Potomac River Generating Station Redevelopment

Carbon Neutrality Analysis

Alexandria, VA

April 7, 2022

SUSTAINABLE BUILDING PARTNERS

2701 Prosperity Ave, Ste. 100
Fairfax, Virginia 22031
www.sustainbldgs.com

Table of Contents

Executive Summary

Power Plant Transformation

The project site is the location of the former Potomac River Generating Station (PRGS), a former coal-fired power plant, in Old Town North Alexandria, that was permanently deactivated in 2012 after 63 years of operation. The 514 MW facility emitted 3.15 million metric tons[1] of CO2e annually, among other contaminants, or nearly 200 million metric tons of CO2e over the course of its operation. Upon acquiring the PRGS site, Hilco Redevelopment Partners (HRP) entered it into the Voluntary Remediation Program (VRP) administered by the Virginia Department of Environmental Quality (VDEQ) in February 2021. Building abatement and soil remediation work will be performed as part of the redevelopment project.

The Old Town North Small Area Plan (OTN SAP) recommends that the Potomac River Generating Station site (PRGS) "strive to achieve carbon neutrality by 2040 and strive to achieve carbon neutral buildings by 2030". HRP proposes to transform the PRGS site into a mixed-use neighborhood that will reconnect this property into the surrounding community and revitalize the location as envisioned in the OTN SAP. The former power plant was closed as a result of the work and advocacy by the community and the City of Alexandria. The future redevelopment project **represents a 99.07% reduction of annual CO2e emissions** from its former use as a coal-fired power plant.

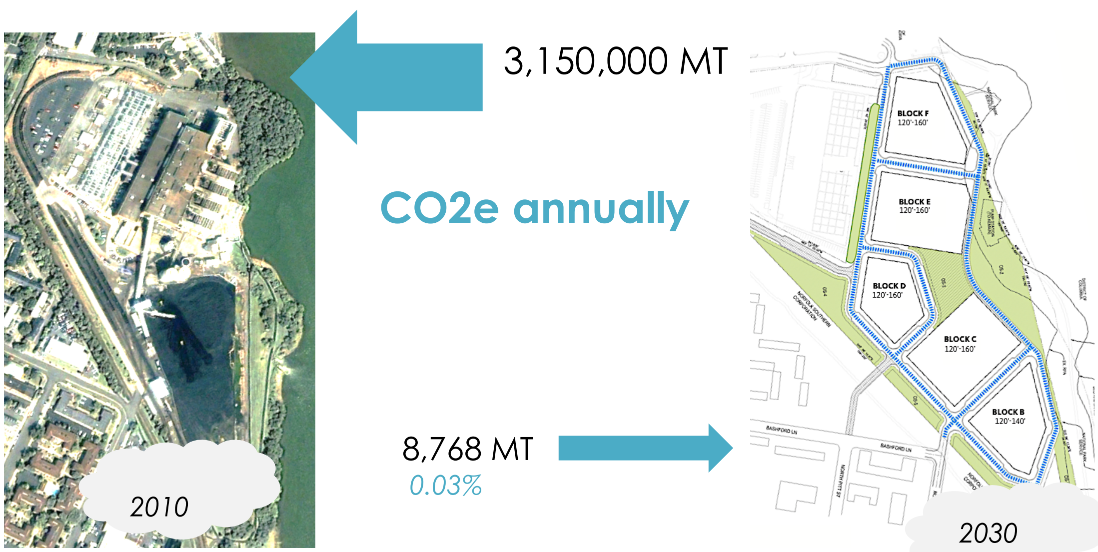


Figure 1: Power Plant Carbon Impact

Redeveloping this former industrial age site into a walkable, mixed-use, energy efficient district significantly reduces carbon emissions at the PRGS site.

[1] Carbon Brief - https://www.carbonbrief.org/mapped-worlds-coal-power-plants

Intent of this Analysis

HRP is committed to providing a sustainable neighborhood for the Alexandria community with the redevelopment of the PRGS site, a former coal-fired power plant. The **purpose** of this Carbon Neutrality Analysis (CNA) is to inform and communicate the strategies that will improve building and site performance over widely-accepted industry benchmarks, and progress toward carbon neutrality as phases of the project are developed.

Sustainable Building Partners (SBP), HRP, and the PRGS project team are studying the feasibility of various potential strategies to decarbonize the PRGS site using this CNA as a framework for decision-making as the design of the project progresses. This CNA supports the understanding, benchmarking, and path toward carbon neutrality for the project, consistent with the goals outlined in the OTN SAP (Section 6.3.III.A.12).

III. ENERGY AND GREEN BUILDING

A. District-Wide Sustainability Measures – Former Power Plant Site

10. Require plan area-wide sustainability through LEED-ND silver or comparable.

11. Require the submission of a Sustainability Master Plan for the former power plant site as part of the submission of the first development special use permit (DSUP) that demonstrates the compliance with the goals and recommendations of the Plan and identifies short-term, mid-term, and long-term strategies and targets to achieve the goal of district-wide sustainability measures. The Sustainability Master Plan should be updated with each subsequent block(s) and/or building(s) to show how the project achieves the Plan's goals.

12. The redevelopment of the former power plant site should strive to achieve carbon neutrality by 2040 and strive to achieve carbon neutral buildings by 2030.

13. Explore the development of district energy systems for heating and cooling on the former power plant site that take advantage of local renewable energy sources, including, but not limited to, geothermal energy, sewage heat, anaerobic digestion, and waste heat from buildings.

B. Energy Use

14. Encourage on-site generation and storage of renewable electricity from solar photovoltaic (PV) and other available renewable resources.

Reference 1: OTN SAP

Carbon Neutrality is achieved through the reduction of onsite carbon emissions resulting from both operational and embodied sources, to the greatest extent feasible, and then offsetting any remaining carbon emissions through the use of on- and offsite renewable energy sources and carbon offset purchase agreements with utility companies.

Carbon emissions include the following and are defined as:

- **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 including emissions avoided by renewable energy production.
- **Carbon sequestration** is the process of capturing and storing atmospheric carbon dioxide via plants and materials.

The redevelopment of the PRGS site is at a very conceptual master planning stage which presents challenges for analyzing specific solutions given the number of unknowns. However, efficiency targets can be set that will help frame future carbon analysis decisions related to the design, engineering, and construction of each phase of the project.

The PRGS framework for **Carbon Neutrality** [2] includes the following goals:

- **Operational Carbon:** Minimum 25% energy efficiency reduction from ASHRAE 90.1-2010 standard
- **Embodied Carbon:** Minimum 10% embodied carbon reduction from an industry baseline[3]
- **Electrification:** Limit onsite combustion equipment, to the greatest extent feasible[4]
- **Onsite Renewable:** Onsite solar panels to the greatest extent feasible[5]
- **Offsite Renewable:** The remaining balance of carbon is addressed via virtual Power Purchase Agreements (PPA), carbon offsets, and renewable energy certificates - additionality[6] (RECs)

This CNA evaluates the total net carbon impact, or total embodied and operational carbon emissions, of the development on an annual basis starting at Year 0 of building operations, the year when all the buildings in the development are delivered.

---

[2] The framework for Carbon Neutrality is adopted from the International Living Future Institute (ILFI) Zero Carbon Certification living-future.org/zero-carbon-certification/

[3] Embodied carbon industry baseline is further defined on pages 32-33

[4] Electrification with the exception of the following: commercial kitchens, emergency uses, for-sale residential kitchens.

[5] The extent of onsite solar photovoltaic panels depends based on available roof space and other competing priorities including open space, building mechanical equipment, amenity space.

[6] "Additionality" is a term adopted by the renewable energy industry to describe when an organization's PPA has the direct effect of adding renewable energy new renewable energy generation to the grid; i.e. without the organization's involvement (PPA) the clean energy project would not have happened (further defined on pages 29-30)

This analysis is the first of many steps to ascertain the potential paths to carbon neutrality at the PRGS site.

As the design advances, the next steps in analyzing the potential for carbon neutrality include:

- Conduct whole building energy modeling to maximize energy savings.
- Design the project to maximize electrification in anticipation of the decarbonization of the electric grid.
- Incorporate on-site renewables to the extent feasible and purchase off-sets to support greening the electric grid.
- Identify embodied carbon in materials through a whole building life cycle assessment.

In addition to operational and embodied carbon, which is the primary focus of this CNA, the following additional emissions elements are addressed in the Appendix:

- Sequestration
- Transportation
- Waste
- Refrigerant

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 conceptual building massing and currently available technology. While this analysis identifies strategies to reduce carbon emissions in the built environment that SBP and HRP will continue to study, at this early stage of the design, it is not possible to select exactly which materials, methodologies, and technologies will be employed. These strategies will continue to be studied for their impact and feasibility and appropriately incorporated as the project advances toward building design.

Study Area Boundary and Elements

Existing Condition: The PRGS project is a redevelopment of a decommissioned power plant facility located on 18.8 acres in the Old Town North neighborhood of the City of Alexandria. The property contains the decommissioned power plant, transformers and electrical equipment, remnants of a rail yard, areas where coal and coal ash were formerly stored, and various support buildings, including a former pumphouse.

