City of Alexandria Energy & Climate Change Action Plan

WORKING DRAFT – 10/20/2022

October 2022

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Acknowledgements

The City of Alexandria Energy and Climate Change Action Plan (ECCAP) was developed in partnership with the Alexandria Department of General Services and the Department of Transportation and Environmental Services. Throughout the development of this plan the Departments sought input, guidance, and feedback from other Departments across the City, as well as, community and civic groups, commissions, organizations and residents and business operating in the City.

The *Energy and Climate Change Task Force* was initiated by City Council under Resolution 2958, which established the Task Force and its purpose to provide guidance to the City of Alexandria during the process to update the ECCAP.

The Task Force is comprised of 12 members appointed by the City Manager, as well as one member designed by the Environmental Policy Commission. The 13 members include general community representation; environmental advocates; energy, climate, and related technical experts; representatives from Alexandria's youth and representing equity issues; and those representing engagement with Alexandria's businesses and institutional partners.

Energy and Climate Change Task Force Members:

- Javier Bastos
- Leah Devendorf
- Mary Harris, Co-Chair
- Fiona Herbold
- Praveen Kathpal
- Alyssa Morin
- Raquel Nicora
- Marian Pegram, Co-Chair
- Josh Sawislak
- Marta Schantz, Environmental Policy Commission
- Rose Stephens-Booker
- Stephen Walz
- Sangina Wright

The City would also like to recognize the efforts and contributions of:

Mayor and City Council

- Mayor Justin Wilson
- Vice Mayor Amy Jackson
- Councilman Canek Aguirre
- Council Member Sarah Bagley
- Councilman John Chapman
- Councilwoman Alyia Caskins
- Councilman R. Kirk McPike

Departments and Offices

- City Manager's Office
- Department of General Services
- Department of Transportation and Environmental Services
- Department of Community and Human Services
- Department of Planning and Zoning
- Department of Project Implementation
- Department of Recreation, Parks, and Cultural Activities
- Department of Finance
- Office of Communications & Public Information
- Office of Housing
- Office of Management & Budget
- Office of Performance Analytics
- Office of Race and Social Equity
- Code Administration
- Virginia Department of Health/Alexandria Health Department
- Alexandria Economic Development Authority
- Alexandria Transit Company (DASH)

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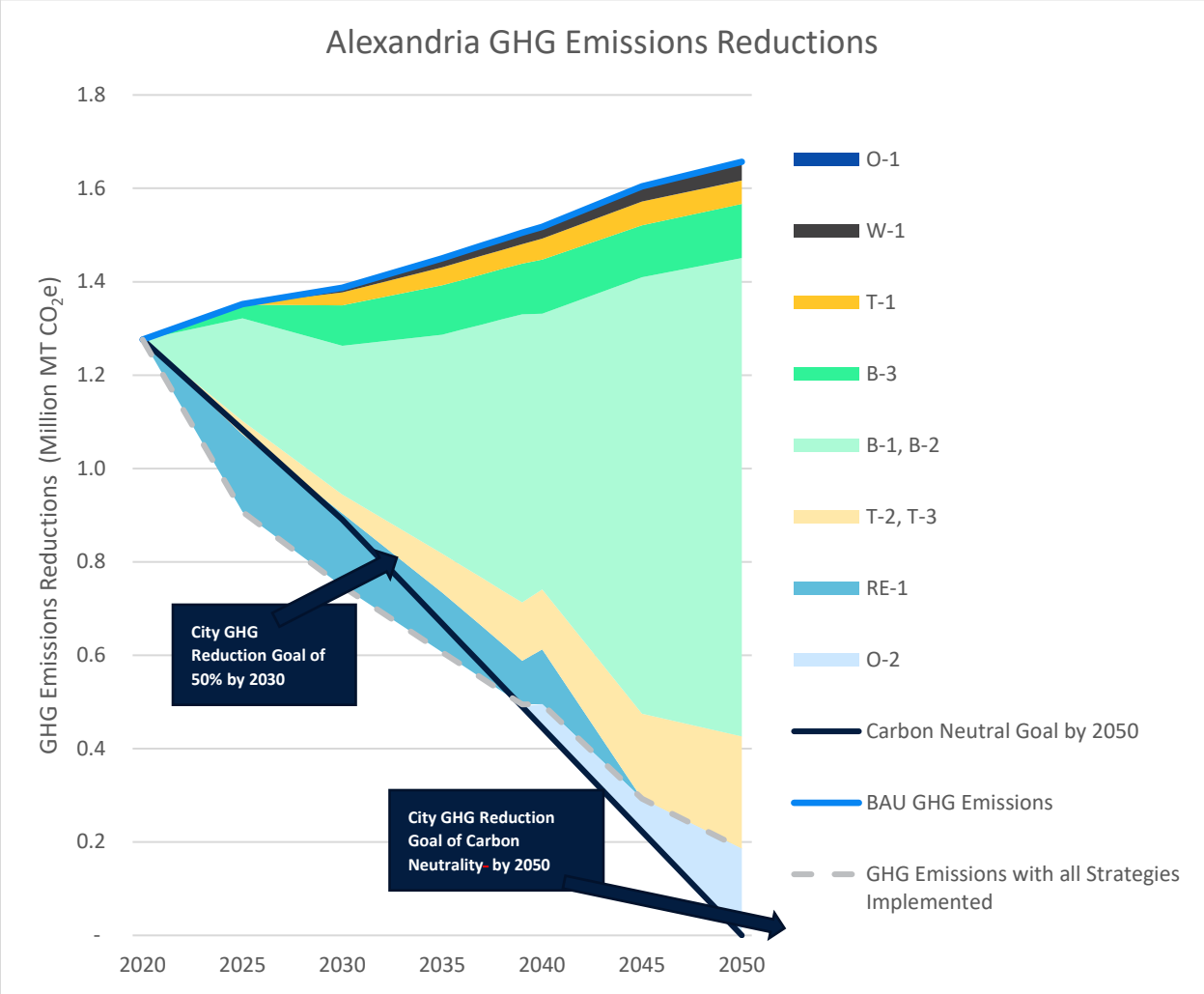
Executive Summary

This update to the Energy and Climate Change Action Plan (ECCAP) provides a roadmap for the City of Alexandria to accelerate deep reductions in greenhouse gas (GHG) emissions and adapt to the most pervasive impacts of climate change within the City.

The ECCAP lays out a possible pathway for the City to achieve its GHG emissions reductions goals of 50 percent by 2030 and carbon neutrality by 2050 compared to 2005 levels. The thirteen strategies across five sectors (Buildings (B), Renewable Energy (RE), Transportation (T), Other (O), and Waste (W)) in this ECCAP demonstrate a path to meeting the City's GHG goals, while also considering the cost and equity implications of the actions.

Figure ES- 1. A Pathway to Meet Alexandria's GHG Reduction Goals



The ECCAP also describes the climate impacts on the City, specifically the potential impacts of flooding and extreme heat. Recognizing the City's existing adaptation and resilience actions, the ECCAP includes recommendations and next steps to expand existing efforts and provide new adaptation and resilience strategies.

Background

The ECCAP builds on the City's existing energy, GHG reduction, and adaptation efforts, and reflects guidance from City staff and the Energy and Climate Change Task Force and input from Alexandria residents and businesses. The ECCAP incorporates goals and strategies established in the Environmental Action Plan 2040 (EAP 2040), the Metropolitan Washington Council of Governments (MWCOG) 2030 Climate Action and Energy Plan, and the 2017 Northern Virginia Hazard Mitigation Plan, among others. The ECCAP strategies recognize and integrate City, regional, and State initiatives, such as the Alexandria Green Building Policy, regional priority actions identified by the MWCOG, and the energy transition guided by the Virginia Clean Economy Act (VCEA).

Strategies and Actions to Reduce GHG Emissions

The ECCAP identifies the City's significant GHG emitting sectors, including buildings, transportation, energy, and waste strategies to reduce GHG emissions in line with achieving the City's GHG goals of 50 by 2030 and carbon neutrality by 2050. To achieve these goals the ECCAP also identifies other strategies that will need to be used, including addressing fugitive gas system leaks and recognizing and understand the role of future technologies as they continue to be developed. For each strategy the ECCAP includes specific action the City will take, along with its stakeholders and partners.

These actions include acceleration of renewable energy deployment in the City in support of VCEA through initiatives such as SolarizeAlexandria, a municipal aggregation program, large-scale offsite renewable energy projects, and a transition of all City government facilities to 100 percent renewable energy.

A cleaner electricity supply complements efforts in the commercial and residential building space to decarbonize and improve energy efficiency. Specifically, these actions include establishing an incentive program to encourage Green Building renovations, supporting access to decarbonized buildings fuel supply, and accelerating decarbonization measures at City-owned buildings.

For the transportation sector, actions include reducing vehicle miles traveled (VMT) through actions such as an expanded transit network and transit-oriented development. In addition, to VMT reductions, the ECCAP actions include accelerated vehicle electrification including electric vehicle (EV) charging infrastructure, and an increase in alternative fuel use in the City vehicle fleet.

Waste sector emissions will be reduced through actions specified in the EAP2040 that aim to recover resources and reduce GHG emissions and other forms of pollution by optimizing and safely handling the collection and processing of solid waste and reduce total solid waste collected from City-served residential customers.

Climate Change Impacts in Alexandria


Higher average temperatures and more frequent heat waves


More intense storms with heavy rainfall


Sea level rise from the Potomac River inundating coastal areas


More frequent flood events

Extreme winter weather conditions

Reducing Climate Risk

Climate impacts in Alexandria include extreme heat, flooding, drought, lighting/thunderstorms, and extreme winter conditions, and draws from existing studies to assess the risks associated with these impacts. Within the ECCAP the primary focus in on potential impacts of flooding and extreme heat throughout the City, including within various neighborhoods and demographic groups. To address these climate change impacts the ECCAP includes planning and adaptation strategies the City may undertake in the future to expand existing initiatives or adopt new approaches.

Three categories of adaptation and resilience strategies are included in the ECCAP:

1. Activities to integrate climate change risk and resilience considerations into existing municipal decisions and activities;
2. Specific activities to reduce, manage, and coordinate a response to impacts from increasing temperature and extreme heat; and
3. Specific activities and next steps to continue to reduce, manage, and coordinate a response to impacts from flooding.

Climate Equity

Although climate change impacts everyone, its impacts tend to exacerbate disparities and inequities. Through the ALL Alexandria resolution, the City acknowledges the need for and importance of community involvement in developing and implementing policies to achieve more equitable outcomes. In line with ALL Alexandria, the ECCAP considers and integrates equity across both GHG reduction and climate adaptation strategies, with a particular focus on thinking about equity in terms of both risks and benefits, as well as implementation of strategies.

Community Engagement

The ECCAP was developed by engaging with the City's community and stakeholders through Task Force meetings, community engagement workshops, directed outreach, commission engagement, and public comment. The success of the ECCAP will be in part based on the continued involvement and participation of the community in implementation of the ECCAP. To that end, the ECCAP calls for actions that include education initiatives, incentives, technical assistance, and building new partnerships and relationships.

ECCAP Implementation

Achieving the ambitious goals laid out in this plan will require that the Alexandria community comes together across sectors to work collaboratively to achieve this vision for the City's future. However, there are tangible next steps for the City and stakeholders alike to take that will ensure that these plans translate into impactful actions. These span continual communications and engagement with the community and stakeholders, establishing protocols for demonstrating accountability and progress, tracking progress through established transparent metrics, and seeking and securing funding (e.g., from the Infrastructure and Investment Jobs Act (IIJA) and the Inflation Reduction Act (IRA))

Introduction

In the past few years, communities across the country have experienced unprecedented impacts from a changing climate, from more intensive storms and flooding to wildfires and extreme heat waves. In response, governments, companies, organizations, and citizens have increasingly recognized the need to both reduce the impacts of climate change and adapt to them.

