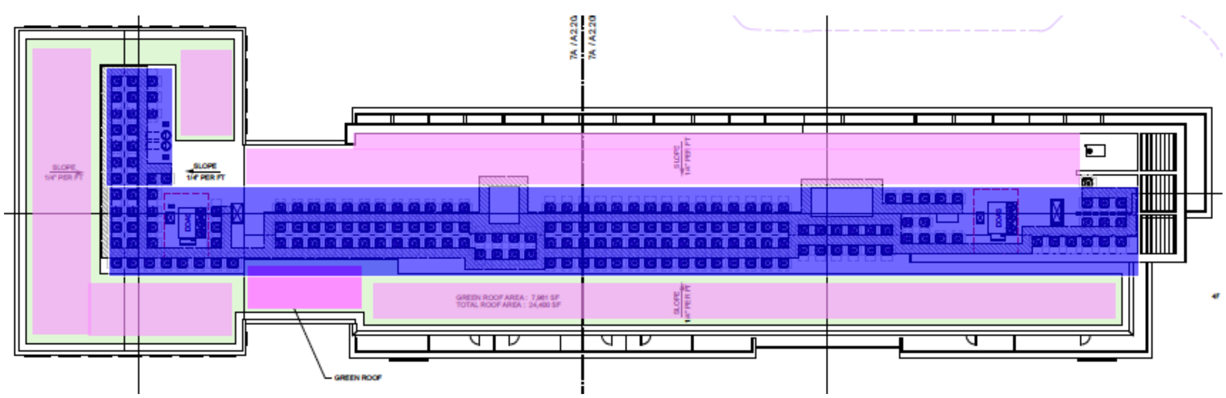


Figure 15: Potential PV Layouts

[6] *Ground Source Heat Pump – although sometimes termed a renewable energy source, ground source heat pumps are not a renewable energy source and is instead a heat source/sink.*

The results for each building relative to the goals and requirements are summarized in Table 7. The optimized PV design has the potential to offset 6% of the total Phase 1 development annual energy use.

Table 7: Theoreteical PV Performance

Building	Type	Site EUI (kBtu/sf)	Solar Production (% annual energy use)
Block 4	Office	40	0%
Block 7	Academic	75	6%
Block 10	Office	40	14%
Block 14	Office	40	3%
Block 15	Residential	47	6%
Block 19	Residential	45	5%
Block 18	Office	40	5%
Block 20	Residential	45	10%

The project team is pursuing solar-ready infrastructure for the development blocks. Solar-ready will include design and building elements such that future PV installation can be accomplished with minimal impact to the building. The project team acknowledges the benefits of on-site solar PV, in combination with off-site renewables, in decarbonizing the built environment and continues to explore potential applications for on-site PV.

Fourth: Research and Purchase PPAs and/or RECs and/or industry accepted credits.
Off-site renewable energy installations and purchases are a key element in a resilient and decarbonized future. These mechanisms allow renewable energy projects to be deployed and financed at scale, avoiding typical boundaries to on-site PV for urban-based projects. Off-site renewable energy falls into two categories – mandatory compliance based purchasing and voluntary purchasing. Mandatory compliance based purchasing are set by states through policy and voluntary based purchasing includes mechanisms such as the following:

Renewable Energy Certificates (RECs) represent one megawatt-hour (MWh) of electricity generated by a renewable energy source connected to the grid. A REC does not represent a direct purchase of renewable energy or the physical delivery of renewable energy to the building. It may also not represent a renewable energy source tied to the project's grid. Instead it is a market commodity and instrument to verify renewable electricity use claims and fuel renewable energy projects by tracking and assigning ownership to renewable energy generation. Green-e certified RECs are strongly encouraged since Green-e acts as a third-party that ensures the purchaser receives verified clean energy and gets what they paid for. The price of a REC is based on supply and demand. The REC market is highly volatile due to increased demand and interest in cleaner energy purchases.