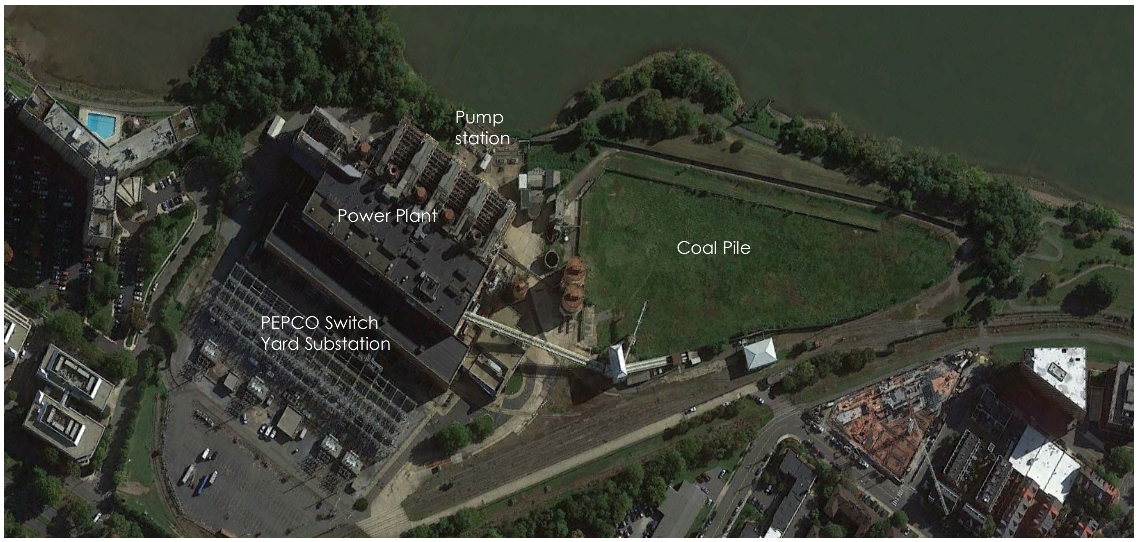


Figure 2: Existing Site Conditions

Proposed Condition: The PRGS site will be redeveloped in phases. The development will transform the location into a vibrant, urban, mixed-use community that will include office, residential, arts, hotel, entertainment, retail, and restaurant use. The property will be re-connected to the surrounding Old Town North neighborhood through the extension of the existing street network into the new development and the seamless integration of new publicly accessible parks with existing and future public open space.

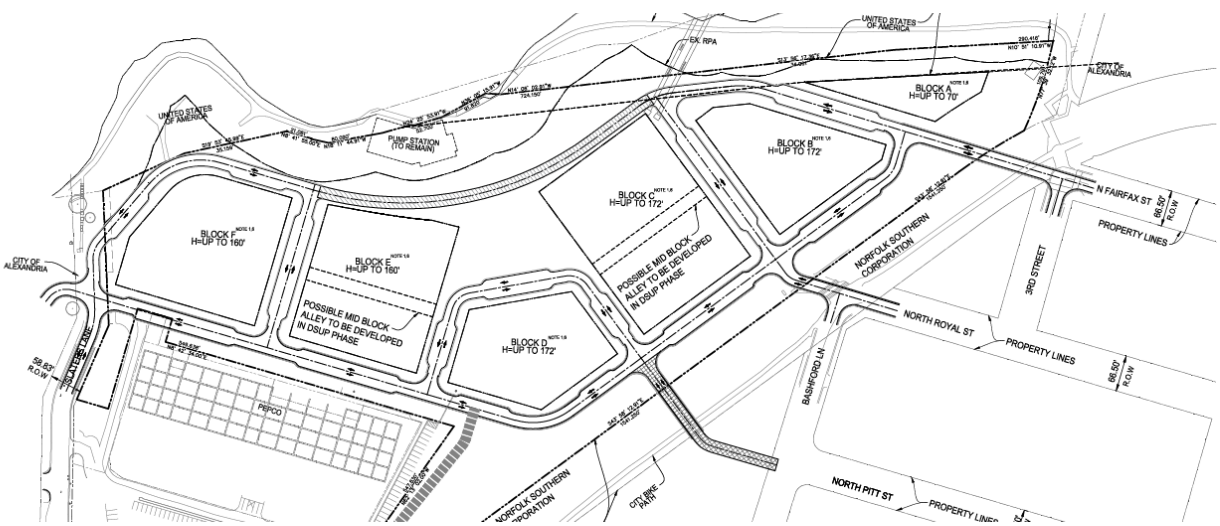


Figure 3: Proposed Site

Key components of the site and project are defined below:

- Site area is 18.8 acres, of which approximately 6-7 acres is developable for buildings.
- Adjacent to National Park Service and the Mount Vernon Trail to the east and an existing Pepco substation and Norfolk Southern land to the west and south.
- Proposed redevelopment of up to 2.5 million gross square feet of mixed-use development on six blocks.
- Delivers approximately 5 acres of onsite publicly accessible open space.

This CNA addresses the carbon emissions for the following elements over time:

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

Carbon Neutrality Framework and Strategies

The goal of carbon neutrality in the context of the built environment is to reduce or neutralize the cumulative carbon emissions produced by the creation and operation of buildings and their users. Reduction strategies and mechanisms can be implemented at various times throughout a project's lifecycle and certain strategies that may be infeasible today may become feasible in the future. Market conditions, industry transition, project location, and technological advancements can directly impact the feasibility of carbon reduction strategies and are therefore unique to a specific project.

This CNA establishes carbon emissions reduction targets and outlines possible strategies that can help advance the goal of carbon neutrality at the PRGS site. **Establishing efficiency targets at this early stage of project planning provides a framework for future analysis that can be used to inform decisions as the project design advances.**

The analysis uses a benchmark building based on typical building performance in the DMV (District of Columbia, Maryland and Virginia) area, as an industry baseline to set decarbonization targets for the PRGS project.

Figure 4 below depicts the estimated cumulative carbon emissions associated with a typical benchmark building over a 20-year time period. Anticipated carbon emissions sources include:

- Carbon emissions from material selections and construction methodologies as they relate to the substructure, superstructure, and building envelope
- Carbon emissions from resident, tenant, occupant and/or owner utilization of carbon emitting energy sources
- Carbon reduction measures from reduced onsite energy usage, usage of materials with low embodied carbon, onsite renewable energy generation, and offsite carbon offsets

The left side of the graph demonstrates that embodied and operational carbon emissions create a carbon profile, or carbon footprint, of 294,607 **metric-tons (mT)** over a 20 year timeframe. The right side of this figure shows how carbon emissions can be reduced through operational energy efficiency measures (hatched blue bar) and embodied carbon reductions (hatched dark green bar) to **230,071 mT** over 20 years, an estimated **reduction from industry benchmarks of 23%**. Remaining carbon reductions can be met through a combination of on-site renewable energy (e.g., solar panels) and off-site renewable energy (e.g., power purchase agreements) to help move us towards the goal of carbon neutrality as the electric grid itself is weaned from fossil fuel sources.

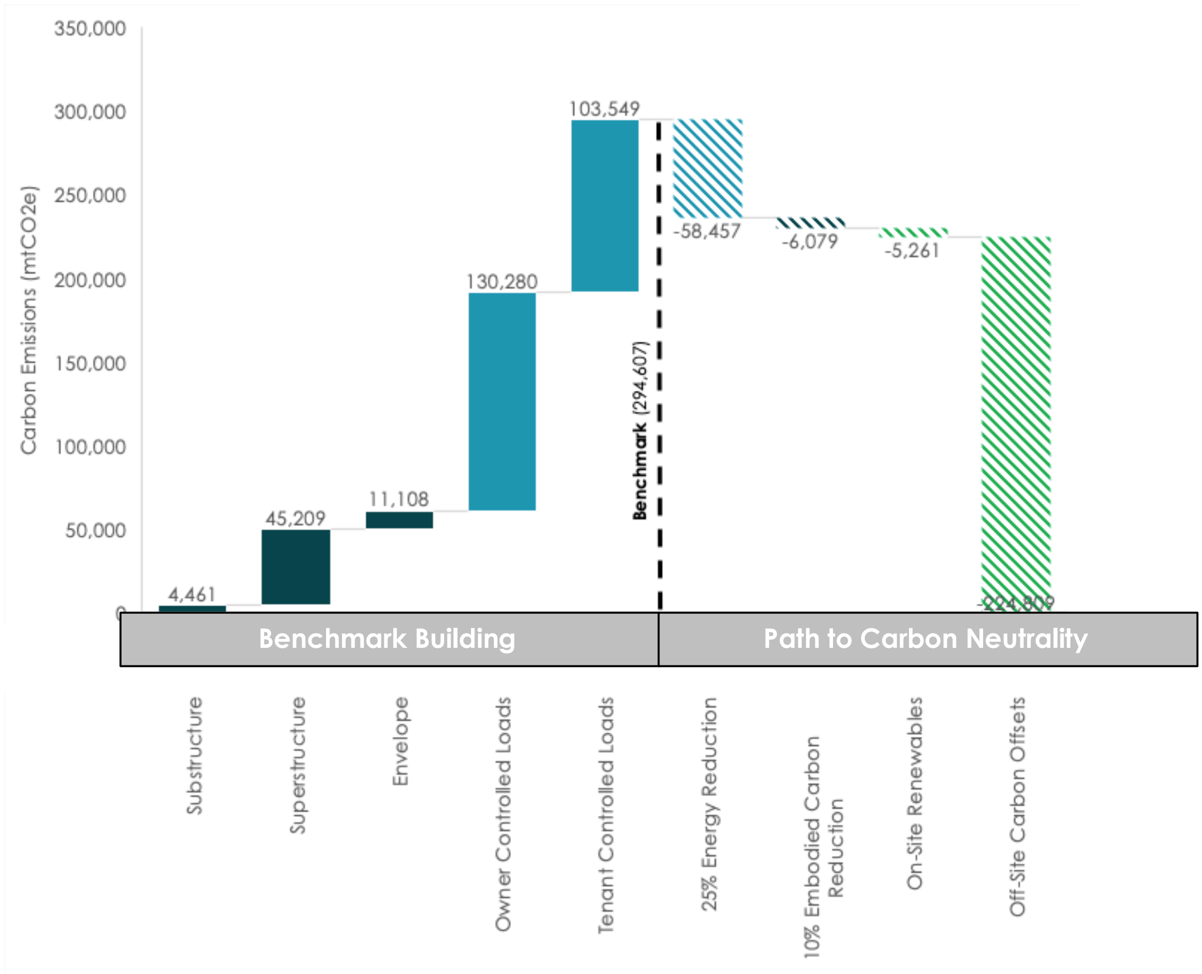


Figure 4: Benchmark Building and Path to Carbon Neutrality - Lifecycle Carbon Emissions (over 20 Years)

As shown in Figure 4, a variety of reduction strategies are required to fully offset the benchmark building's lifecycle carbon emissions. **No single strategy is sufficient and a combined approach involving significant offsite carbon offsets is necessary to achieve neutrality**.