In **July 2019**, the Alexandria City Council adopted the City's Environmental Action Plan 2040 (EAP2040), which established community-wide greenhouse gas (GHG) emission reduction goals of 50% by 2030 (base year 2005) and 80-100% by 2050. These goals were also adopted regionally and are based on the Intergovernmental Panel on Climate Change's (IPCC) recommendations to limit global temperatures from increasing more than 1.5-degree Celsius above pre-industrial levels to prevent more severe climate change impacts. In **October 2019**, the Alexandria City Council adopted a resolution declaring a climate emergency, recognizing that climate change poses a grave threat to everyone in Alexandria and around the world. In **September 2020,** the City Council approved Resolution 2958, establishing the Energy and Climate Change Task Force to provide guidance to the City of Alexandria during the process to update the City's Energy and Climate Change Action Plan (ECCAP). The City adopted the initial ECCAP in 2011, three years after the original Environmental Action Plan was adopted (2009).

In the past 10 years, the urgency of climate change has become more apparent as local governments and its citizens face daily challenges stemming from a warming planet. Specifically, technology, policy, financing, and programmatic options for energy and climate change have rapidly evolved while the City and the broader D.C. Metro Region has been forced to adapt. Furthermore, though this plan outlines significant actions which the City may undertake to reduce greenhouse gas (GHG) emissions, much has been done at both the local, regional, state, and federal levels to limit GHG emissions. The ECCAP captures these trends, changes, and work that has been done towards GHG reductions and includes details on how Alexandria has worked to adapt to climate change. The ECCAP outlines a set of actions the City, stakeholders and Alexandrians can take to meet the GHG reduction goals and become more resilient to climate change for future generations.

Purpose of the ECCAP and Development Process

The ECCAP is developed by the City of Alexandria as an update to the 2011 Energy and Climate Change Action Plan 2012–2020. Significant advancements in climate change science and solutions, identification and analysis of climate-induced vulnerabilities, climate adaptation and resiliency practices, and climate action planning approaches provides the City opportunity to meaningfully advance the Alexandria community's efforts towards climate change action. In addition, the Energy and Climate Action Plan update places a significant focus on prioritizing ALL Alexandria to support racial and social equity as a critical lens to advance energy and climate change action planning.

The ECCAP provides a roadmap to assist the City in responding to increasingly severe climate change impacts and environmental emergencies. The ECCAP aligns with the goals in the 2019 EAP2040 and builds upon existing City energy, greenhouse gas reduction, and climate action efforts. The ECCAP leverages regional priority actions identified in the MWCOG 2030 Climate and Energy Action Plan, as well as the climate action planning efforts underway or completed by the City's regional and national peers.

ALL ALEXANDRIA

The Alexandria City Council issued the ALL Alexandria resolution in 2021 to acknowledge the need for and importance of community involvement in developing and implementing policies to achieve more equitable outcomes. The resolution includes four specific pledges:

1. Ensure that race and social equity are incorporated and centered in all planning
2. Implement and sustain structures and systems to advance race and social equity
3. Align and implement policy efforts designed to advance race and social equity goals
4. Ensure accountability mechanisms related to the progression and transparency of work to advance race and social equity.

Source: Resolution No. 2974, City of Alexandria Virginia.

The ECCAP's development is supported through input and guidance by the Energy and Climate Change Task Force (ECCTF), and input by the Alexandria community through community engagement workshops. This guidance includes feedback on the ECCAP's various analyses and planning considerations, including business-as-usual (BAU) GHG emissions projections, evaluation of climate change vulnerabilities and equity considerations, climate adaptation recommendations, and the consideration of implementing the EAP2040's actions as well as the identification, evaluation, and prioritization of recommendations for additional policy, programmatic, or technology actions to achieve specific, science-based emissions reductions consistent with the EAP2040's targets and goals. Such actions may include, but are not limited to, efforts that:

1) Increase renewable energy production and availability for city residents/businesses
2) Work to curtail consumption of fossil fuels
3) Engage Alexandria residents and businesses in emissions-reducing actions
4) Identify opportunities for climate adaptation and resiliency policies and practices

Additionally, the ECCTF provides guidance on the ECCAP's implementation roadmap, funding and budgeting strategies, specific implementation steps and approaches, and methods to measure and track progress against time-specific goals consistent with the EAP2040.

Achieving the City's climate goals through implementation of the ECCAP's strategies and actions requires collaborative action from the City government along with the Alexandria community, and its businesses, institutions, utilities, regional partners, as well as significant contributions by state and federal government.

The ECCAP's development also included leveraging partnerships with regional and national partners. For example, the City leveraged previous climate action planning efforts by the MWCOG and the Northern Virginia Regional Commission (NVRC), along with many Metropolitan Washington regional peers, including, but not limited to, Arlington County and Fairfax County in Virginia, the District of Columbia, and Montgomery County in Maryland. In addition, the City leveraged best practice climate action planning information, resources, and examples through participation in an integrated climate action planning cohort program through ICLEI – Local Governments for Sustainability,[1] the Urban Sustainability Directors Network peer exchange, and other organizations. Notwithstanding, ECCTF and members of the Alexandria community graciously provided best practice climate action planning examples to help inform the City's ECCAP development process.

The process to develop the ECCAP included several overlapping phases:

1) **Initiations:**
    a. The Environmental Action Plan 2040 (EAP2040) set a target to reduce community-wide GHG emissions by 50% by Fiscal Year 2030 and 80–100% by Fiscal Year 2050—given a baseline of Fiscal Year 2005—with support by significant contributions at the state and federal level towards renewable energy and energy efficiency mandates. The EAP2040 introduced short-term Action 1.1.1 to:
        i. By FY2021, establish a multidisciplinary task force to guide an update of the ECCAP. The ECCTF will base its recommendations for improvements in energy efficiency for both new and existing private and public buildings on the Green Building Policy. The Plan will include recommendations for specific policies and programs, each with funding strategies, to achieve emissions reductions targets by:
            1) Increasing of renewable energy production and availability for city residents and businesses;
            2) Working to curtail consumption of fossil fuels;
            3) Engaging Alexandria residents and businesses in emissions-reducing actions;
            4) Identifying opportunities for climate adaptation policies and practices.
    b. The ECCTF was established by the Alexandria City Council by Resolution 2958 in September 2020. Subsequently, members of the ECCTF were selected by the City Manager after an open application process.
2) **GHG Inventories, Regional Energy and Climate Action Plan, Transportation Mitigation Studies:**
    a. Coordination with MWCOG on
        i. 2005 - 2018 GHG Inventories

[1] See https://icleiusa.org/ for more information.

   ii. MWCOG Regional Energy and Climate Action Plan
   iii. Transportation Planning Board (TPB) 2021 Climate Mitigation Study

3) **Goal and Priority Setting, Planning and Scoping:**
   a. The ECCTF was established in May 2021 and convened four times from May 2021 – December 2021. During this time, the ECCTF learned about important background information regarding the ECCAP's development, including the City's existing body of climate action and environmental sustainability, considerations for climate mitigation solutions.
4) **Community engagement**
5) **Analysis and reduction planning, vulnerability assessment and climate adaptation planning**
6) **Development of ECCAP report**

Relationships to Other Energy and Climate Plans in the City and Region

The City of Alexandria has shown its commitment to addressing climate change through actions and various planning efforts. This ECCAP recognizes and builds on these efforts and others throughout the region, including:

- The predecessor plan to this, the 2012-2020 Energy and Climate Change Action Plan (eCAP).
- The 2019 updated EAP2040, which provides strategic guidance for the City's efforts to reduce greenhouse gas emissions, improve energy efficiency, protect stormwater resources and waterways, improve mobility options, and reduce waste.
- The 2019 WasteSmart plan which provides Alexandria's 20-year strategy plan to sustainably recover resources.
- The 2021 Alexandria Mobility Plan provides policies and strategies that will guide transportation decisions for the next 10 years in pursuit of enhanced quality of life, sustainability, and equity, centered around the concept of choice.
- The 2021 Alexandria Electric Vehicle Charging Infrastructure Readiness Strategy, which provides a framework for advancing EV charging infrastructure in the City of Alexandria, Virginia.
- The 2022 Alexandria Transit Vision, which lays out a roadmap for the future City bus networks to provide more useful bus service for the City of Alexandria by introducing frequent, all-day bus service to areas where more people will be able to use it. The new bus networks will significantly increase access to frequent transit for low income, minority, and senior residents, while establishing important bus connections to the future Potomac Yard Metrorail Station and other key development areas.
- The MWCOG 2030 Climate and Energy Action Plan which establishes priority collaborative actions for area governments and partners to work on together over ten years to help move the region towards meeting its 2030 climate mitigation and resiliency goals.

- Transportation strategies are informed by the National Capital Region TPB Climate Change Mitigation Study of 2021, which assesses transportation-related actions needed to reduce GHG emissions and strives towards achieving regional goals for 2030 and 2050.

Building on these plans and the City's existing policies and programs the ECCAP offers a strategic pathway towards the City's goals of 50% emissions reduction by 2030 and 80-100% reduction by 2050 while also adapting to and becoming more resilient to the impacts of climate change. The strategies and guidance in the ECCAP focus on reducing GHG emissions across key sectors and preparing for the key impacts of flooding and heat, while applying a lens of diversity, racial and social equity, and inclusion in keeping with the ALL Alexandria vision.

Current Energy and Climate Context for Alexandria

Climate Change Impacts in Alexandria

In Alexandria, the effects of climate change can already be felt in the form of increasing temperatures and more frequent and intense flooding events. A study conducted by the MWCOG as part of the 2030 Climate and Energy Action Plan identified flash and riverine flooding and extreme heat as the greatest climate risks to the area. Drought, coastal flooding, lightening/ thunderstorm, and extreme winter conditions were also identified as local climate-related risks.

The Potomac River in the D.C. area is anticipated to rise 1.51-2.07 feet by 2060 under an intermediate emissions scenario.[2] This could inundate some low-lying coastal areas and contribute to increased flooding in the City. Additionally, National Oceanic and Atmospheric Administration (NOAA) has

Climate Change Impacts in Alexandria

- Higher average temperatures and more frequent heat waves
- More intense storms with heavy rainfall
- Sea level rise from the Potomac River inundating coastal areas
- More frequent flood events
- Extreme winter weather conditions

[2] NOAA, Sea Level Rise Viewer, https://coast.noaa.gov/slr/#/layer/vul-soc/0/-8580120.72562164/4695745.0055577895/13/satellite/152/0.8/2050/inter/midAccretion.

identified several regions within Alexandria as having a medium or high level of vulnerability to flooding.[3]

Temperatures are also projected to continue increasing in Alexandria. Historically, Alexandria has experienced an average of eight days per year with temperatures over 95°F. That number is projected to increase to 19-20 days by 2030 and 26-33 days by 2050. The ECCAP identifies areas of the city where residents are likely to be vulnerable to extreme heat. Heat vulnerability is based on average summer temperatures, proximity to green spaces and cooling centers, and socioeconomic characteristics.