Power Purchase Agreements (PPAs) represent a contract with a renewable energy generator. In the case of Virginia, it sits in both the retail and PJM unregulated markets. Most buildings and projects would be required to purchase their electricity through the retail market, which is comprised of Dominion and Appalachian Power, but would have access to the unregulated market to contract off-site renewable energy sources. There are two types of PPAs:

- A Direct PPA is a direct purchase of renewable energy and the physical delivery of renewable energy to the project through the grid. Since the delivery is through the grid, the full electricity demand of the building may be met by both renewable and non-renewable energy sources.

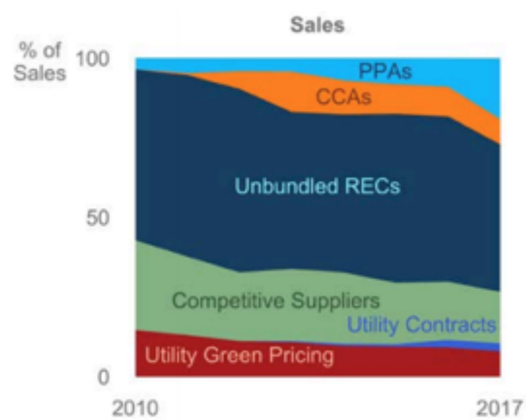
- A Virtual PPA is a financial instrument whereby renewable energy output and RECs are purchased at a set price but then sold into the wholesale market. The buyer is subject to the fluctuations in wholesale price of electricity on a daily basis and therefore may earn or pay money, also known as a "contract for differences".

Virtual PPAs have gained significant traction in the industry due to the financial component of the contract structure. As a result, it has spurred significant growth of off-site renewable projects in the United States. Buyers benefit from economies of scale and therefore PPAs are more attractive to both the buyer and seller for large-scale projects, typically comprised of non-residential buildings and large corporations. The market is responding and a buyer aggregation contract structure is starting to develop, but the contract structure still typically includes one large commercial buyer coupled with smaller commercial buyers representing at least 10 MW of energy use.

Electric Provider Programs include various options where the customer purchases or participates in a program through their utility including but not necessarily limited to:

- REC purchase
- Renewable attribute purchase
- Shared solar subscription

These programs are valuable options for small businesses, multifamily residential buildings, and single family homeowners who don't have the economies of scale to participate in a PPA. Of note, the Virginia Assembly enacted new sections under the Code that allows Dominion Energy Virginia customers to participate in shared solar projects by purchasing subscriptions to a shared solar facility. This option is very new and interested customers can only now start registering to participate (as of July 1, 2021).



Reference 3: Trends in Green Power Market

Community Choice Aggregations (CCAs) allow communities to aggregate their loads collectively to procure green power as a single bulk purchase. This mechanism addresses the issues of PPAs for residential customers. However, it is limited to states with an investor-owned utility such as Illinois, California, Ohio, Massachusetts, and New York.

Carbon Offsets are sometimes referenced in the same context as RECs and PPAs; however, they are fundamentally different. REC and PPA purchases drive new renewable energy sources onto the market and can offset Scope 2 emissions and decarbonize purchased electricity whereas a carbon offset purchase secures a reduction of carbon emissions someplace to neutralize or offset carbon emissions on site.

Carbon Sequestration

Carbon Sequestration is the process of capturing and storing atmospheric carbon dioxide. Plants naturally sequester atmospheric carbon during photosynthesis. Concrete paving materials (e.g. pavers, sidewalks, etc.) also sequester CO2 due to the porous nature and chemical properties of the material, allowing CO2 to react with and bind to molecules in exposed concrete.

Climate Positive Design's Pathfinder Tool was used to analyze carbon sequestration impact. The tool quantifies cradle to grave emissions associated with carbon sources (construction materials), carbon costs (replacement and maintenance), and carbon sinks (vegetation). For the purpose of this analysis, the Pathfinder Tool evaluates impact over a 50-year period. North Potomac Yard Phase 1 includes a large public park and 9 proposed building blocks with green roofs and outdoor areas. The proposed vegetation types and paving materials for the site development currently reflect a Carbon Neutral Site by 2043 (see Figure 16).