The following sections explore each of these strategies in more detail:

- **Operational Carbon:** Minimum 25% energy efficiency reduction from ASHRAE 90.1-2010 standard
- **Embodied Carbon:** Minimum 10% embodied carbon reduction from an industry baseline
- **Electrification:** Limit onsite combustion equipment, to the greatest extent feasible
- **Onsite Renewable:** Onsite solar panels to the greatest extent feasible
- **Offsite Renewable:** The remaining balance of carbon is addressed via virtual Power Purchase Agreements (PPA), carbon offsets, and renewable energy certificates - additionality (RECs)

Operational carbon emissions occur as a result of energy usage when a building is in operation. The PRGS project is targeting a 25% reduction in operational carbon emissions from the industry baseline (ASHRAE 90.1-2010). In other words, by implementing energy efficiency strategies in building envelope and systems design, carbon emissions may be reduced from approximately 11,691 mT CO2/year to approximately 8,768 mT CO2/year, eliminating approximately 2,923 mT CO2/year (58,457 mT CO2 over 20 years). See Figure 5 below.

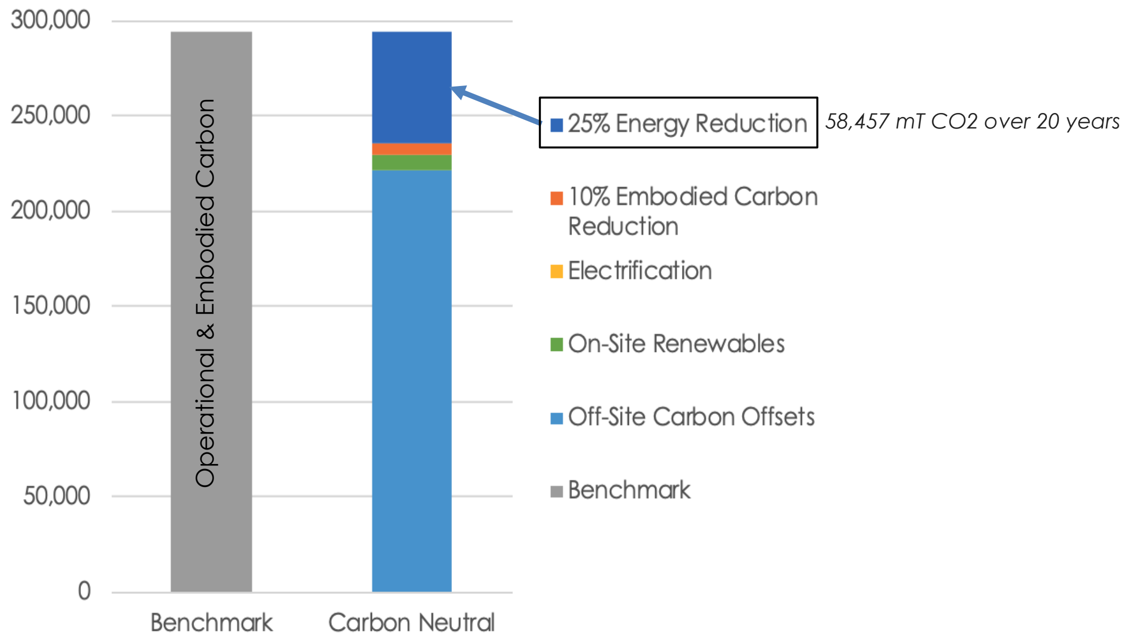


Figure 5: Carbon Neutral Solutions as Compared to Benchmark Building – Energy Reduction

<u>Key considerations and drivers relative to operational carbon include:</u>

- Energy efficiency and demand reduction is the first and most critical strategy to reduce carbon emissions in any project. Reducing the onsite energy demand lowers the burden on the utility grid, both overall and at peak load times.

- Ventilation loads required by code typically equate to a third of the total owner-controlled operational energy loads. There is technology that can mitigate the energy required, but it cannot be entirely removed. Heat pump technologies can be employed but are typically limited in capacity to around 60-tons, which means most buildings will require multiple units, which can create space and coordination issues on the roof. Energy recovery is also an effective strategy but requires considerable coordination to collect multiple exhaust streams to a central location. The effectiveness of energy recovery systems can also be reduced by unbalanced flows, which are difficult to avoid in multifamily buildings.

- Heat pump technology has advanced for large-scale water heating applications and has the potential to reduce energy consumption by 30-40% over a gas-fired central systems. Design challenges associated with this technology include limits in the performance of off-the-shelf systems. For example, the largest commercial system by AO Smith (AHPA 250) has a recovery rate of 340 gal/hr and a minimum operating temperature of 40°F. A typical 300-unit multifamily building, demonstrating the 30-40% reduction, would require approximately 25 units and 3,500 SF of roof space. Additionally, the system would require an additional 1 Megawatt of electric resistance backup for use during cold weather. These issues would impact available roof area for PV and building electrical service. Strategies including use of underground parking garage and/or residential corridors are being studied as potential alternate strategies to accommodate heat pump water heating. Custom units are also available at a considerable cost premium and are not able to fully mitigate limitations during cold weather operation.

- Direct tenant loads (unit lights, plugs, appliances) and base owner responsibilities (lighting, elevators, booster pumps, garage, etc.) represent over half (50-55%) of a building's energy usage (assuming EnergyStar appliances and high efficiency LED lighting). Although some opportunities exist to further reduce these loads such as high efficiency elevators, induction stoves, and additional lighting controls, opportunities are limited. This poses specific challenges for multifamily buildings since opportunities to generate additional savings are mostly limited to less than 50% of energy use. Tenant loads could shift with programming and are impacted in a great extent to individual uses in a multifamily unit.

Figures 6 and 7 show the carbon emissions profile of a multifamily building with an energy use intensity (EUI) of 45 kbtu/sf[7]. This profile represents a scenario for a potential design that puts the buildings in range of achieving the 25% energy efficiency target of this assessment. The carbon emissions for this building illustrate the relative carbon emissions from tenant loads and the challenges outlined in the bullet point above. The PRGS redevelopment team will be able to utilize these solutions to reduce energy usage and carbon missions to achieve our carbon neutrality goal.