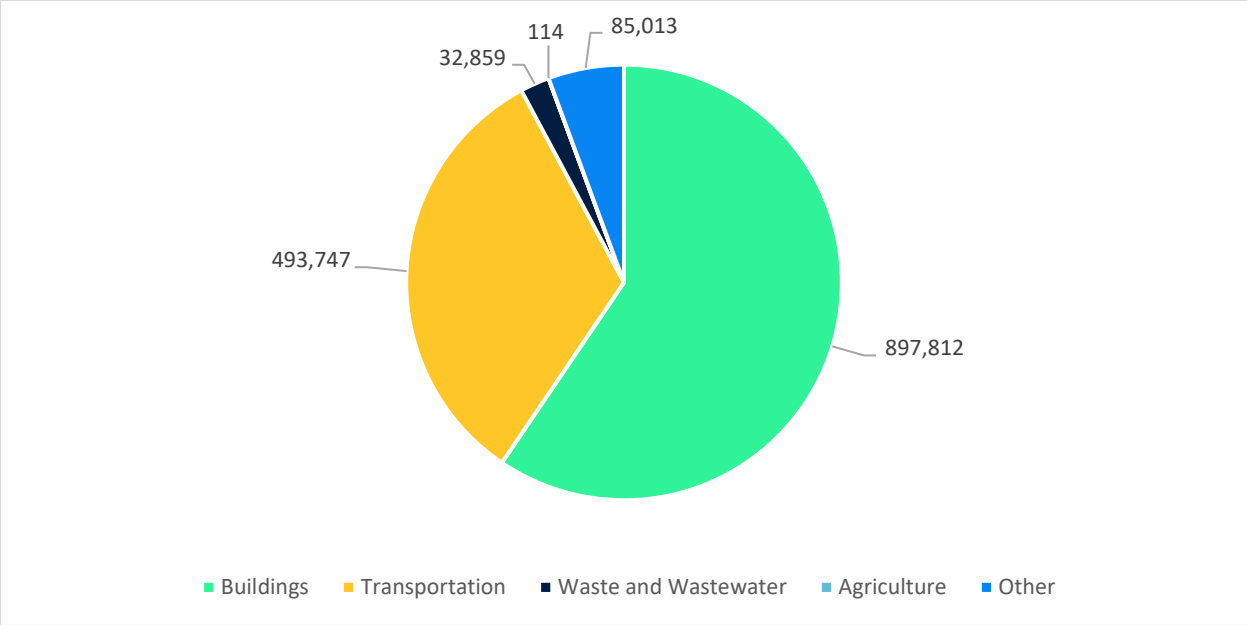
While the impacts of climate change cannot be completely avoided, they can be reduced by curbing greenhouse gas emissions and proactive climate adaptation planning. The ECCAP focuses on potential impacts of flooding and extreme heat in Alexandria, and details initiatives and strategies to address the impacts of climate change locally.

GHG Emissions in Alexandria

In 2018, Alexandria's total GHG emissions were 1.48 million metric tons of carbon dioxide equivalent ($MTCO_2e$). The majority of emissions (59%) came from the use of energy in residential and commercial buildings. Transportation emissions account for 33% of overall emissions, with most (80%) from on-road sources. The category "other" represents hydrofluorocarbon and refrigerant emissions, as well as fugitive emissions from natural gas distribution, and contributed 6% of the City's 2018 emissions. Waste and wastewater emissions were 2% of total emissions, followed by agricultural emissions (e.g., from agricultural soils), which were well under 1% of the City's total emissions. Figure 1 shows total GHG emissions allocated by sector.

Figure 1. 2018 GHG Emissions By Sector ($MTCO_2e$)

[3] NOAA, "Social Vulnerability to sea level rise in Alexandria," Sea Level Rise Viewer, https://coast.noaa.gov/slr/#/layer/vul-soc/0/-8580120.72562164/4695745.0055577895/13/satellite/152/0.8/2050/inter/midAccretion.



Climate Equity

The City of Alexandria is committed to working toward a world where everyone is embraced for who they are and that all are able to thrive and reach their greatest potential. Equity means promoting just and fair inclusion throughout our city and creating the conditions in which everyone can participate, prosper, and reach their full potential. To integrate equity through City plans and actions, the City has developed the ALL Alexandria resolution.

ALL Alexandria Vision: Alexandria is a caring, kind, compassionate, fair, just, and equitable city that is an affordable, livable community for all.

ALL Alexandria Goal: Reduce and eliminate disparities and inequities experienced by All Alexandria residents, especially residents of color and those that have been historically and systemically marginalized.

In line with ALL Alexandria, this climate action plan considers and integrates equity across both GHG reduction and climate adaptation strategies presented, with a particular focus on thinking about equity in terms of both risks and benefits, as well as implementation of strategies. The approach by which equity was assessed and is addressed differs for both climate mitigation and climate adaptation strategies.

Equity in GHG Reductions

To assess equity within GHG reduction strategies the City used the following approach:

Step 1. Develop equity assessment framework and indicators. In line with ALL Alexandria, the City developed an equity framework and indicators to assess GHG mitigation actions that help reduce and eliminate disparities and inequities experienced by Alexandria residents, especially for marginalized and minority residents. The equity framework is presented in Table 1 below.

Step 2. Host a workshop with multiple City departments and staff. In the summer of 2022 City departments and staff convened to discuss the equity framework and GHG strategies for the ECCAP and approaches for ensuring equitable benefits resulting from and equitable implementation of those strategies.

Step 3. Provide a qualitative assessment of GHG strategies using input from the workshop and the equity framework and indicators. The City assessed the GHG reduction strategies to qualitatively to determine if the strategy will have a detrimental, neutral, or beneficial impact on equity. The evaluation is a result of reviewing and assessing the questions and considerations for each indicator and is presented for each strategy and action presented in the GHG strategies section. Equity is also considered when developing the key milestones and when considering implementation of each strategy and action (e.g., energy equity or access to technologies and programs).

Table 1. Equity Indicator Definitions and questions

Indicator	Definition and Questions
Economic	**Actions that support economic benefits (e.g., poverty reduction, lower energy costs) and reduce economic disparities.** • Does an action reduce energy burden, utility cost burden, or transportation cost burden for communities, especially marginalized and minority communities? • Does an action ensure energy reliability, reduce energy intensity, and/or reduce per capita energy consumption? • Does an action generate new living wage construction, manufacturing, clean technology, green infrastructure, or similar employment opportunities? • Does an action introduce training, job placement, and career growth opportunities to support disadvantaged communities and/or the transition of workers away from carbon-intensive industries? • Does an action align with existing local economic policies and goals?
Health	**Actions that support health benefits (e.g., improved air quality)** • Does an action help address the needs of or improve health outcomes for vulnerable populations (e.g., marginalized and minority communities, elderly)? • Does an action directly reduce PM2.5 or other particulate matter and air pollutants (e.g., ozone, diesel PM)? • Does an action directly result in or support mechanisms to improve air quality?

Indicator	Definition and Questions
	• Does an action directly result in or support mechanisms to improve indoor air quality (e.g., building electrification, improved monitoring systems and data collection)? • Does an action reduce VMT, with an emphasis on peak hour congestion, and reduce air pollution exposure for sensitive populations? • Does an action support more active transportation modes or increased physical activities? • Does an action reduce health risks to sensitive populations, such as people with respiratory or cardiovascular diseases? • Does an action reduce VMT, with an emphasis on peak hour congestion, and reduce air pollution exposure for sensitive populations?
Social	**Actions that support social and other quality-of-life benefits (e.g., reduced traffic congestion, increased opportunities for socioeconomic mobility).** • Does an action help address the needs of or provide increased opportunities for socioeconomic advancement of marginalized and minority communities? • Does an action create or protect natural or recreation spaces? • Does an action improve educational attainment across communities? • Does an action reduce the housing burden across communities? • Does an action encourage closer housing-work proximity to reduce transportation cost burden and GHG emissions? • Does an action alleviate poverty? • Does an action align with existing local social policies?

Equity in Climate Adaptation

Adaptation strategies were created with the knowledge that the impacts of climate change will not be experienced uniformly among community members. People who are elderly, young, low-income, or disabled are more vulnerable to climate change impacts, especially as they become more frequent and intense. Municipal plans and operations can proactively address systemic inequities by identifying the communities at greatest risk and considering the distribution of resources related to climate resilience.

This plan identifies communities likely to face the worst impacts from flooding, extreme heat, and other climate-related hazards. For extreme heat in particular, the City provides an interactive web map that uses socioeconomic data to provide an overview of heat vulnerability across the city. The City of Alexandria recommends that its resources for combating the impacts of extreme weather be primarily directed towards vulnerable communities to alleviate the consequences of climate change. Adaptation strategies include expanding climate-focused outreach and education, improving emergency

management response, and making infrastructure improvements in the most vulnerable communities.

GHG Emissions and Reduction Strategies

Existing GHG Reduction Strategies and Programs

The City of Alexandria's existing strategies and programs to reduce community greenhouse gas serves as a foundation for this updated ECCAP's promotion of actions to support the reduction of community-wide GHG emissions.

The City of Alexandria's **Green Building Policy**, adopted by City Council in 2019, identifies: 1) the pathways to achieve the City's green building performance standards, including certification through nationally recognized green building rating systems, 2) a minimum level of green building certification for both private and public developments, and 3) priority "Performance Points" within each rating system that a project is expected to achieve. The Green Building Policy applies to new private development, new public development (including City-owned and Alexandria City Public Schools (ACPS) building) and major renovations that require a Development Site Plan (DSP) or a Development Special Use Permit (DSUP). In addition, new public development is required to also achieve net-zero energy defined as an energy-efficient building where, on a source energy basis, the actual annual delivered energy is less than or equal to the on-site renewable exported energy. For renovations of City-owned buildings that do not require a DSP or a DSUP, the City will apply LEED Interior Design and Construction (ID+C) and LEED Operations and Maintenance (O&M) rating systems as a guideline for interior design and construction projects and targeted renovations of individual building systems (e.g., heating, ventilation, and air conditioning (HVAC), roof, windows, plumbing). Actual third-party certification may be used when technically and financially feasible.

The **Alexandria Commercial Property Assessed Clean Energy (C-PACE)** program, established in 2021, is an innovative financing program enabling owners of commercial, multifamily (5+ units) and industrial properties to obtain low-cost, long-term financing for eligible clean energy, stormwater management, and resiliency improvements. Clean energy improvements can include energy efficiency, renewable energy, electrification, water efficiency, and EV charging infrastructure projects and technologies.

The City continues to work closely with Dominion Energy to implement **light-emitting diode (LED) streetlighting retrofits** with nearly 50% retrofitted to date. The completion of these streetlighting retrofits is anticipated for 2023.

Since 2015, the City has worked with the Northern Virginia Regional Commission (NVRC) and the Local Energy Alliance Program (LEAP) to offer bulk discounted solar system pricing and other energy savings through **SolarizeAlexandria**. As of 2022, over 80 properties have installed solar panels through the program, totaling over 500 kW of newly installed solar energy system capacity. SolarizeAlexandria also offers participants special pricing on EV charging stations and battery storage. The SolarizeAlexandria application process is open annually year from March through June.

The City offsets nearly 90% of its operational electricity use with purchased **Renewable Energy Certificates (RECs)** from wind, solar, and other renewable energy resources from around the U.S.

The City of Alexandria's support of the **Energy Masters** program continues to serve Alexandria residents living in affordable housing communities.

The City's **Energy Efficiency Loan Program** offers eligible low- and moderate-income Alexandrians energy assessments to identify key issues and solutions, and loan funding to complete energy efficiency improvements such as air sealing, insulation, energy efficient appliances as well as heating and cooling systems. The program serves owner occupants with combined incomes below 80% of the area median income by family size. Eligible households may receive no interest loans for energy efficiency improvements for their homes. Repayment of the loans is deferred for 99 years or until the property is sold or the owner(s) move, whichever comes first.

The City partners with community organizations to support weatherization assistance programs to help low and moderate-income City residents weatherize their homes and reduce their monthly energy bills. For example, Community Housing Partners Corporation is the Commonwealth of Virginia's **Weatherization Assistance Program (WAP)** local provider to include diagnostic tests to evaluate areas of heat loss, and the installation of energy efficiency improvements, such as repairing or installing attic and wall insulation and weather-stripping doors. The City also assists in coordination of heating and cooling assistance through the Virginia Department of Social Services, as well as referring income-eligible households to utilize Dominion Energy Share program.