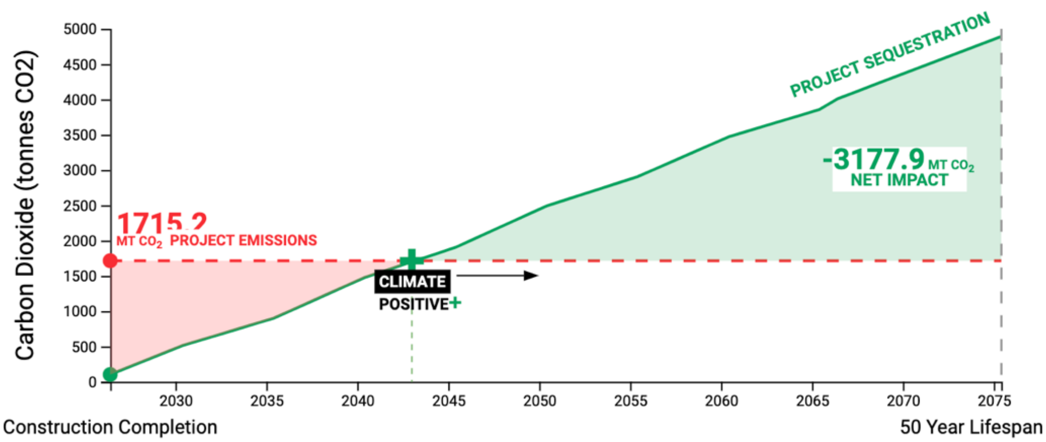


Figure 16: Phase 1 Site Carbon Sequestration Potential

Potomac Park is the largest contributor to the site's carbon sequestration effort. Based on Table 8, the park will sequester 23.1 lb CO2e per square foot over a 50-year period whereas the buildings will only sequester an average of 9.3 lb CO2e per square foot over 50 years.

Table 8: Net Carbon Sequestration Impact over 50 Years

Facility	Carbon Sequestered, Landscaping (lb CO2e/sf)	Embodied Carbon, Site Materials (lb CO2e/sf)	Net Impact (lb CO2e/sf)
Potomac Park	+23.1	-2.6	**+20.5**
Average Building	+9.3	-5.5	**+3.7**

- Vegetated Roof provide some level of carbon sequestration, but have limitations in terms of available area and depth of soil for large plantings.
- Plant size and type impact carbon sequestration capacity and rate. In general, larger and deciduous plantings will sequester more carbon over their lifetime when compared to smaller shrubs and evergreen plantings.
- Impervious materials, like concrete, do sequester carbon throughout the use phase. However, these materials typically emit much more carbon than is sequestered.

Transportation

To move people around, any form of transportation requires emissions. Even some of the most sustainable transit (walking) causes minor CO2 emissions. Furthermore, as a society, we value time and convenience. While walking and biking may generate less emissions, it may not be feasible considering the distance. In order to optimize transit, providing option, reducing emissions, and increasing vehicle efficiency are necessary. There are two types of pollutants from vehicle emissions:

- Direct emissions - Standard vehicle emissions include tailpipe emissions, evaporation from vehicle fuel systems, and evaporation during the fueling process. Electric vehicles create zero direct emissions.
- Well-to-Wheel emissions - Standard vehicles use gas; emissions are created from extracting, refining, distributing, and burning petroleum. Electric vehicles (EVs) use electricity; emissions are attributed to the fuel source of the power plants, which also includes extracting, processing, and distributing the fuel to the power plant.

The US Department of Energy quantifies average annual emissions of each vehicle type. Equivalent carbon emissions for vehicle type based on the carbon intensity of the SRVC grid (675.42 lbCO2/MWh) are shown in Figure 17.