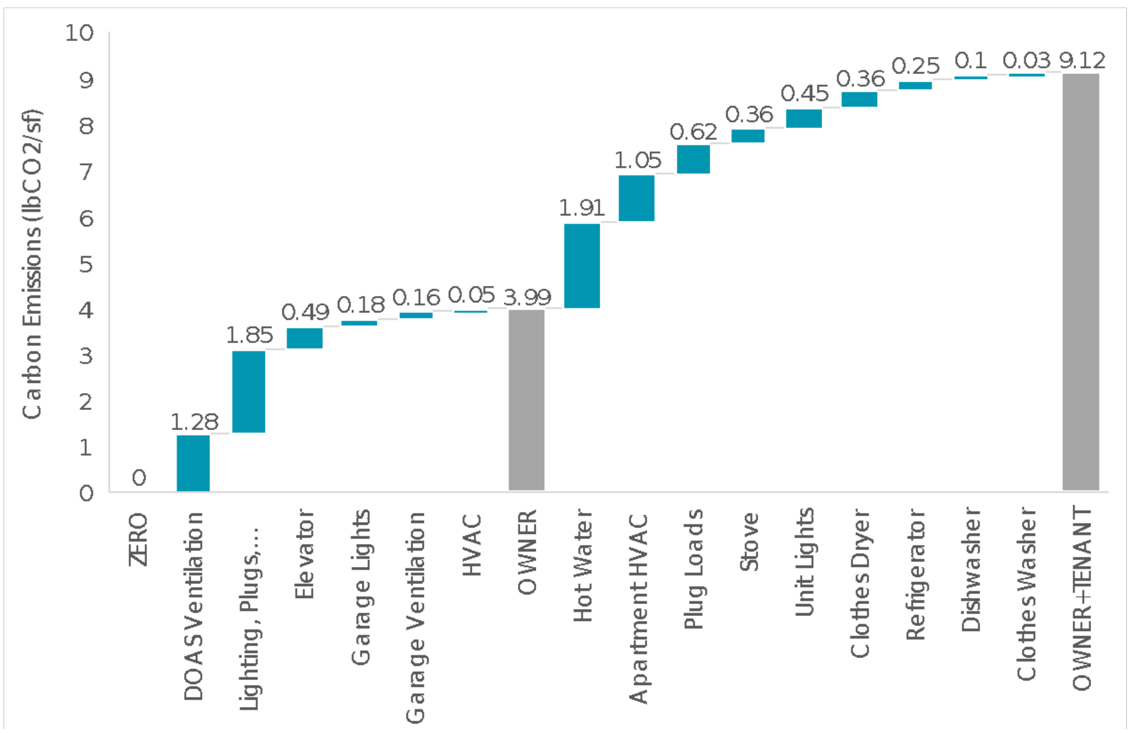


Figure 6. Typical Multifamily Building Operational Carbon Emissions

[7] Further information on EUI on page 24

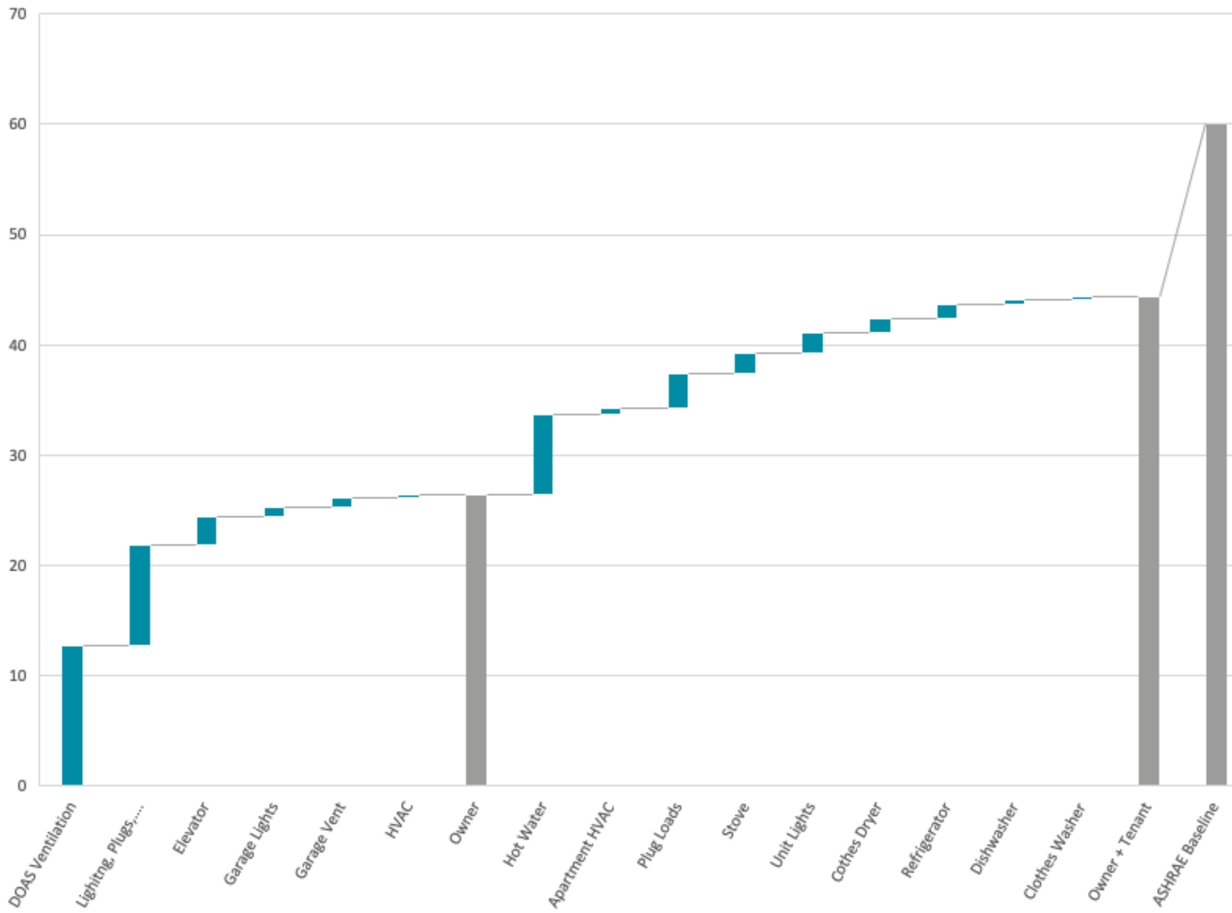


Figure 7. Typical Multifamily Energy Use Intensity (EUI) kbtu/sf

The PRGS development is considering a number of strategies to assist in meeting the carbon neutrality goal. The feasibility of a strategy includes a number of considerations which may include cost, physical limitations, customer expectations, and carbon impacts. At this early stage of the development, it is too early to definitively determine whether these technologies will be included. The following technologies have been identified through city and community engagement:

- District Wide Systems leverage the scale of the development to identify opportunities of shared energy resources that will work to reduce energy, reduce carbon footprint of the entire development, as well as creating an infrastructure for sustainable solutions.

  The PRGS team is actively researching these opportunities for shared HVAC response which includes centralized heating. Additionally, opportunities under investigation include cooling systems supplemented with ground source heat pumps and a possible central mechanical plant. These district wide systems are not limited to heating and cooling, but also include identifying opportunities in stormwater management solutions and transportation infrastructure. The team is actively in the process of studying several district wide solutions for energy savings, impact relative to phasing, carbon emission reductions, and first cost.

- Grid Interactive Buildings integrate the following energy management technologies and approaches: energy efficiency, distributed energy sources (such as solar panels and battery storage), and demand flexibility.

  Usage of fossil fuels or renewable energy sources to power the utility grid varies throughout the year and day. When demand increases (typically in the evenings for multifamily buildings) the renewable sources in the grid are not typically available and fossil fuel sources are used. There is an opportunity to lower the emissions impact and consume energy at times of lower emissions, when renewable sources are being used to power the grid. A grid interactive program can use active forecasting data including 24 hour rolling forecast and historical data to predict times of storage and use for optimized carbon solutions.

  Design strategies to reduce peak load demand and to consume or store energy and heat when supply from renewable sources is readily available are being studied by the PRGS team.

- Cogeneration is the process of using natural gas combustion to generate electricity onsite and using the waste heat loads in the buildings, for example to heat domestic hot water. The fundamental technology consideration is counter to the goal of electrification. Cogeneration is typically a cost saving measure, but not a carbon saving measure. The PRGS development is unlikely to include this technology.

- River water resource involves using the Potomac river as a heat sink/source for the HVAC system(s) that serves the PRGS site. The PRGS team did an initial engineering study to determine the feasibility of using the Potomac River as a heat sink/source. The shallow depths of the river mean that the river water may be too close to the ambient temperature to provide a meaningful enough temperature differential for this system to work efficiently. Further analysis is needed to determine if this is a viable strategy.

- Microgrids are small, localized energy systems capable of balancing supply and demand to maintain stable service within a defined boundary. Most are grid-connected but capable of disconnecting and operating autonomously (islanding). Microgrids that are connected to the main utility grid can support a portion of the power requirements for extended periods when the grid is not available. Microgrids can be effective solutions on projects with very large land mass but are more challenging to achieve on urban sites like PRGS. Additionally, current battery technologies provide only limited storage capacities which must be factored in to any microgrid system design. The feasibility of incorporating any microgrid solutions will be studied further as project design advance.

Takeaways:

- The PRGS development team is studying comprehensive site-wide and building-level strategies that target a minimum 25% energy savings; keeping in mind the owner has a limited ability to influence roughly half of the energy use in the building.

Embodied carbon means all the CO_2 emitted in producing materials. These emissions occur during extraction, processing, manufacturing, and transportation of building materials. The PRGS development is targeting a 10% savings in embodied carbon emissions, reducing CO_2 from the industry equivalent baseline [8] of approximately 60,777 mT CO_2 to 54,700 mT CO_2 across the entire project. This represents a savings of approximately of 6,078mT CO_2. See Figure 9 below.

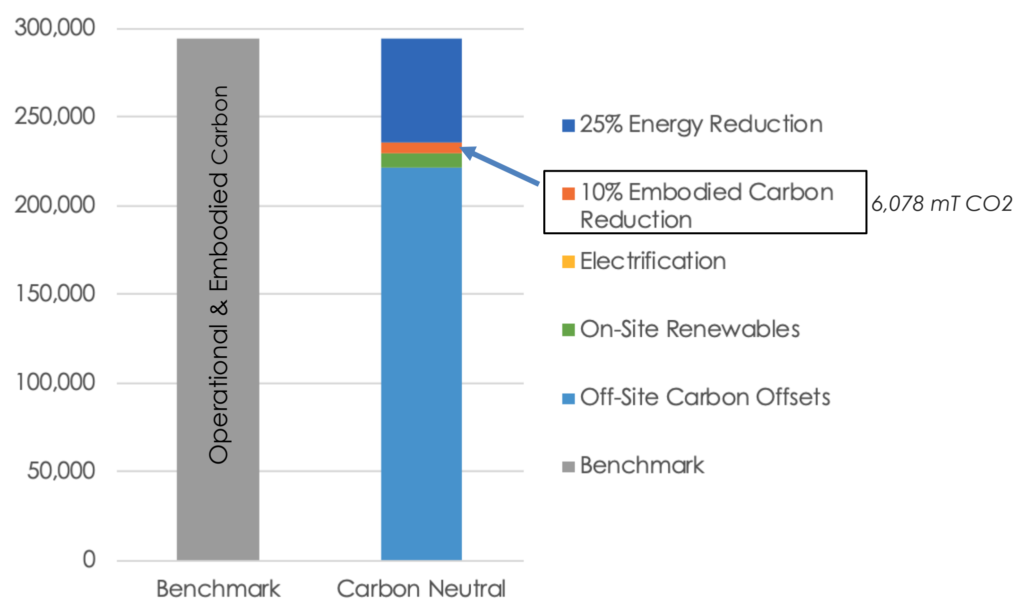


Figure 5: Carbon Neutral Solutions as Compared to Benchmark Building – Embodied Carbon

<u>Key considerations and drivers relative to embodied carbon include:</u>

The industry is still in its infancy relative to studying, benchmarking and reducing embodied carbon. However, there is heightened awareness around this aspect of carbon neutrality and increased disclosure and reporting by the industry will be required in order to develop and track new techniques and strategies.

- The embodied carbon of the PRGS project is estimated to equate to approximately 6 years of its operational carbon.
- The use of materials with Environmental Product Declarations (EPDs) will help drive transformation within the industry.
- Concrete is a carbon intensive material and recent advancements in cement production could be a key strategy for reducing embodied carbon at the project.
- Recent and ongoing advancements in carbon sequestration technology and adoption of 2021 IBC codes for large-scale mass timber construction represent future opportunities for the use of carbon sequestering materials.

[8] Embodied carbon baseline further detailed on page 25 and 26 of this report.

- Sourcing products from regional manufacturers, where feasible, can reduce carbon emissions related to transporting products to the site.

The carbon density profile has been established for this analysis on a carbon per square foot basis, similar to EUI. Embodied carbon emissions are locked in at the end of construction and therefore are not represented on an annual basis. Figure 8 represents a typical multifamily building located in the DMV is approximately 49.4 lbCO2/sf. The selection of less carbon-intensive materials can help reduce embodied emissions as can other design considerations such as the adaptive reuse of the existing pumphouse.