The City promotes the Virginia non-profit **Local Energy Alliance Program's (LEAP)** suite of energy assessment, weatherization, and energy efficiency services in partnership with the NVRC. LEAP is an implementation partner to Dominion Energy and Washington Gas's energy efficiency incentive program offerings.

The **Alexandria Mobility Plan (AMP)** was adopted in November 2021 and focuses on expanding high-quality transportation choices so transportation in the City continues to serve the needs of residents, businesses, and visitors. The AMP is a strategic update to the 2008 Transportation Master Plan and sustainability is a guiding principle. Many of the policies and strategies in the plan seek to make transportation options in Alexandria more sustainable including reducing congestion, making transit greener and more convenient, and creating a comfortable walking and bicycling environments.

The continued implementation of the Vision Zero Action Plan and Complete Streets Design Guidelines supports the use of low-carbon mobility options aligned with the EAP2040. Numerous crossing improvements citywide, most notably on Commonwealth Avenue and Braddock Road and others have helped increase safety for students walking and biking to Naomi Brooks Elementary and George Washington Middle School. On Braddock Road, a new **H**igh-Intensity **A**ctivated Cross**walk** (HAWK signal) improved safety for students walking or

biking to Minnie Howard Campus and Episcopal High School. The posted speed limit was reduced on Seminary Road to minimize fatal and severe crashes.

The City joined the region's **Capital Bikeshare** system in 2011 and so far has installed over 60 stations to serve the community, including expansion to the West End.

The Alexandria Transit Company—Driving Alexandria Safely Home (DASH)—started implementation of the **Alexandria Transit Vision** - a strategic effort to design a more useful and equitable bus network that encourages more people to get to more places using transit – and a "**Fare Free DASH**" program in September 2021. These two programs have increased service levels by over 15% and substantially increased the accessibility and usefulness of public transit in Alexandria. The Alexandria Transit Vision features major improvements to service span and frequency on key transit corridors, with an emphasis on improving transit access for Alexandria's Senior, Disabled, Minority, and Low-Income communities.

The City of Alexandria identified three corridors throughout the community as **Bus Rapid Transit** (BRT) Corridors. Since its launch in August 2014, the National Landing-Potomac Yard Metroway provides frequent BRT premium service between the Braddock Road Metro Station and Pentagon City Metro Station, with service through the Alexandria and Arlington sections of Potomac Yard and the Crystal City area of Arlington. The West End Transitway, to include a BRT system along the Van Dorn/Beauregard corridor and Duke Street In Motion, focused on ensuring transit improvements along the Duke Street corridor, from Landmark Mall area to the King Street Metro Station, provide efficient transportation options that align with all users' needs, wants and expectations.

The City of Alexandria invests in **Smart Mobility** transportation technologies that improve road safety and traffic management while also preparing the City to take advantage of future transportation infrastructure advancements, such as self-driving cars and real-time traffic management. The Alexandria ITS program is installing transit vehicle signal priority (TSP) along key transit routes. The purpose of TSP is to provide reliable transit bus operation by improving schedule adherence. In the transit world, running behind schedule is very bad but, running ahead of schedule is even worse. The goal of TSP is to keep buses running on schedule with little to no variation. Smart buses will request priority from traffic signals when running behind schedule. The signals will then try and get the bus back on schedule through extending the green light or shortening the red light. This is part of a regional effort which will allow buses to seamlessly travel between jurisdictions.

DASH currently operates fourteen battery electric buses as part of its transition to operating a 100% **Zero-Emission Bus fleet**; the largest deployment of zero emissions buses in the Commonwealth of Virginia. These busses represent the first step in an ongoing expansion of DASH's battery electric bus in the transition to a 100% zero emissions fleet. Altogether, the 14 total battery electric buses will reduce DASH's carbon emissions footprint by over 14,000 tons over the buses' lifespan. DASH has started its Zero Emissions Bus

Implementation Study Phase II and Facility Expansion Pre-Design to support the remainder of the fleet's transition to zero emissions by 2035.

In April 2021, the City Council adopted the **Electric Vehicle Charging Readiness Strategy (EVRS)**. The EVRS provides a framework for advancing electric vehicle charging infrastructure and describes current initiatives, technologies, and public perceptions related to EV charging in Alexandria. The EVRS provides recommendations to build a thriving electric vehicle ecosystem to contribute to achieving the City's GHG emission goals in the EAP2040.

The **Alexandria Library Climate Resilience Hub** dedicates materials, events and space to that help educate residents about extreme weather preparedness and other impacts of climate change. Alexandria Library's Climate Resilience Hub is located at the Kate Waller Barrett Branch.

In September 2022, the Alexandria City Council authorized establishment of an **Office of Climate Action** to respond to the ongoing climate crisis which continues to impact the well-being of our community. The creation of the City's Office of Climate Action marks a monumental achievement aimed at combating climate change through a city-wide approach to empower the Alexandria community to actively participate and contribute to sustainable action. A Climate Action Officer and Public Affairs and Engagement Specialist will join five reallocated employees from the partnering departments to serve in the City's Office of Climate Action. The overall composition of the Office of Climate Action both recognizes the prior and ongoing efforts across City departments and aims to set up an implementation and partnership-oriented approach. The Office of Climate Action will lead efforts in a variety of areas, including but not limited to, energy efficiency, high performance buildings, renewable energy, climate change mitigation and reporting, electric mobility, business assistance, community engagement, and advocacy. The Office of Climate Action will work closely with City departments, other governmental entities, and the community in achieving EAP2040 and ECCAP commitments.

BAU Scenario

The Alexandria BAU model estimates future annual emissions under the assumption that no new policies or actions are taken to mitigate emissions as of 2018. It incorporates factors such as projected population growth, economic growth, and electricity grid emission factors. It does not assume or incorporate any additional GHG emissions reductions from anticipated future action (e.g., anticipated state level policies such as VCEA).

In 2018, Alexandria's total GHG emissions were 1.48 million metric tons of carbon dioxide equivalent ($MTCO_2e$). In the BAU scenario, Alexandria's GHG emissions are expected to grow to 1.65 million $MTCO_2e$ by 2050. This represents a 12% increase compared to 2018 emissions. Most of the growth is driven by commercial sector buildings emissions due to

projected high job growth and population rates, which are used as proxies for increases in building square footage.

Between 2020 and 2025, Alexandria is projecting six times the annual job growth as compared to other years in the forecast. This increased job growth drives commercial building square footage growth by 8-11% from 2020 to 2025, compared to the 1-2% in all other years in the forecast. As a result, commercial building emissions are predicted to grow by 55% from 2020 to 2025. The growth in commercial building emissions growth is largely due to expected mixed use projects with significant new multifamily residential components. In the BAU, GHG emissions from buildings are projected to nearly double as depicted in Figure 2. The growth in GHG emissions is in large part due to commercial new construction, not existing buildings, as depicted in Figure 3.

Figure 2. Alexandria BAU GHG Emissions

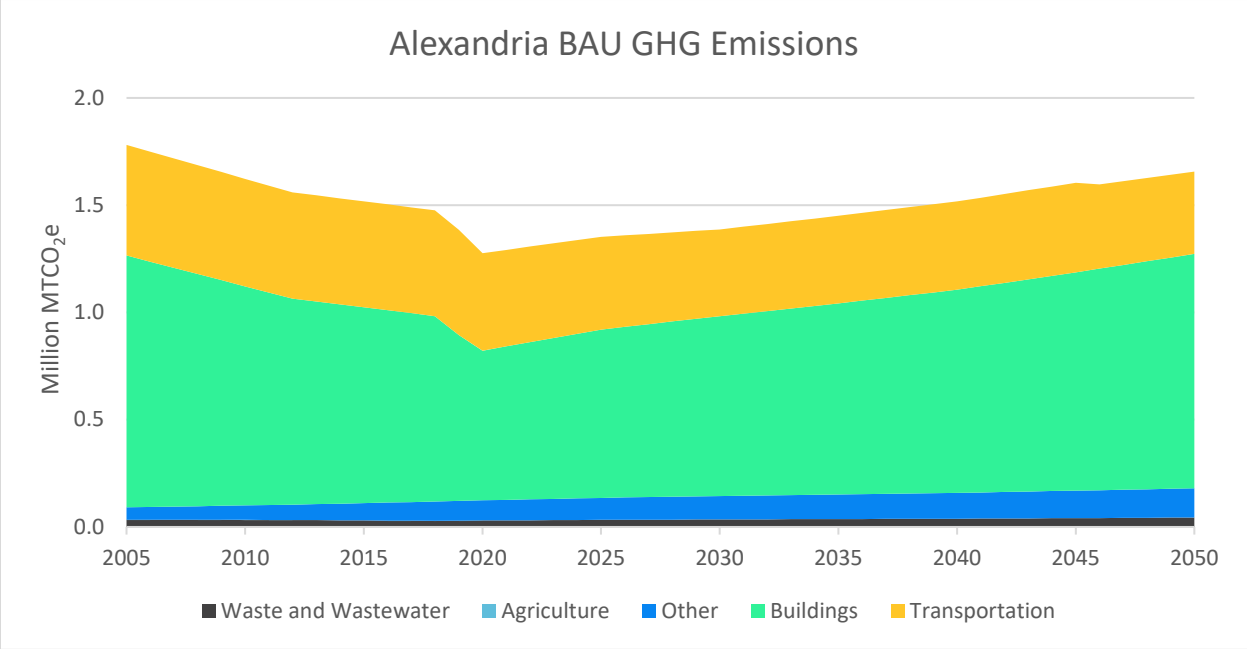
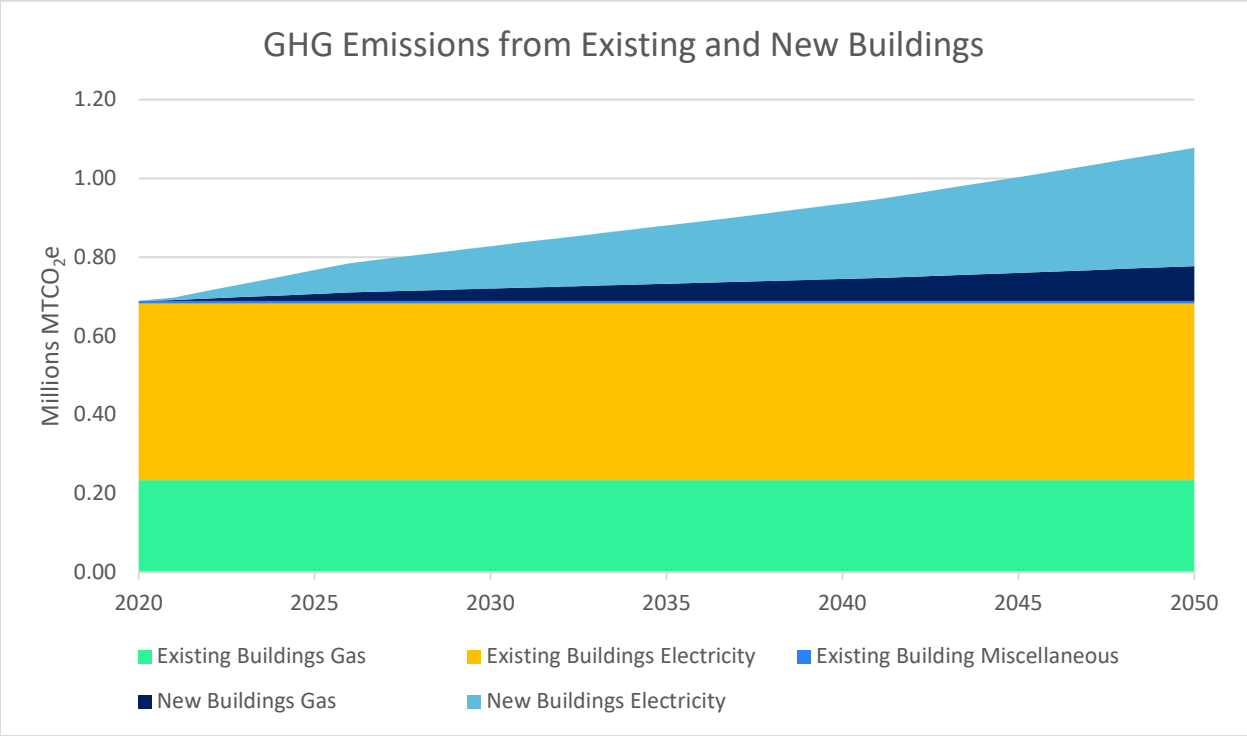


Figure 3. GHG Emissions from Existing and New Buildings



GHG Reduction Priority Strategies and Actions

As established in EAP2040, the City of Alexandria's GHG targets are to reduce community-wide GHG emissions by 50% by 2030 and 80 to 100% by 2050. The City is planning to use multiple strategies and actions to both achieve and accelerate progress towards achieving these goals. Working with the understanding of resource and authority constraints that Alexandria faces (see City Authority and Influence box), the City identified and analyzed priority strategies and actions that will be used to reduce the City's GHG emissions.