While minor changes to the car design can make it more efficient, the emissions associated with gasoline production and combustion are fairly consistent. In contrast, carbon emissions from electric-powered vehicles are less consistent and driven primarily by the carbon intensity and fuel source of the grid. These emissions translate to electric vehicles at the charging location.

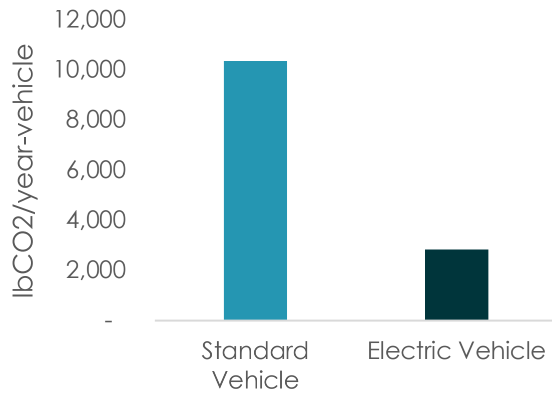


Figure 17: Vehicle Emissions

A reduction in carbon emissions from electric vehicles is dependent upon the decarbonization of the electric grid. The rate at which this will occur is covered in the Operational Carbon section. While the instinct may be to rush to install EV chargers, it is important to consider the building's ability to meet power demands, the utility's request to demonstrate a need for energy, grid reliability and rate of decarbonization, and future modes of transportation. Installing just enough EV charging to stimulate the market may strike the right balance between progressing decarbonization of transportation and preventing a sharp increase in electrical demand.

Carbon emissions can also be reduced by encouraging less single-occupancy vehicle use, regardless of the type of vehicle. The following strategies and programs are being implemented to support this goal and have directly impacted the number of parking spaces provided within Phase 1:

- Building dense, mixed-use developments
- Providing public Transit: Potomac Yard metro station, Rapid Bus transit line, GO Alex, etc.
- Providing bicycle networks: dedicated and connected bike network/lanes, Capitol bike share
- Offering rideshare and other incentives: City of Alexandria incentives

Waste

According to the EPA GHG report, 91 million metric tons of CO2e were emitted in 2019 from municipal waste facilities, which is 82% of the total direct emissions from saste. Methane, carbon dioxide, and many other compounds are associated with emissions contributing to global warming. Other considerations associated with landfill waste include soil contamination and impact to the local air quality. Key strategies to reducing greenhouse gas emissions from waste include recycling and composting:

> Recycling limits the amount of waste in landfills and reduces the need for virgin materials and the associated greenhouse gas emissions from extracting raw materials and processing materials to make new products. methane, which is a major byproduct in landfills can be 20-35 times more effective at storing heat in the atmosphere than carbon dioxide.
>
> Composting allows organic waste to naturally decompose. When organic waste enters a landfill, the decomposition process is anaerobic, or lacking oxygen. The anaerobic decomposition process results in a byproduct of methane and carbon dioxide. Composting allows for an aerobic decomposition process where free flowing oxygen facilitates microorganisms to break down the waste into a useful byproduct for future use.

Based on the Public Solid Waste Services in Northern Virginia and the District of Columbia report issued July 2020, the per capita waste is reported to be 5.99 pounds waste per day and 2.4 pounds recycling per day. The EPA quantities the metric tons of CO2 emitted from waste at 2.9 mTCO2e/ton of waste generated.

The total mT CO2 for three waste scenarios are shown in Figure 18. The recycling scenario assumes a 50% recycling rate for offices and 28% recycling rate for multifamily. The compost + recycling scenario assumes half of landfill waste could be directed to composting.