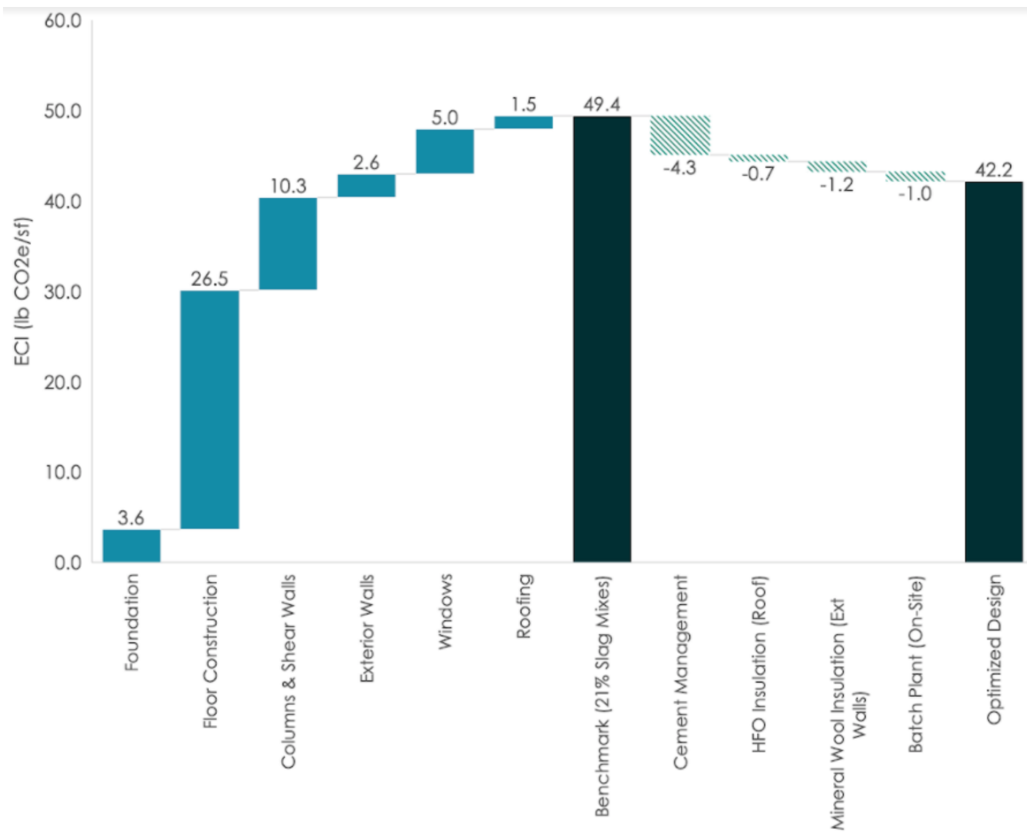


Figure 8. Embodied Carbon Intensity of a Typical Multifamily Building

Takeaways:

- The embodied carbon is fixed once construction is complete. Whereas strategies can be deployed over time to realize continuous operational carbon emission reductions, similar strategies cannot be deployed to achieve embodied carbon reductions. The PRGS development will target 10% embodied carbon reduction through a variety of strategies.

Electrification is the goal of minimizing or eliminating onsite combustion of fossil fuels for the purposes of reducing direct on-site Scope 1 emissions. A non-fossil-fuel based energy generation source from the utility provider, is a primary step in curbing significant GHG emissions associated with the built environment. It is important that as the built environment moves towards full electrification that the electric utility provider make significant strides towards cleaning up the grid in alignment with this change, which is discussed below under electrification.

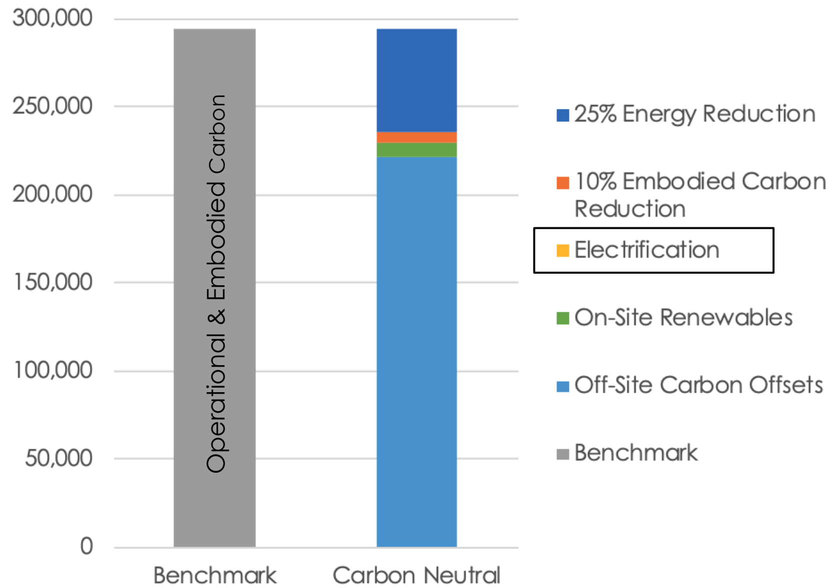


Figure 5: Carbon Neutral Solutions as Compared to Benchmark Building – Electrification

<u>Key considerations and drivers relative to electrification include:</u>

- The PRGS team is exploring full and appropriate[9] electrification as an alternative to on-site combustion to the extent feasible while taking into consideration market factors associated with commercial kitchens, for sale residential, and emergency life-safety.
- The Virginia Clean Economy Act (VCEA) requires Dominion Energy Virginia to be carbon-free by 2045. Therefore, operational carbon emissions are anticipated to decrease over time due to changes in how electricity is generated at the source. This is one of the most important factors in achieving carbon neutrality. It is important to understand that electrification of buildings in and of itself does not result in an immediate reduction in carbon emissions, which is why the above chart does not show a corresponding reduction. Emissions are driven by the site-to-source efficiency of the primary source of that electrical energy and, in the case of the PRGS project, the primary fuel-source for generating electricity is natural gas combustion (see Figure 8) now and in the foreseeable future. The utility will need to meet an estimated 30% increase in demand (~100M MWh to 130M MWh) for electricity over the next 25 years while still moving to carbon-neutral power generation. The building industry will need to encourage and support off-site grid improvements to meet these targets.

[9] "appropriate" electrification assumes minimal -to- no electric resistance-based heating sources

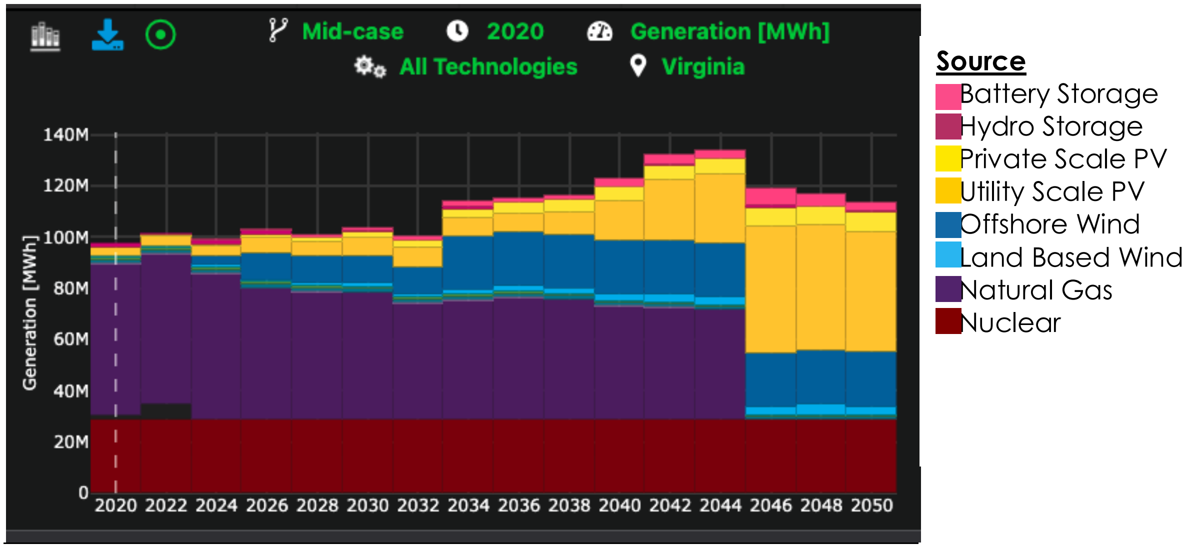


Figure 9. NREL Cambium tool: Predicted Grid Generation composition by year (Mid Case)

Figure 9 reflects the challenges Dominion Energy will have to meet VCEA by 2045:

- 2020 predicted generation with Natural Gas is 60,000,000 MWh (equating ~60% of total generation)
- 2044 predicted generation with Natural Gas is 40,000,000 MWh (equating ~30% of total generation).
- 2044 predicted generation Utility Scale PV is 30,000,000 MWh (equating ~23% of the total generation). The total anticipated renewable generation is expected to be 60,000,000 MWh (equating ~44% of the total generation)
- 2045 predicted generation with Natural Gas is 0 MWH (requires 78% of renewable energy, which is not realistic because it would require a more rapid adoption, than estimated by NREL, of utility scale renewable energy otherwise natural-gas will remain a primary fuel source for the utility well past the 2045 timeframe)

- Electric resistance heating is an extremely inefficient means of heating (air and water). Electric resistance uses approximately two times more energy and results in three times more emissions than that of local on-site natural gas combustion which would result in higher emissions for that particular end-use. Electric resistance heating should not be considered a method of meeting electrification goals. Electric resistance is often a common means of heating domestic hot water with in-unit storage tanks.

Table 2: Source Carbon Emission Scenarios[10]

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

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

- 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 more non-renewable based energy sources to meet an increasing demand. This coupled with the rapidly increasing demand for clean reliable electricity could pose long term utility resiliency issues. Optimizing the value of every kWh is an important step that resource availability for future projects.

- 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 more non-renewable based energy sources to meet an increasing demand. This coupled with the rapidly increasing demand for clean reliable electricity could pose long term utility resiliency issues. Optimizing the value of every kWh is an important step that resource availability for future projects.

- The PRGS team is exploring the feasibility for heat pump-based technology as it is applied to heating large volumes of ventilation air and domestic hot water for multifamily applications. Reference Key Considerations and Drivers in Operational Carbon section of this report.

Takeaways:

- It is important that buildings begin to transition to appropriate electrification to be in a position to capitalize on cleaner energy at the point of which it is available. Preparing buildings now for appropriate electrification is an important step toward carbon neutrality as the electric grid becomes less dependent on fossil-fuels for electricity generation. As the PRGS project advances toward building design, electrification strategies will be evaluated for feasibility and their potential to advance carbon neutrality goals, both at the time of implementation and in the future.

- There are some current engineering challenges as it relates to full heat-pump based solutions for domestic hot-water (e.g. spatial considerations, cold-air, submetering, electrical capacity, others) and ventilation air (e.g. capacity, availability, roof area, compressor lock-out / electric resistance back-up, others) heating in this climate zone. Solutions of which will continue to be explored as building designs are developed and site-based solutions are further refined.

- In order for electrification to have a meaningful impact on carbon reductions for this specific project, the energy grid itself must be transformed at a rate faster than that currently expected (over the next 25 years). The utility's challenge will be to meet future increases in electricity demand in a way that significantly increases the deployment of utility scale solar.