These priorities are mostly focused on addressing the highest emitting sectors, buildings and transportation, but also cover waste and other types of emission reductions such fugitive methane emissions associated with natural gas use. They build directly on and incorporate the plans and work the City has already done or is doing (e.g., the strategies and actions outlined in EAP2040). Additional details about the strategies and supporting actions listed in Table 2 below are provided in the following sections. The strategies and actions summarized reflect the technology context and policy landscape today. As technologies evolve and policies that address GHG emissions at the federal and state levels continue to develop the City's priorities will priorities will also evolve.

City Authority and Influence

The Commonwealth of Virginia follows the "Dillon Rule", as opposed to the "Home Rule." Dillon Rule and Home Rule are opposing legal interpretations of local government authority. In Virginia, under Dillon Rule, state law is pre-emptive of local law unless the state confers the power to local government. The Dillon Rule is strictly interpreted so that if there is reasonable doubt about whether a power has been conferred to a local government, then it has not been. Within Virginia, this limits the ability of local governments to require, for example, stricter green building practices in the private sector than the standards set by the state. This does not preclude the City, though, from implementing standards for their own operations, running voluntary programs (e.g., City of Alexandria Green Building Policy), influencing and advocating for state policy changes, and requiring new building requirements. The City of

Table 2. Alexandria's Priority GHG Reduction Strategies and Actions

STRATEGY/ACTION	GHG REDUCTIONS	COST	EQUITY
Building Energy Sector			
B-1 Support decarbonizing buildings through financial opportunities	**2030:** 320,000 $MTCO_2e$ **2050:** 1.02 million $MTCO_2e$ (Includes B-2)	**$$**	**+**
B-1.A Support opportunities for a City or regional green bank			
B-1.B Increase Marketing and Promotion of Alexandria C-PACE Program			
B-1.C Establish an incentive program(s) that encourages Green Building renovations of existing buildings			
B-2 Educate and drive implementation of the City Green Building Policy	Estimated in B-1	**$**	**+**
B-2.A Support compliance with the City Green Building Policy			
B-2.B Design and implement a program to support residential and commercial energy efficiency and beneficial electrification			
B-3 Increase decarbonized buildings fuel supply	**2030:** 87,000 $MTCO_2e$ **2050:** 116,000 $MTCO_2e$	**$$**	**+**
B-3.A Increase energy supply from resource recovered gas and hydrogen			
B-4 Accelerate implementing feasible decarbonization efforts for City-owned buildings	Not estimated	**$$$**	**/**
Transportation Sector			
T-1 Reduce vehicle miles traveled (VMT)	**2030:** 30,000 $MTCO_2e$ **2050:** 50,000 $MTCO_2e$	**$$$**	**+**
T-1.A Implement strategies from the Alexandria Transit Vision and Mobility Plans			
T-1.B Land use changes focused on redistribution of future growth to activity centers and areas better served by transit			
T-1.C Advocate for reduced transit fares and parking pricing in workplaces			
T-1.D Support telework policies			
T-1.E Promote a job/housing balance by focusing on-site affordable housing units near transit, jobs, and amenities			
T-2 Accelerate the deployment of electric and alternative fuel vehicles	**2030:** 41,000 $MTCO_2e$ **2050:** 240,000 $MTCO_2e$ (Includes T-3)	**$$$**	**+**
T-2.A Implement recommendations that support EV charging infrastructure development			
T-2.B Provide education and outreach to the community about EVs and available state and national incentives			

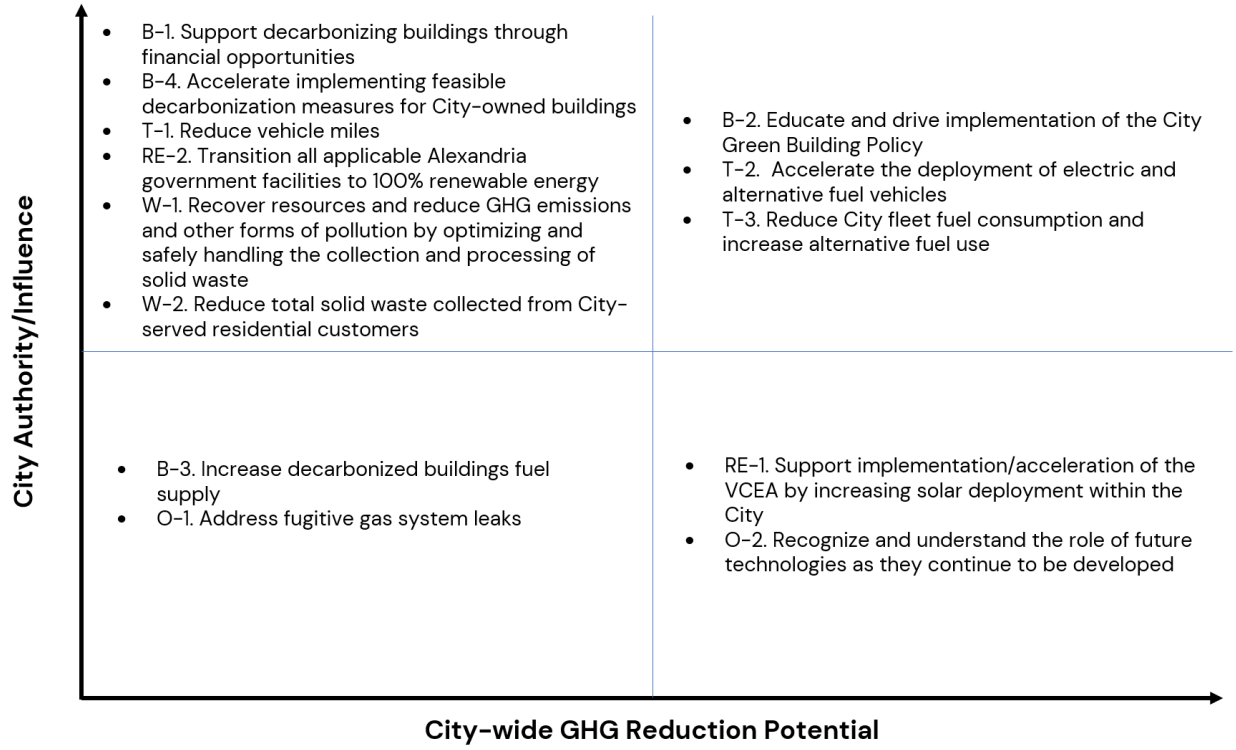
STRATEGY/ACTION	GHG REDUCTIONS	COST	EQUITY
T-2.C Advocate with Dominion and regulators for fee-based EV charging; educate the community about these options			
T-2.D Transition public fleets to electric (DASH)			
T-2.E Connect private fleets with partners and opportunities to educate and incentivize electrification			
T-3 Reduce City fleet fuel consumption and increase alternative fuel use	Estimated in T-2	**$$$**	/
T-3.A Reduce vehicle size of City fleet			
T-3.B Increase average fuel economy of City fleet			
T-3.C Reduce VMT through various best practices			
T-3.D Purchase vehicles with highest emissions certification standards			
T-3.E Increase use of alternative fuel vehicles and equipment (i.e., electric and hybrid vehicles)			
Renewable Energy Sector			
RE-1 Support implementation/acceleration of the Virginia Clean Economy Act (VCEA) by increasing solar deployment within the City	**2030:** 160,000 $MTCO_2e$ **2050:** None	**$$**	+
RE-1.A Increase on-site renewable deployment within the City			
RE-1.B Support deployment of battery storage through promoting community ownership, incentives, and pairing with onsite renewables			
RE-1.C Consider implementation of municipal aggregation program			
RE-1.D Encourage large-scale offsite renewable energy working with businesses and others within the City to procure through PPAs			
RE-2 Transition all applicable Alexandria government facilities to 100% renewable energy	Not estimated	**$$**	/
RE-2.A Implement government operations renewable electricity actions from the EAP 2040			
Waste Sector			
W-1 Recover resources and reduce GHG emissions and other forms of pollution by optimizing and safely handling the collection and processing of solid waste	**2030:** 8,900 $MTCO_2e$ **2050:** 39,000 $MTCO_2e$ (Includes W-2)	**$$**	/
W-1.A Implement actions defined in the EAP 2040 addressing resource recovery and GHG emissions			
W-1.B Implement actions defined in the EAP 2040 that will reduce solid waste from City-served residents			
W-2 Reduce total solid waste collected from City-served residential customers	Estimated in W-1	**$**	/
Other Sector			

STRATEGY/ACTION	GHG REDUCTIONS	COST	EQUITY
O-1 Address fugitive gas system leaks	**2030:** 620 $MTCO_2e$ **2050:** 1,500 $MTCO_2e$	**$**	**/**
O-1.A Set requirements for Washington Gas to report level of leaks in Alexandria distribution system and upstream piping systems			
O-1.B Analyze whether the state approved SAVE rider provides for a fair recovery of pipeline infrastructure upgrades to reduce leaks			
O-2 Recognize and understand the role of future technologies as they develop	**2030:** None **2050:** 186,000 $MTCO_2e$	**$$$**	**/**

Notes:
Cost indicators are as follows: $ means low cost, $$ means moderate cost, $$$ means high cost.
Equity indicators are as follows: / means neutral or minimal potential impact, + means beneficial or favorable impact.