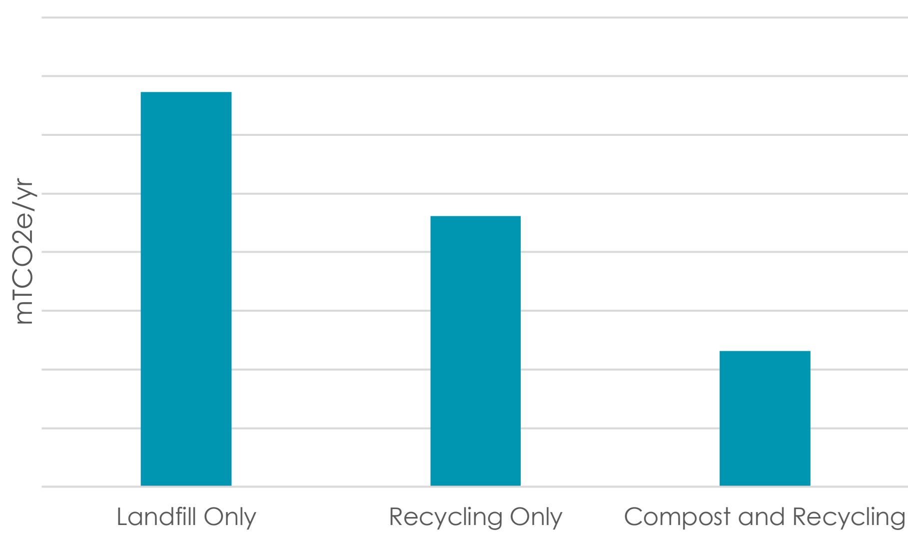


Figure 18: Carbon emission for Different Waste Streams

Refrigerant

Refrigerants are critical to refrigeration and air conditioning systems used to maintain building operation and function. There are two main impacts most refrigerants have on our environment: depletion of the stratospheric ozone layer (ODP) and contribution to global warming potential (GWP), or carbon dioxide. The Montreal Protocol is a multinational agreement to regulate the production and consumption of chemicals that contribute to ozone depletion. The agreement is the only treaty that was adopted by all UN member nations and is an evolving process based on new technologies and studies. Table 13 below summarizes the impact.

Table 9: Summary of Refrigerants in the Montreal Protocol.

Main Types	Refrigerants	Montreal Protocol Status	Impact*
CFC *chlorofluorocarbons*	R-11, R-12, R-114, R-500	Phased out	ODP: 0.2 - 1.0 GWP: 4,000 - 10,000
HCFC *hydrochlorofluorocarbons*	R-22, R-123	Phasing out 2020 developed countries	ODP: 0 - 0.04 GWP: 1,000 - 12,000
HFC *hydrofluorocarbons*	R-23, R-134a, R-407a, R-410a	Phase down 80-85% by the late 2040s	ODP: 0 GWP: 75-2,000
Natural refrigerants	CO_2 ammonia	Acceptable	ODP: 0 GWP: 0-3

*ODP = lbs CFC/lb refrigerant GWP = lb CO2/lb refrigerant

The North Potomac Yard Development will not include CFCs or HCFCs since they are currently phased out of new equipment. HFCs are currently widely used in our market (such as R-410a) and do not contribute to ozone depletion. However, these refrigerants will have a carbon impact which is communicated in terms of Global Warming Potential (GWP). For comparison,

The use of natural refrigerants have a lower GWP but would comprise performance and efficiency:

- Propane is highly flammable.
- Ammonia is highly toxic and corrosive.
- Propane and Carbon Dioxide must be operated at a high pressure.
- They do not operate as efficiently as hydrocarbons
- They may require more electricity to provide the same amount of cooling.

Technology is evolving and new refrigerants are under development that reduce environmental impact, increase equipment efficiency, and avoid other hurdles of natural refrigerants.

Resources

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https://alexandriava.gov/uploadedFiles/tes/EAP2040v25.pdf

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https://www.manufacturingtomorrow.com/article/2017/09/how-to-solve-the-challenges-of-using-natural-refrigerants-in-cooling-system-design/10361

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https://www.epa.gov/snap/substitutes-residential-and-light-commercial-air-conditioning-and-heat-pumps