Onsite renewables reduce the energy demand on the electric grid by producing energy onsite redevelopment through methods such as solar photovoltaics (PV) panels. However, the magnitude of onsite energy production is limited by factors such as space constraints, energy storage and financial feasibility. The current analysis assumes 3% of the annual energy use of the PRGS project can be met through onsite solar which would equate to a savings of 263 mT CO2/year and 5,261 mT CO2 over a 20-year time frame.

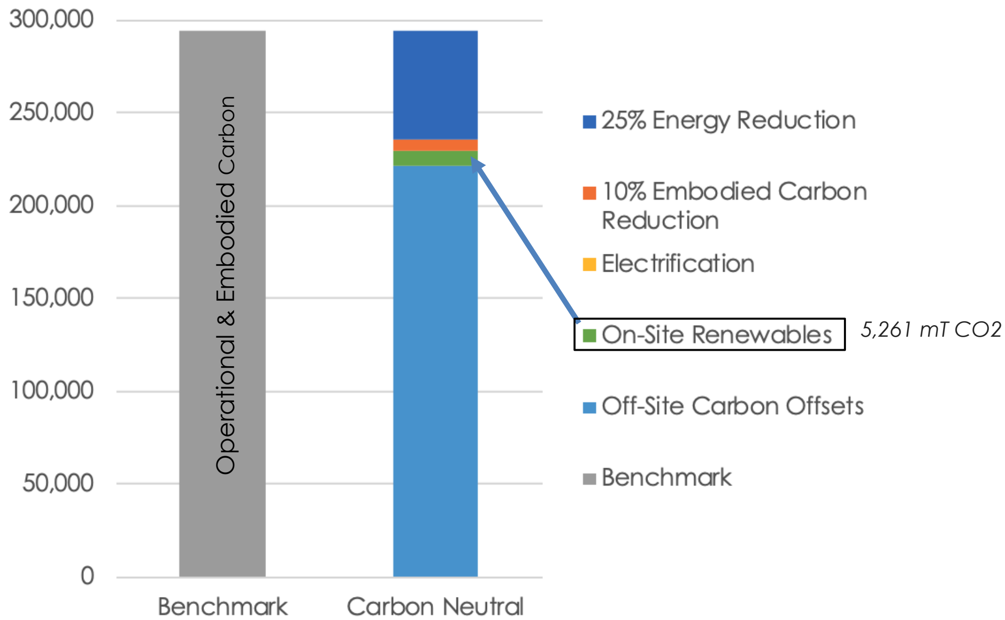


Figure 5: Carbon Neutral Solutions as Compared to Benchmark Building – On-site Renewables

Key considerations and drivers relative to onsite renewables carbon include:

- It is very challenging for onsite renewables on dense, urban sites, to generate enough energy to off-set a substantial portion of a project's energy demand due to space constraints and other conflicts. Theoretically, solar PV may be able to generate 10% of the energy demand, but that quantity of PV would require 60% of the total roof area, which may be prohibitive given other demands on roof space.

- HVAC equipment, program space, life safety equipment, green roof will all be factored into the consideration for available roof space. At this point in time, the design elements are not at a point that the available roof space is known.

- Onsite PVs have become more cost-effective over the years, but are still significantly more expensive than offsite power purchases. The PRGS development team is studying the extent to which PV can be included in the design with the intent to maximize its use.

Takeaways: The PRGS project will evaluate the feasibility and the potential carbon reduction impact of incorporating onsite renewables such as PV, weighing the various space roof space requirements related to green space, rooftop mechanical systems, and amenity space.

Offsite renewables provide the biggest opportunity for carbon emission reduction at the PRGS project over time. The remaining operational carbon could be offset through offsite renewable Power Purchase Agreements (PPAs) and carbon offset credits[11].

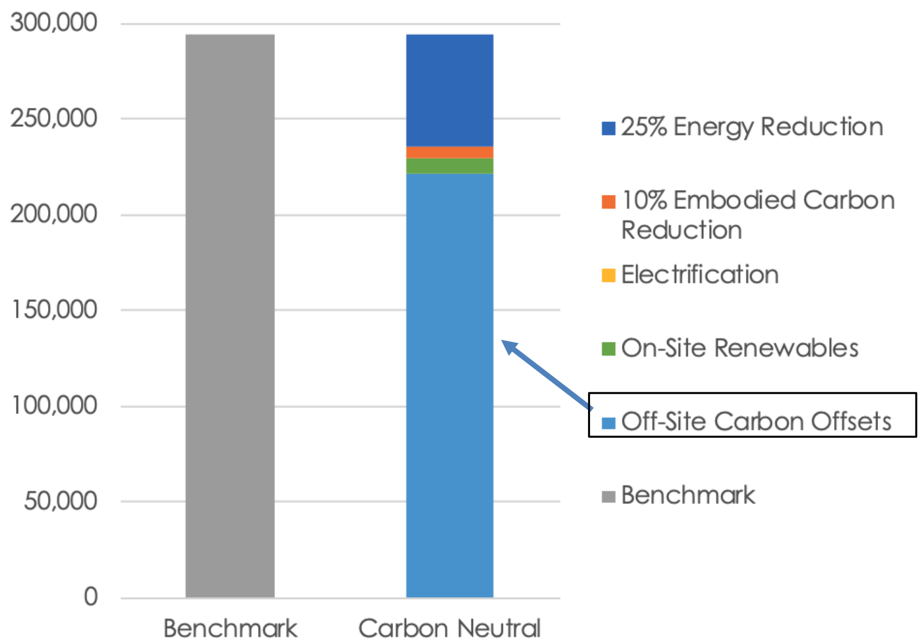


Figure 5: Carbon Neutral Solutions as Compared to Benchmark Building – Carbon Offsets

Key considerations and drivers relative to offsite renewables include:

- Off-site renewable energy purchases, like renewable energy credits (RECs), drive renewable energy into the grid. The price of RECs is currently very volatile due to increased demand as different entities work to meet their carbon neutrality goals. It is a fundamental 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. However, the possibility of small-scale power purchase agreements is currently being researched by the PRGS team. These contracts can be relatively complex. See Pages 29-30 for further detail on PPAs.
- PPAs are currently challenging for whole-building multifamily projects since each unit is individually metered versus the whole building energy consumption of a commercial building. New mechanisms, like co-ops or aggregates, are needed to allow participation at an individual tenant level to have a measurable impact on the industry.
- A carbon offset credit represents a validated emission reduction of a set amount of CO2 avoided, sequestered, or destroyed towards a carbon reduction goal elsewhere.

Takeaways:

- New dense development can help to stimulate the introduction of new off-site renewable energy assuming the utility is able to introduce simplified, small scale ($\leq$1 MW) building, cost effective -to- cost neutral PPAs.

[11] Further details on PPAs and carbon offset credits provided on pages 29-30

- The PRGS development recognizes the importance of off-site renewable energy in order to meet carbon neutrality goals. As such, the project team will continue to explore options for off-site renewables (PPAs, RECs, Offsets) as the development moves forward.

Decision Making Process for a Carbon Neutral Redevelopment

Though early in the development process, the PRGS development strives to identify a path towards carbon neutrality. The Carbon Neutrality Framework identified in this document provides minimum targets related to operational and embodied carbon, on- and off-site renewables, and electrification goals that the development team will continue to review throughout the decisions making process.

This CNA provides an assessment of what is possible and provides a window into the future steps to continue to meet the development goals**.** The efficiency targets established at this early stage of site planning provides a framework for future analysis that can be used to inform decisions as the project design advances.

The goal of meeting carbon neutrality on the PRGS site will be a constantly evolving process as building designs are created and new technologies help to make solutions financially feasible to implement. Starting now at the concept site planning stage allows HRP and its design and engineering team to build a framework to achieve carbon neutrality as presented within this analysis. HRP will continue to research and analyze solutions to meet our carbon neutrality goals in the following ways:

First: Conduct whole building energy modeling.

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. Modeling 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. 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
- Onsite renewable energy (offset electric consumption):
- Offsite 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. Refer to the appendix for a more comprehensive definition of these metrics used in whole building energy modeling.

This 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 PRGS 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.

Median regional EUIs[12] are based on comparable buildings delivered within the last 10 years in Washington, DC. Buildings were considered comparable if the following conditions were met.

- >150,000 sf
- Delivered between 2011 and 2021
- Site EUI between 30 and 90 kBtu/sf-yr (excludes outliers that likely provided incorrect benchmarking data)
- The dataset used consisted of 2019 reported usage from 60 buildings

Based on these assumptions, we determined the following, shown in Table 4 Median Regional EUI:

- Median EUI is 48kBtu/sf-yr
- 50% of buildings fall between 40 and 63 kBtu/sf-yr and there is a larger range in the of EUIs in the 25% greater than the median than the 25% below the median.

Building Type	Median US EUI	Median Regional EUI	Potential EUI
Office			40
		48	(17% less)
	53		(25% less)
Multifamily**			40
		56	(28% less)
	60		(33% less)
Hotel***			75
		70	(-7% less)
	137		(45% less)

Table 1: Site EUI Summary by Building Type*[13]

[12] *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.

[13] *Traditional Townhomes are not included in the Table since Median US EUI information is not available. Target EUIs don't include EV charging stations.

We then summarized the potential EUIs for office, multifamily, and hotel building types planned for the PRGS development and compared them to the median US and median regional EUIs. The following tables show the additive derivation of the potential EUIs studied 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 2019 SRVC electric grid, which currently stands at 675.42 lb/MWh.

Table 2: 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	6.46	1.28	Direct to unit, dehumidified with temp optimization, DX cooling, electric heat
Common Area HVAC	0.26	0.05	Variable Frequency Drive System
Common Area Lighting, Plugs, Supplemental	9.34	1.85	All LED
Garage Lights	0.9	0.18	LED with occupancy sensors
Garage Ventilation	0.83	0.16	CO/NOx control with VFD
Elevator	2.47	0.49	Typical high efficiency elevator
SUBTOTAL	20.26 kBtu/sf	4.01 lbCO2/sf	
Tenant/Occupant Controlled			
Hot Water	9.63	1.91	Electric water heater with low flow fixtures
Apartment HVAC	5.29	1.05	14 SEER Heat Pumps with cycling fans
Plug Loads	3.15	0.62	Typical, not under influence of project team
Stove	1.8	0.36	Electric
Clothes Dryer	1.31	0.36	Energy Star, electric
Unit Lights	2.29	0.45	All LED
Refrigerator	1.26	0.25	Energy Star
Dishwasher	0.49	0.1	Energy Star, includes water heating
Clothes Washer	0.17	0.03	Energy Star, includes water heating
SUBTOTAL	25.39 kBtu/sf	5.13 lbCO2/sf	
TOTAL	45.7 kBtu/sf	8.9 lbCO2/sf	

**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 3: 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 in the District of Columbia. This is a data set used to establish a benchmark of recently delivered building energy performance in our region. 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 to decarbonize the electric grid.