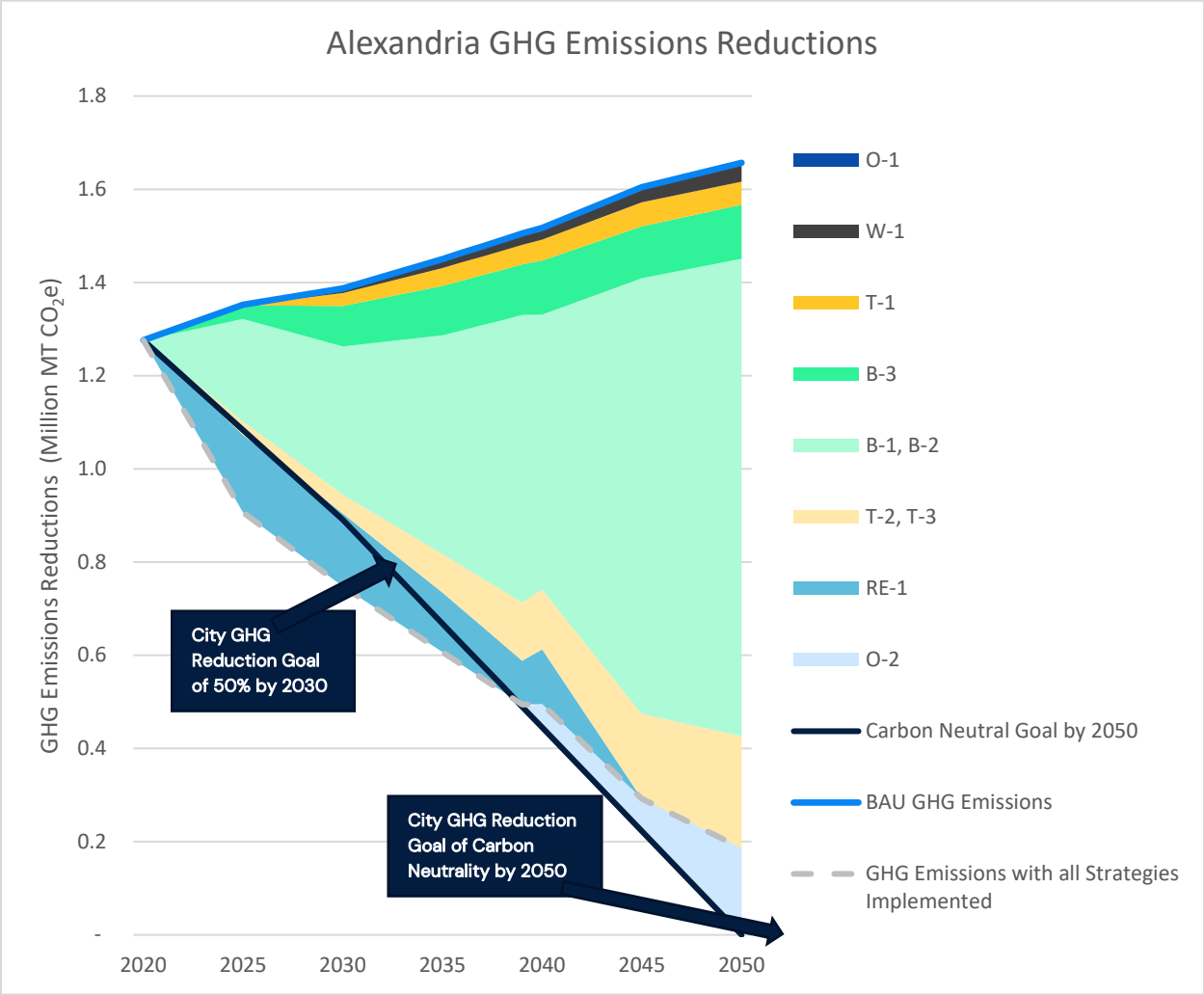
Figure 4 below presents another view of each GHG reduction strategy organized by GHG reduction potential and City authority or influence. Organizing strategies with this approach and based on the GHG reduction modeling presented below, along with the qualitative analysis included within this ECCAP on relative cost and equity impacts, will help guide the City in allocating resources and effort to implement this ECCAP.

Figure 4. GHG Reduction Strategies Organized by GHG Reduction Potential and City Authority/Influence



The City analyzed a potential GHG reduction pathway related to these strategies and actions by considering the technical potential, feasibility, and availability of the technologies needed to reduce emissions from within each sector to meet the City's GHG reduction goals of by 50% by 2030 and 80-100% by 2050. Existing state and local GHG policy targets (e.g., VCEA, 2019 City Green Building Policy) are met or exceeded within the modeling, but constraints with current policies and regulations were not considered. While each specific strategy and action was not modeled using a bottom-up approach, at least everything identified within this ECCAP will be needed to drive the levels of technology implemented within the GHG reduction pathway presented in Figure 5.

Figure 5. A Pathway to Meet Alexandria's GHG Reduction Goals



The modeled GHG reduction pathway for the City of Alexandria results in a 58% reduction of emissions by 2030 from a 2005 base year, and 90% by 2050, meeting Alexandria's 2030 and 2050 emission reduction target. Most of the reductions in emissions come from decarbonization of the building sector, including investing in a cleaner grid. Reductions in transportation emissions also play a major role.

Buildings

Decarbonization of the building sector is a result of a combination of measures. Existing buildings modeling included deep energy efficiency measures such as change to HVAC, new building envelopes, and lighting retrofits. Additionally, electrification of HVAC, cooking, and hot water from buildings was prioritized as equipment reaches the end of its useful life. Electrification in concert with the cleaner grid allowed for buildings to emit only a very small amount of carbon. New buildings were modeled as both highly efficient and almost entirely powered by electricity in alignment with the City's green building policy.

Electricity Grid

Decarbonization of the electricity grid is foundational to Alexandria's goals. In addition to lowering the carbon of existing electricity uses, it enables deep reductions for uses that are electrified such as building energy and transportation. The modeled grid in the policy shows a decrease in emissions of over 97% by 2050 compared to the 2020 grid and is near zero emissions per unit of electricity.

Transportation

In the transportation sector, decarbonization will occur from anticipated increases in adoption of EVs in future years. As EVs make up larger and larger shares of the overall fleet, the amount of electricity used to power the fleet will grow. Existing and future clean grid policies mean that the transportation fleet will realize some emissions reductions through anticipated electrification and associated reduction in electricity generation emissions factors alone despite increases in population and vehicle miles traveled (VMT).

Additional measures have been simulated to further encourage decarbonization in the transportation sector, and these measures fall into three pathways:

1) Vehicle Technology and Fuels (VT),
2) Mode Shift and Travel Behavior (MS), and
3) Transportation System Management and Operations along with efficiency improvements from autonomous vehicles (transportation systems management and operations (TSMO) + connected/automated vehicles (CAV)).

VT measures include aggressive increase in EV sales (50% of light duty vehicle sales by 2030 and 100% by 2050, 30% of medium and heavy-duty truck sales in 2030 and 100% by 2050, and 50% of the bus fleet by 2030 and 100% by 2050.) They also include increased up take of biodiesel and renewable diesel.

MS measures include land use changes to accommodate new housing in activity centers with high quality access to transit, reductions in transit fares and travel times, priced workplace parking, sustained telework participation, and increased bicycle, pedestrian, and micromobility uptake for short trips.

Lastly, TSMO + CAV measures incorporate marginal effects from new ITS hardware for reducing congestion in area roadways. Benefits in fuel economy from eco-driving behavior of CAVs are also included.

The impacts from these policies are summarized in Table 4. Baseline reduction estimate are presented first, which represent benefits that would be realized anyway in future years without additional action by the city. Next, individual pathway contributions, including VT, MS, and TSMO + CAV are presented. These represent the benefits that would be realized if the measures supporting that pathway were introduced. It should be noted that the emissions reductions from these pathways are inclusive of the baseline reductions, and as such should be interpreted as the results of the pathway as if they were implemented in

isolation of the other pathways. The COMBO Pathway combines the results of all individual pathways and also includes the baseline effects[4]. Results for both the ICF Reference Grid case, incorporating on the books policies, and the Alexandria Clean Grid case, a more aggressive projection of a decarbonized grid, are both included.

Table 3. Summary of GHG Reductions Estimated for all Transportation Scenarios Under all Electric Grid Cases (% Reductions from 2005 Level)

Pathway	Key Components	2030		2050	
		Ref. Grid	Clean Grid	Ref. Grid	Clean Grid
Baseline	Base assumptions for vehicle technology; population growth through 2050	-20%	-20%	-32%	-33%
VT	50% of new light-duty (LD) vehicle sales are EVs in 2030, with 100% by 2040; 30% of new medium- or heavy-duty (M/HD) truck sales are EVs in 2030, with 100% by 2050; 50% of buses on the road are EVs in 2030, 100% in 2050; biofuels/renewable diesel make up 10% of diesel fuel use in 2030 and 20% in 2050	-26%	-27%	-74%	-87%
MS	Land use changes, including new housing in the region; transit fares reduced 50% by 2030 and 75% in 2050; all workplace parking in activity centers priced by 2030; 10% reduction in transit travel time by 2030 and 20% by 2050; 25% telework; increased bike/ped/micromobility	-27%	-27%	-39%	-40%
TSMO + CAV	Optimized ITS/TSMO, with benefits from CAVs by 2050	-21%	-21%	-34%	-35%
COMBO	Combined scenario: VT+ MS + TSMO	-34%	-35%	-77%	-88%

Additional Strategies to Accelerate Climate Action

The City recognizes that although the modeled strategies will achieve the City's GHG reduction goals, there are additional strategies that could be explored to accelerate climate action and go beyond the City's goals. These additional strategies include (a) existing technologies that may be costly; (b) to be developed technologies; and (c) accelerated action. Specifically, these additional strategies could encompass technologies like carbon capture, utilization, and storage, advanced batteries, and very rapid shifts to move the fleet

[4] COMBO emission reductions can be approximately calculated by subtracting the baseline percent from the VT, MS, and TSMO + CAV pathway results. Next, multiply 100% by 1 minus the resulting differences.

toward zero emissions vehicles, so that nearly all new vehicles sold in the next few years would be electric or other zero emissions (well beyond the most aggressive EV sales targets in place today). In addition, further reducing single occupancy vehicle trips and VMT could be achieve through cordon pricing, VMT pricing, or other policy constructs that are feasible but do not yet exist.

Key Milestones

The modeled GHG reduction pathway demonstrates key milestones that will put Alexandria on the path to meetings its GHG goals. These milestones across major-emitting sectors are summarized in Figure 6. It is important to understand that this is just one potential pathway. Looking decades into the future inherently has several uncertainties such as technology development, costs, policy, and customer behavior. This, compounded with how different technologies and policies across sectors may interact (e.g., if the electric sector decarbonizes at a slower pace, emission reductions in the buildings sector will also be slower because building use electricity), will results in changes to these milestones over time. These milestones are presented to provide more insight into the modeling conducted and the magnitude of change that needs to occur for the City to meet its GHG reduction goals.

Figure 6. Key Milestones that will Put Alexandria on a Path to Meet its GHG Reduction Goals

Key Milestones	2025	2030	2040	2050
Clean Electricity Resources (% clean generation resources)	30%	50%	85%	100%
Decarbonized Building Fuels (% supply)		5%	30%	50%
New Building Decarbonization (% net zero ready buildings)	95%	95%	95%	95%
Passenger Vehicle Electrification (% on road vehicles)	10%	40%	80%	90%
Landfill Waste Diversion (% diverted)	2%	25%	60%	90%

Costs, Equity, and City Staff Resources for Actions

Additional lenses that are useful for understanding the potential impacts of GHG reduction strategies and actions on the Alexandria community include:

- **Equity:** An indication as to the directional impact of the action in the context of the equity assessment framework and indicators presented above.
- **Costs and Savings:** A measure of the general costs and savings for the City to implement the actions. These costs may be incurred, and savings realized from the City, community members, businesses to implement the action. Costs and savings considered include considerations of program or policy implementation and technology and energy costs and savings. The impacts presented do not consider any cost offsetting through incentives, tax credits, or federal or other funding resources.
- **City Staff Resources:** An indication of the level of resources, in terms of staff time and effort), that would be needed to implement the action.

Each action was evaluated across these types of impacts and summarized in each respective action table.