This section focuses design to maximize electrification in anticipation of the decarbonization of the electric grid. 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[14]. A combined approach will yield the best results in a shorter timeline. Considerations relative to these three driving forces include:

Non-electric resistance solutions: 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

[14] NREL's *Electrification Futures Study: Scenarios of Power System Evolution and Infrastructure Development for the United States*

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.

Decarbonization through policy: 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 and are further detailed in the Appendix:

- Heat pump technology for central ventilation – 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 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: Incorporate on-site renewables to the extent feasible and purchase off-sets to support greening the grid.

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[15]. Solar PV is the only feasible and promising renewable energy technology for integration into the overall development scheme when considering FAA regulations, thermal capacity of available resources, and surface area.

The development is maximizing the opportunity for usable open space as an amenity for the community and visitors. The main parking structures will be located underground which will optimize the availability of this space. While this configuration provides many sustainability and community benefits, it limits the available space for PV. Building mounted solutions provide the most feasible solutions.

The theoretical PV scenario has the potential to offset 3% of the building total annual energy use. The results for each building relative to the goals and requirements are summarized in Table 4.

Table 4: Theoretical PV Performance at 3%

Building	Type	Site EUI (kBtu/sf)	Roof Area	
			(sf)	Percent
Block A	Office	40	2,500	12%
Block B	Residential	40	7,250	18%
Block C	Residential	40	10,000	18%
Block D	Residential	40	5,500	16%
Block E	Residential	40	10,000	19%
Block F	Office Hotel	40/70	14,000	19%

The project team is exploring the feasibility of PV and infrastructure as well as expanding solar-ready infrastructure for the development blocks. The project team acknowledges the benefits of onsite solar PV, in combination with offsite renewables, in decarbonizing the built environment and continues to explore potential applications for onsite PV.

Offsite 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 onsite PV for urban-based projects. Offsite 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:

> <u>Renewable Energy Certificates (RECs)</u> 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

[15] *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.*

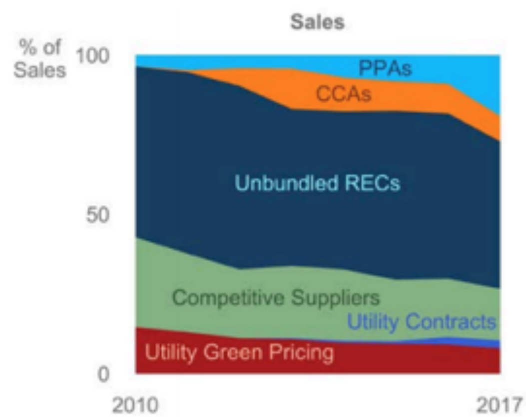
encouraged since Green-e acts as a third-party that ensures the purchaser receives verified clean energy and gets what they paid for. The price of a REC is based on supply and demand. The REC market is highly volatile due to increased demand and interest in cleaner energy purchases.

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 offsite 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 offsite 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.



Reference 2: Trends in Green Power Market

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).

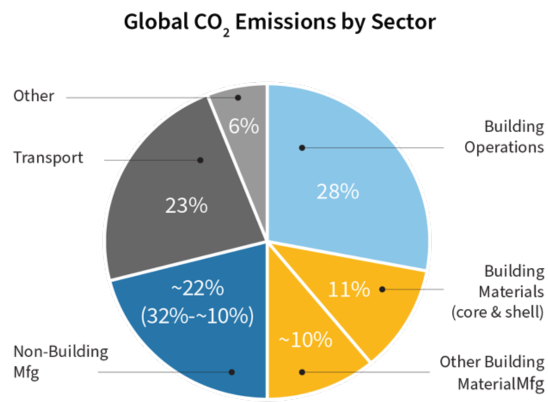
Community Choice Aggregations (CCAs) allow communities to aggregate their loads collectively to procure green power as a single bulk purchase. This mechanism addresses the issues of PPAs for residential customers. However, it is limited to states with an investor-owned utility such as Illinois, California,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

Fourth: Identify embodied carbon in materials through a whole building life cycle assessment.

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%).

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.



Reference 3

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 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.

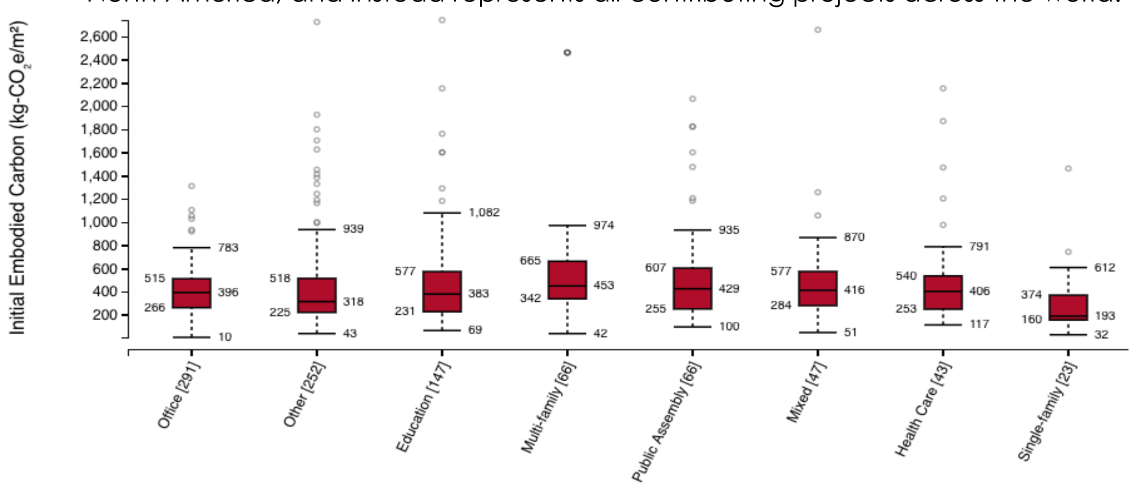
In combination, multiplying a bill of materials or material take-off by impacts disclosed in EPDs quantifies the whole-building impacts.

Figure 11: Methodology for quantifying whole-building embodied carbon

Limitations in setting benchmarks stem from tracking and reporting embodied carbon still 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 4: Embodied Carbon Benchmark Results[16]

[16] Reference 4 is from the *CLF Embodied Carbon Benchmark Study*

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.

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 PRGS buildings are being evaluated.

Table 5: CLF Benchmark Data for Boundary A (cradle-to-gate)

Building Type	**CLF** (kgCO2/m2)	**CLF** (lbCO2/sf)
Multifamily	453	93
Hospitality	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 PRGS 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 development.

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

- 400,000 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 the reference buildings is around 49 lbCO2/sf, depending on the timeline of construction and can be reasonably reduced to approximately to 42 lbCO2/sf using strategies and materials currently available in the market.

Table 6: Estimated Embodied Carbon Sources and Strategies to Reduce Impact

Contributor	ECI (lb CO2/sf)	Basis of Design
Elements Contributing to Embodied Carbon Emissions		
Foundation	3.6	Concrete, Auger Cast Piles
Floor Construction	26.5	Concrete, Post-Tensioned Slab
Columns & Shear Walls	10.3	Concrete, 26'x22' column spacing
Exterior Walls	2.6	Brick Construction, typical
Windows	5.0	Aluminum-framed storefront/fixed, typical
Roof	1.5	HFC XPS Insulation
TOTAL Anticipated ECI	**49.4**	
Strategies Contributing to Embodied Carbon Emissions Reductions		
Cement Management Practices	2.1	Increase SCM, Type 1L cement, CarbonCure
HFO Insulation (Roof)	0.7	HFC 134a-free rigid insulation
Mineral Wool Insulation (Ext Walls)	1.2	Mineral wool board, typical
Batch Plant (On-Site)	1.0	On-site concrete mixing, reduced transport
TOTAL Anticipated ECI (After Reductions)	**44.4**	**10% Reduction**

For comparison, embodied carbon will represent 85% 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.

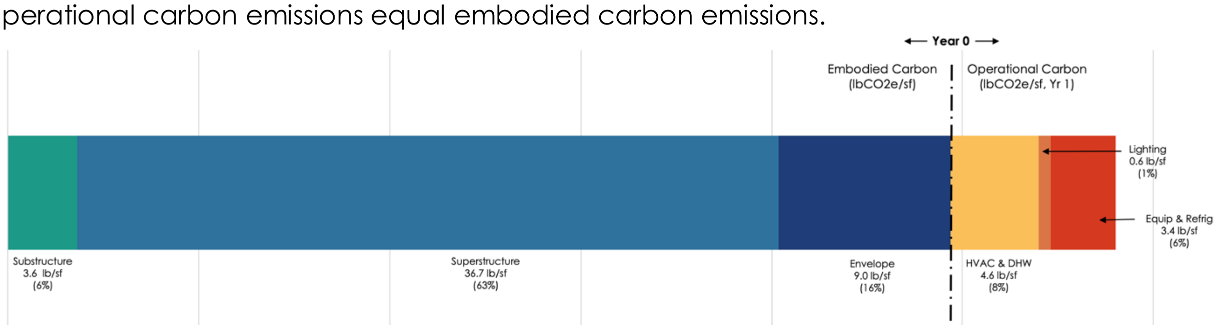


Figure 12: Carbon Emissions at Initial Occupancy

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 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 will be the primary tool for achieving the 10% embodied carbon reduction goal of the development. The following are key strategies that can be deployed to reduce the embodied carbon of concrete and meet the overall development goal:

- 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 6 quantifies and estimates cement management strategies for this assessment at 4.3 lbCO2/sf to meet the 10% overall development embodied carbon reduction goal:

- Avoid winter pour, which results in SCM restrictions to meet cure time requirements
- Increase in slag above the 21% eastern benchmark
- 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. 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.