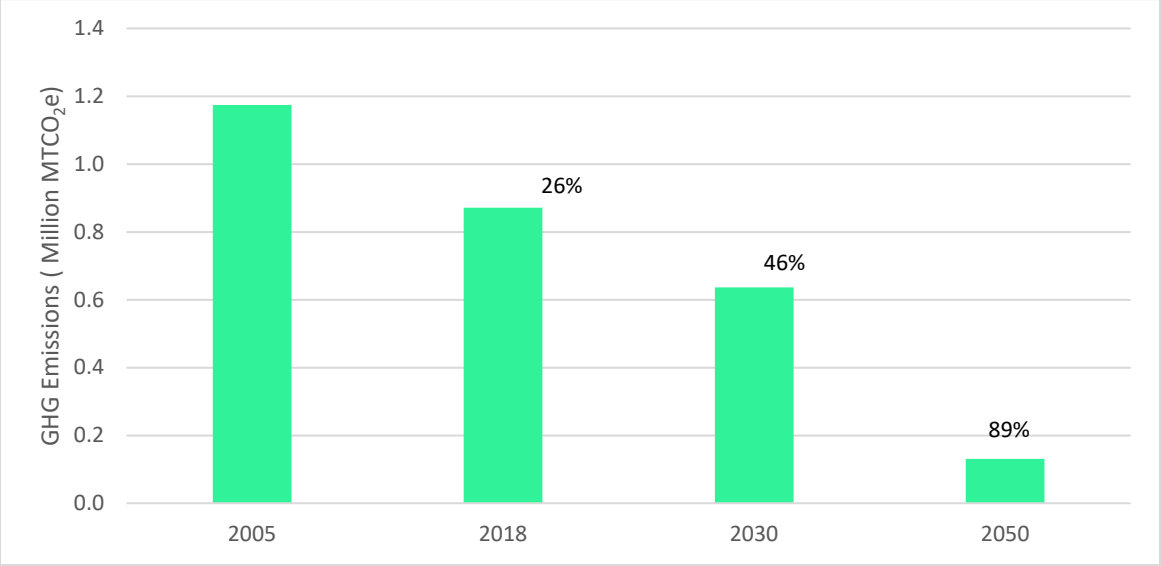
Building Energy

The buildings sector includes four priority strategies:

- B-1: Supporting decarbonizing buildings through financial opportunities
- B-2: Educate and drive implementation of the City Green Building Policy
- B-3: Increase decarbonized buildings fuel supply
- B-4: Accelerate implementation of all feasible decarbonization measures for City-owned buildings

These strategies will result in a 46% reduction in GHG emissions by 2030 and an 89% reduction in GHG emissions by 2050 as compared to the 2005 base year (see Figure 7). As of 2018, GHG emissions were reduced by 26% as compared to 2005. This is mostly from a cleaner electricity supply, electrification, and energy efficiency. These reductions occur despite considerable new growth in the building sector through 2050.

Figure 7. Buildings Energy GHG Emissions Under the GHG Reduction Pathway



B-1: Support decarbonizing buildings through financial opportunities

This strategy focuses on opportunities to finance and incentivize building efficiency and beneficial electrification for new and existing buildings. Building retrofit strategies should also consider lower global warming potential refrigerants to further reduce emissions. Actions the City can take to help spur investment in building decarbonization include:

- **B-1.A:** Support opportunities for a a City or regional green bank
- **B-1.B:** Promote C-PACE financing
- **B-1.C:** Establish an incentive program that encourages Green Building renovations

Strategy B-1 and B-2 Modeling Results

Total GHG Emissions Reduced from BAU

320,000 $MTCO_2e$ (2030)

1.02 million $MTCO_2e$ (2050)

Interactions with Other Strategies

Strategy B-1 would help support implementation of Strategy B-2 (Educate and drive implementation of the City Green Building Policy). A cleaner energy supply through strategies B-3 and RE-1 will compound with strategies B-1 and B-2 to increase the GHG reductions from on-site energy (electricity and fuels) use for new and existing buildings.

Equity

Through each of the actions within this strategy the City can develop and use tailored approaches to benefit low- and moderate-income residents of Alexandria. Programs, and more specifically marketing and engagement efforts, metrics tracked and technical assistance, can be tactically used to target the low and moderate income (LMI) communities and multi-family building owners and ensure that benefits of financing opportunities are distributed equitably or more proportionally towards the LMI community in line with the ALL Alexandria vision and goals.

As a result of decarbonizing buildings there will be reductions in energy use and a shift to cleaner energy supply within the City. The resulting air quality and related public health impacts will be experienced by all population groups in the county and within the City. Therefore, this strategy likely will not more significantly benefit LMI communities or disadvantaged populations within Alexandria.

GHG Reductions

When combined with the actions under strategy B-2 (educate and drive implementation of the City Green Building Policy) GHG emission reductions for new and existing buildings are expected to be 320,000 $MTCO_2e$ below BAU levels in 2030 (37%/63% new/existing buildings) and 1.02 million $MTCO_2e$ in 2050 (69%/31% new/existing buildings). Overall strategies B-1 and B-2 combined are expected to result in a 62% reduction from base year 2005 buildings' GHG emissions in 2030 and a 95% reduction from base year buildings emissions in 2050.

Cost

The costs associated with establishing and administrating financial and incentive programs in support of building efficiency and beneficial electrification for new and existing buildings opportunities will include City staff and consultant support expenses associated with starting-up and administering such initiatives. These costs could be encumbered by the City directly, or paid for by grants or as a component of program administration. Over time, through administration fees and interest, a green bank could become financially self-sustaining, and only seek outside investments from local government to launch new products or services.

The funding for the actual initiative will depend on scale and breadth of the program. For example, the total pool of funding will be smaller for a limited incentive for specific appliances based on income ($50 water heater replacement for LMI) compared to whole dwelling retrofits. In addition, the source of funding can be augmented and structured based on the underlying program, and can be sourced through application for competitive Federal funding opportunities, tax credits, funding from the Regional Greenhouse Gas Initiative, among others. In one example, Montgomery County Council members proposed legislation that would allocate 10 percent of the county's energy-tax revenue to its green bank, amounting to approximately $18 million annually. In another example, PACE programs have enabled private lenders to finance building upgrades and then to receive their loan repayment through the jurisdiction's property assessment. Over the last decade, PACE loans have financed over $800 million in projects across 35 states.

B-1.A: Support opportunities for a City or regional green bank

Description	The City should consider opportunities to implement or support a City or regional green bank. A green bank, or green investment bank, is a government-owned or quasi-public banking institution established or capitalized using local, state, or federal government funding that leverages private capital to support investment in clean energy projects, including residential and commercial energy efficiency, beneficial electrification, and renewable energy systems. Local green banks are available to Virginia local governments by ordinance per 15.2-958.3:1 of the Code of Virginia, as amended. A first step in establishing a green bank is to analyze the market potential for, and the costs, benefits, and equity implications of establishing a City or regional green bank. Currently, regional examples of green banks include neighboring Washington D.C. and Montgomery County, MD. Recently, Fairfax County also took action to assess and design a green bank. A green bank is a financial institution (generally public or quasi-public) using financing techniques and market development tools to accelerate deployment of clean energy.
Equity Impacts and Implementation Considerations	Impacts: Green banks provide programs to a range of different demographics and increasingly focus on underserved markets such as LMI communities. With strong program design, green banks can have significant positive impacts on disadvantaged populations. Implementation: During implementation of green bank programs, Alexandria should ensure that equity considerations are attached to loan products and programs to maximize participation to underserved populations.
Cost Considerations	Costs of green bank startup and administration should be nominal relative to the funding available for projects. The total funding for the green bank will depend on the scale and breadth of the underlying program.
Risks and Uncertainties	While green banks and associated implementation programs are a growing tool used by governments to reduce carbon emissions, they require significant governmental support and public sector investment to succeed.
City Staff Resources	
Lead Implementer(s)	
Stakeholders and Partners	

Milestones and Next Steps	**Status**

•	
•	
•	

B-1.B: increase Marking and Promotion of Alexandria C-PACE Program

Description	The City of Alexandria launched a C-PACE financing program in 2021. The Alexandria C-PACE program is an innovative financing program enabling owners of owners of commercial, multifamily (5+ units), institutional, and industrial properties to obtain low-cost, long-term financing to implement eligible clean energy, stormwater management, and resiliency improvements. These improvements support reducing GHG emissions primarily from the City's commercial buildings sector. While the GHG reduction potential for clean energy projects supported by the Alexandria C-PACE program is significant, to date there have been a limited number of C-PACE projects executed in Virginia, and no projects in Alexandria. Increasing marketing, promotion, and training opportunities supports awareness of C-PACE financing to identify, increase, and accelerate clean energy project opportunities.
Equity Impacts and Implementation Considerations	Impacts: C-PACE's potential equity impacts are limited to improving clean energy opportunities for multifamily affordable housing and small businesses. Implementation: The City should provide dedicated promotion opportunities to affordable housing developments and small business owners.
Cost Considerations	Current C-PACE administration costs are negligible and the responsibility of the City's 3rd-party CPACE Administrator. Costs to provide additional marketing, promotion, and workforce training.
Risks and Uncertainties	To date there have been limited Virginia C-PACE projects and no projects in the city of Alexandria. While utilizing Alexandria's C-PACE program to implement eligible clean energy projects offers many benefits to owners of eligible properties, participation in the Alexandria C-PACE program is not mandatory. Participation in the Alexandria C-PACE program is voluntary and left to the determination of property owners.
City Staff Resources	
Lead Implementer(s)	

Stakeholders and Partners	

Milestones and Next Steps	**Status**
•	
•	
•	

B-1.C: Establish an incentive program(s) that encourages Green Building renovations of existing buildings

Description	In alignment with the EAP2040 actions, As another financing option, the City will should consider establishing a green building incentive program(s) that encourages energy efficiency, beneficial electrification, or building renovations of existing buildings that aligns with the outcomes of the City's 2019 Green Buildings Policy. Incentives could be aligned with meeting certain levels of greenhouse gas emission reductions and could align with standards that promote and accelerate building decarbonization (eg. This could include PassiveHaus, etc.) or other standards that accelerate decarbonization could be considered, with more incentives for higher standards. This action aligns with the following EAP2040 actions 3.1.8, 3.1.9, and 3.1.12.
Equity Impacts and Implementation Considerations	Impacts: A green buildings renovation incentive program can improve access to funding for low-and-moderate income (LMI), including pairing with additional state (including Weatherization Assistance Program), federal, or utility incentives or services With a strong program design, such a program can have significant positive impacts on disadvantaged populations. Implementation: Incentives and programs should be identified to provide direct benefits to LMI communities.
Cost Considerations	Costs to evaluate options, startup, and administer a Green Building renovation incentive program should be nominal relative to the incentives available for projects. The total incentive amount available will depend on the scale and breadth of incentives and sources of funding. Incentives could be paired with financial opportunities related to a City or regional green bank or the Alexandria C-PACE program for commercial, multi-family (5+ units), and institutional properties. Additionally, incentives could pair with available state, federal, or utility incentive programs to enhance incentive offerings.

Risks and Uncertainties	While incentive programs are used by governments to reduce GHG emissions, they require careful program design and require an adequate and reliable source of funding. In addition, a user friendly and easy to understand program is critical in ensuring that Green Building renovation incentives are actually utilized.
City Staff Resources	
Lead Implementer(s)	
Stakeholders and Partners	

Milestones and Next Steps	**Status**
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B-2: Educate and drive implementation of the City Green Building Policy

Through this strategy, the City will work with stakeholders to drive the implementation of the City's Green Building Policy, which sets cutting-edge green building standards for new development and public buildings. This includes new public buildings achieving net-zero energy, defined as an energy-efficient building where, on a source energy basis, the actual annual delivered energy is less than or equal to the on-site renewable exported energy. Actions the City can take to help spur investment in building decarbonization include:

- B-2.A: Support compliance with the City Green Building Policy; and
- B-2.B: Design and implement a program to support residential and commercial energy efficiency and beneficial electrification.

Interactions with Other Strategies

Strategy B-2 would be supported through the implementation of strategy B-1 (support decarbonizing buildings through financial opportunities). A cleaner energy supply through strategies B-3 and RE-1 will compound with strategies B-1 and B-2 to increase the GHG reductions seen from on-site energy (electricity and fuels) use for new and existing buildings.