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

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 Forter a, 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.

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 15). 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)

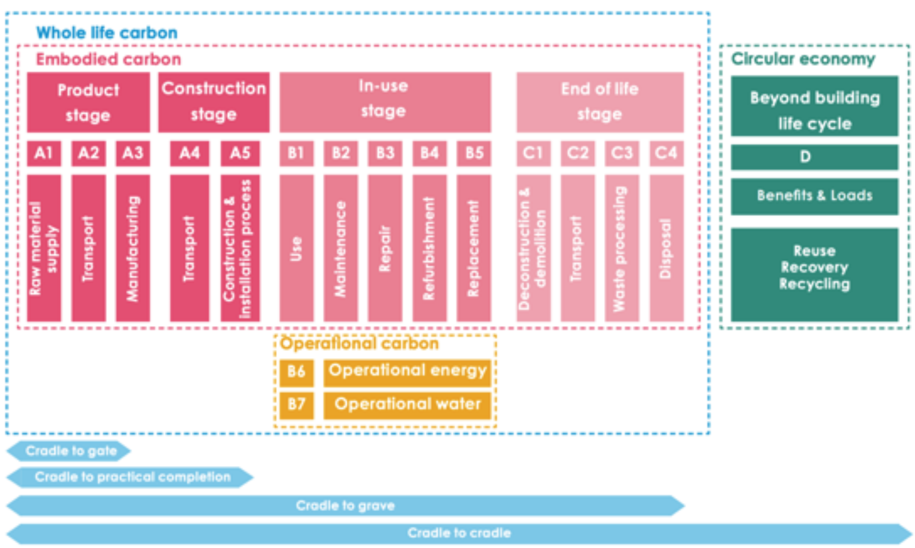


Figure 13: Carbon Impact System Boundaries

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.

Whole Building Energy Modeling

List of industry standards for understanding and comparing building energy performance:

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 onsite combustion and onsite electric use, site EUI is typically referred to. The national median site EUIs for anticipated property types are listed in Table 5 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.

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 based on the landscape design. The tool was used to analyze associated with carbon sinks (vegetation). For the purpose of this analysis, the Pathfinder Tool evaluates impact over a 50-year period. The PRGS development includes a large open space area and six proposed building blocks likely to include green roofs and outdoor areas. The proposed vegetation for the site development is currently concept level, but provides an order of magnitude impact for the development for 50 years.

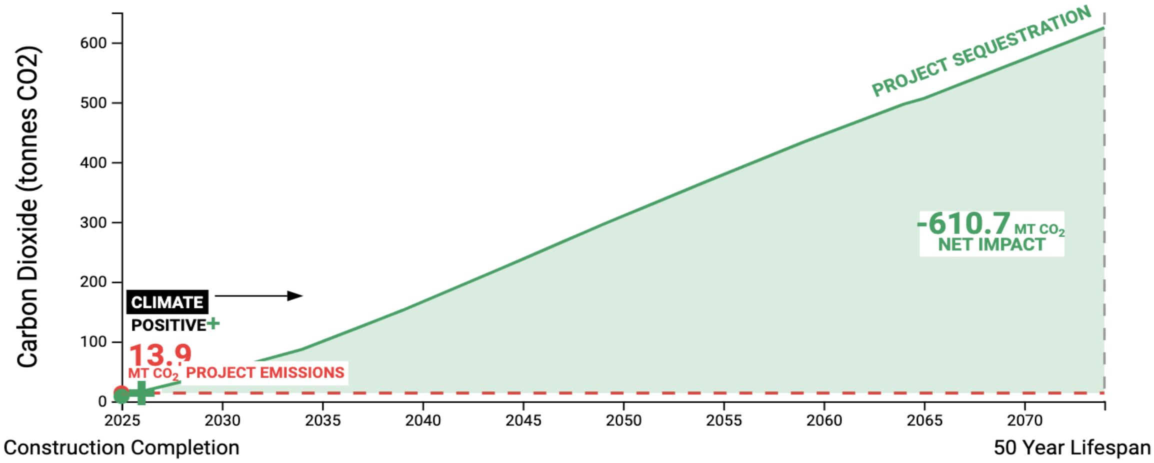


Figure 14: Site Carbon Sequestration Potential

Based on Table 7, the vegetation will sequester 610.7 MT CO2e over a 50-year period.

Table 7: Net Carbon Sequestration Impact over 50 Years

Boundary	Carbon Sequestered, Landscaping	
	lb CO2e	MT CO2e
PRGS Site	1,346,000	610.7
PRGS Site and Adjacent NPS	3,474,000	1,576

- Vegetated Roofs 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.

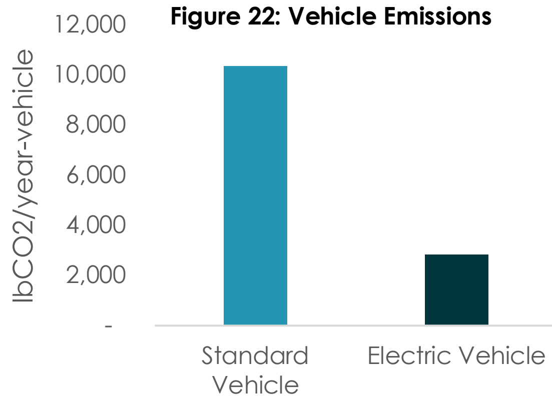
- Well-to-Wheel emissions - Standard vehicles use gas; emissions are created from extracting, refining, distributing, and burning petroleum. Electric vehicles (EVs) use electricity; emissions are attributed to the fuel source of the power plants, which also includes extracting, processing, and distributing 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 22.

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.

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.

Figure 22: Vehicle Emissions



Carbon emissions can also be reduced by encouraging less single-occupancy vehicle use, regardless of the type of vehicle. The following strategies and programs can support this goal:

- Building dense, mixed-use developments
- Providing bicycle networks (bike share, dedicated and connected bike network/lanes)
- Offering rideshare (City of Alexandria incentives)
- Providing public Transit: WMATA Metro, GO Alex, etc. (Public transit 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 waste. Methane, carbon dioxide, and many other compounds are associated with emissions contributing to global warming. Other considerations associated with landfill and waste-to-energy plants 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 decOomposition 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. All trash in the City goes to the waste to energy plant. The most recent recycling rate for the City is almost 50% with a small but active composting community (about 500 participants) at the Farmers Markets year round.

The total mT CO2 for three waste scenarios are shown in Figure 16. 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.

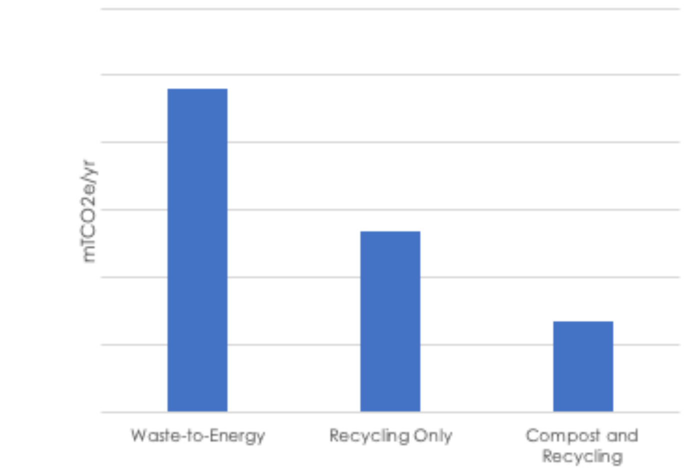


Figure 16: Carbon emission for Different Waste Streams

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 8 below summarizes the impact.

Table 8: 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 PRGS 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

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

https://www.alexandriava.gov/uploadedFiles/planning/info/masterplan/City_Master_Plan_Map/OldTownNorthSAPCurrent.pdf

https://www.epa.gov/greenpower/green-power-pricing

https://www.epa.gov/greenpower/us-renewable-electricity-market

https://www.epa.gov/egrid/power-profiler#/

https://www.epa.gov/egrid/data-explorer

https://www.nrel.gov/docs/fy19osti/72204.pdf

https://community.exchange.se.com/t5/Active-Energy-Management-Blog/What-is-the-Difference-Between-Direct-and-Virtual-Renewable-PPAs/ba-p/179309

https://www.pillsburylaw.com/en/news-and-insights/virtual-ppas-are-they-right-for-your-company.html

https://rmi.org/insight/virtual-power-purchase-agreement/

https://www.alexandriava.gov/news_display.aspx?id=110544

https://www.dominionenergy.com/virginia/renewable-energy-programs

https://www.energy.gov/sites/prod/files/2020/10/f79/District%20Energy%20Technology%20Fact%20Sheet_9.25.20_compliant.pdf

https://www.eesi.org/files/district_energy_factsheet_092311.pdf

https://www.epa.gov/egrid/data-explorer

https://cambium.nrel.gov/?project=fc00a185-f280-47d5-a610-2f892c296e51&mode=view&layout=Default

https://www.nerc.com/pa/RAPA/PA/Performance%20Analysis%20DL/NERC_SOR_2020.pdf

https://betterbuildingssolutioncenter.energy.gov/sites/default/files/attachments/BB%20Energy%20Storage%20Guide.pdf

https://www.nrel.gov/docs/fy18osti/71839.pdf

https://www.epa.gov/energy/electricity-storage

https://www.alexandriava.gov/uploadedFiles/tes/EAP2040v25.pdf https://www.ipcc.ch/sr15/

https://afdc.energy.gov/vehicles/electric_emissions.html#wheel

https://www.environdec.com/all-about-epds/the-epd

https://carbonleadershipforum.org/the-carbon-challenge/

https://static1.squarespace.com/static/5b9362d89d5abb8c51d474f8/t/5fd95907de113c3cc0f144af/1608079634052/Paving+the+Way+for+Low-Carbon+Concrete

https://info.thinkwood.com/masstimberdesignmanual

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

https://gml.noaa.gov/hats/about/hcfc.html

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

https://www.unep.org/ozonaction/who-we-are/about-montreal-protocol

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

https://gml.noaa.gov/hats/about/hcfc.html

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