Equity

Compliance with the Green Buildings Policy will result in reductions in energy use and a shift to cleaner energy supply within the City. The resulting air quality and related public health impacts will be experienced by all population groups in the county and within the City. Depending on the types of green building improvements made, indoor air quality may also improve resulting in public health benefits (i.e., better indoor ventilation and electrifying appliances). Therefore, this strategy may result in positive equity outcomes in Alexandria. In addition, using implementation approaches such as working with local community groups, translating materials in other languages, and working through ALL Alexandria initiatives can also improve equity outcomes.

GHG Reductions

GHG emission reductions for this strategy are included in the reductions for B-1.

Cost

Green buildings tend to be more complex and incorporate newer technologies, which can lead to higher design and construction costs than less sustainable buildings. However, lower operating costs can result in net cost savings through lower energy bills for both tenants and owners.

B-2.A: Support compliance with the City Green Building Policy

Description	Compliance with the City's Green Building Policy has been fundamental to the reducing greenhouse gas emissions from new private development. The 2019 Green Building Policy update, including the specifying of minimum credit points each new development project must achieve within a minimum level of green building certification from priority "Performance Points" focused on energy use reduction, supports further greenhouse gas reductions from any new private developments currently in planning, design, or construction. Furthermore, the City's Small Area Plan (SAP) and Coordinated Development District (CDD) Conditions processes have introduced additional opportunities to consider reducing greenhouse gas emissions at building and development site-wide scales, including the use of the United States Green Building Council's LEED for Neighborhood Development certification process. In addition, the North Potomac Yards Environmental Sustainability Master Plan (ESMP), the Landmark Mall Site Redevelopment's Energy and Resilience Plan, and the Old Town North Coordinated Sustainability Strategy (CSS) – to include a voluntary Carbon Neutral Analysis (CNA) – to support reducing greenhouse gas emissions to target building and district carbon neutrality consistent with the EAP targets the ECCAP seeks to support. Where applicable, the City has subsequently introduced DSUP conditions to specify additional energy use reduction and greenhouse gas emission reduction targets that include requirements for increases in energy efficiency, beneficial building system electrification, reducing embodied carbon intensity, and on-site and off-site renewable energy use to further pursue carbon neutrality targets. The EAP prompts scheduling future administrative updates to the Green Building Policy to coincide with changes in third-party certification, revisions to the Virginia Uniform Statewide Building Code and implementation of programs established through the EAP actions, with major updates for City Council updates every 5-7 years as needed.
Equity Impacts and Implementation Considerations	Impacts: GHG reductions through adherence to the Green Building Policy will likely benefit all of society. However, additional benefits via improved indoor air quality and public health benefits may be provided to disadvantaged communities through initiatives such as a Green Lease Leader program. Implementation: During design and implementation of programs to encourage Green Building Policy adherence, the City should ensure that equity considerations are integrated and prioritized to maximize positive impacts on disadvantaged populations.
Cost Considerations	Encouraging compliance to the Green Building Policy, be it through an incentive program or a communication campaign, will have costs for the City. Depending on scope and breadth of these programs, costs can range from design and implementation of said programs, and costs associated with incorporation of cleaner, newer technologies.

Risks and Uncertainties	Establishing clear, concise methods of encouraging Green Building Policy adherence is critical to not overwhelm the public.
City Staff Resources	
Lead Implementer(s)	
Stakeholders and Partners	

Milestones and Next Steps	**Status**
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B-2.B: Design and implement a program to support residential and commercial energy efficiency and beneficial electrification

Description	Design and implement a technical assistance program to support accelerating the adoption of energy efficiency and beneficial electrification measures for new and existing residential and commercial buildings. The program should provide technical assistance to participants through various forms (e.g., direct assistance, a information and resource clearinghouse, workshops and training, etc.). Ideally this action should be combined with the offering of financial opportunities, including services provided by a City or regional green bank (B-1.A), the Alexandria C-PACE program for commercial, multi-family (5+ units), and institutional buildings, or any incentives programs for energy efficiency and beneficial electrification (B-1.C). This technical assistance program is necessarily voluntary to participate. A technical assistance program implementation may be able available through local and regional partnerships, not-for-profit coordination, or a contract for a vendor.
Equity Impacts and Implementation Considerations	Impacts: Residential and commercial energy efficiency and beneficial electrification programs serve various demographics and are increasingly focusing on low-and-moderate income (LMI) communities. With an equity focus, a voluntary program to support residential and commercial energy efficiency and beneficial electrification often provides benefits such as reduced energy costs and improved indoor environmental quality, Implementation: Equity considerations should be central during design and implementation of a voluntary program to ensure LMI communities stand to benefit. This could include addressing the long-standing principal-agent /renter-landlord issue through constructs such as green leases.
Cost Considerations	The costs of an energy efficiency and beneficial electrification program will depend on the breadth and scope of the initiative. If the City were to provide a full-service technical assistance program, this may require an increase in program management and technical assistance staffing to accommodate interest. Marketing and communicating technical assistance may rely on the City's existing communications strategies, but may require additional investments to increase promotion. If the City were to leverage local or regional partnerships, not-for-profit coordination, or vendor support, costs would need to be further evaluated based on the level of technical assistance being provided.
Risks and Uncertainties	A voluntary program doesn't guarantee participation nor emissions reductions. In addition, program success may be in-part attributed to the simplicity and concision of communication about the program, and the ease-of-access of program resources.
City Staff Resources	

Lead Implementer(s)	
Stakeholders and Partners	

Milestones and Next Steps	**Status**
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B-3: Support access to a decarbonized buildings fuel supply

Strategy B-3 Modeling Results

Total GHG Emissions Reduced from BAU

87,000 $MTCO_2e$ (2030)

116,000 $MTCO_2e$ (2050)

Constraints such as space and cost, and customer preferences (e.g., for cooking), will likely lead to continued use of fuels such as natural gas in buildings. Moving from high-carbon sources of energy, such as natural gas, to a fuel supply with lower carbon content, or that are carbon neutral, will help further reduce GHG emissions from building energy use. Low- or no-carbon fuels – typically - resource recovered (or renewable) gas or hydrogen –are still in development and not commercially available at any level of scale. Statutory prohibition limits Virginia local governments from restrict the use of natural gas service to new or existing buildings[5] However, cost drivers – especially from increases in fuel supply options - have shown to influence energy users to shift form higher cost fuels such as fuel oil and propane to natural gas. As such, the City can actively engage in activities to:

- B-3.A: Increase energy supply from resource recovered gas and hydrogen

Interactions with Other Strategies

[5] Virginia House Bill (HB) 1257: Natural gas utilities; retail supply choice. https://lis.virginia.gov/cgi-bin/legp604.exe?221+sum+HB1257.

A cleaner fuel supply to buildings within the City would work with strategies B-1 (Support decarbonizing buildings through financial opportunities) and B-2 (Educate and drive implementation of the City Green Building Policy) to increase the GHG reductions seen from on-site energy (fuels) use for new and existing buildings.

Equity

This strategy is not expected to have significant impacts on equity within the Alexandria community.

GHG Reductions

This strategy is expected to reduce GHG emissions from BAU levels by 87,000 $MTCO_2e$ and 116,000 $MTCO_2e$ in 2030 and 2050 respectively. This reduction is achieved through the use of 4.19 million mmBtu (or energy for 28,000 homes per year) of low or no carbon fuels in 2030 and 2.29 million mmBtu (or energy for 15,000 homes per year) in 2050.

Cost

The cost to support access to a decarbonized buildings fuel supply varies, ranging from an education campaign informing the public of their choice in building fuel supply, to subsidizing the alternative fuel (i.e., resource recovered gas or hydrogen). Policy instruments exist to minimize the public cost of providing such subsidy, such as minimum renewable fuel requirements and low carbon fuel standards, among others. It's important to note that resource recovered gas is currently more expensive than conventional natural gas, and production and processing costs are high.

B-3.A: Increase energy supply from resource recovered gas and hydrogen

Description	The City can help promote the use of low- or no-carbon fuels in buildings through education and outreach. The City may also consider pilot programs in partnership with renewable natural gas providers or soliciting request for information (RFI) to help support understanding of availability, applications, or opportunities to promote use of low- or no-carbon fuels. Providing education, supporting pilot programs, or supporting collection of more information can help address and misconceptions and address how low- or no-carbon fuels may offer additional future options to decarbonize building energy use.

Equity Impacts and Implementation Considerations	Impacts: This strategy is not expected to have significant impacts on equity outcomes within the Alexandria community. However, regional air quality benefits may be an outcome that will lead to overall better public health outcomes, such as fewer cases of asthma, across the community. Implementation: This strategy is not expected to have significant equity impacts within the Alexandria community.
Cost Considerations	The cost of designing and implementing an education campaign will be nominal relative to the cost of transitioning to an alternative fuel. The cost of transitioning to an alternative fuel may be high if subsidized but can be negated if mandated through a policy construct such as a low carbon fuel standard.
Risks and Uncertainties	Many technologies for resource recovered gas projects are in the early stages of development and are not currently deployed at large scale. Not all pipeline infrastructure will be able to accommodate the use of resource recovered gas potentially necessitating costly infrastructure upgrades.
City Staff Resources	
Lead Implementer(s)	
Stakeholders and Partners	

Milestones and Next Steps	**Status**

B-4: Accelerate implementation of all feasible decarbonization measures for City-owned buildings

The EAP2040 outlines a series of actions the City is taking and will take to decarbonize its own buildings in line with the target of improving energy efficiency in City facilities and operations by 50 percent over a FY2018 baseline use by FY2035. Energy efficiency and energy conservation implementation serves as a foundational practice for the City to offset greenhouse gas emissions and lead by example. In addition, energy efficiency provides a reduction in energy use at a lower cost and higher return on investment than many alternatives and serves as a lower-cost pathway to offset the City's GHG emission by a

renewable energy supply. This series of actions being led by General Services and Transportation and Environmental Services include EAP 2040 actions:

- 2.2.1 (update the facility asset condition auditing process for facility asset conditions (Facility Condition Index, (FCI) rating methodology) to reflect facility energy and sustainability performance. In addition, include energy audits, portfolio energy optimization, and similar evaluation processes into the FCI rating methodology. Develop and utilize a portfolio-wide energy model to identify and develop a portfolio wide energy optimization investment plan as part of a broader energy supply transition planning effort)
- 2.2.3 (complete retrofits of 75 percent of all City facilities' practicable conventional lighting with LED lighting. By FY2023 retrofit 95 percent of practicable streetlights and outdoor lighting to LED technology, subject to the availability of a suitable LED solution and zoning constraints)
- 2.2.4 (By FY2027, implement energy efficiency strategies in City facilities and operations to reduce energy use by, at minimum, 25 percent over FY2018 usage)
- 2.2.7 (implement energy efficiency strategies in City facilities and operations to reduce energy use by, at minimum, 50 percent over FY2018 usage)
- 2.1.6 (By FY2040, implement electrification of all City non-electricity energy use (City facilities, operations, and vehicles)).

Interactions with Other Strategies

The acceleration of feasible decarbonization measures will be increased with the financial support for building decarbonization (B-1), new buildings built under the City Green Building Policy (B-2) will increase the stock of decarbonized buildings in Alexandria. Increased building fuel for decarbonized buildings (B-3) will allow for large decarbonization projects without jeopardizing the reliability of energy for buildings. Increased renewable energy use (RE-1 and RE-2) will decarbonize the fuel used in buildings, reducing GHG emissions and support full decarbonization of buildings. With building being decarbonized, there is less need for natural gas, and the pipeline that deliver that gas, helping with strategy O-1 and O-2 in reducing fugitive emissions of natural gas.

Equity

Reduced GHG emissions and pollution from criteria pollutants from the reduction in fossil fuel usage in buildings results in better health outcomes, especially for those in sensitive populations. The reduction in fossil fuel usage additionally provides economic benefits as electricity prices are projected to decrease while fuels as they are phased down in use will become more expensive. This reduces the economic energy burden and is most impactful in disadvantaged communities where energy costs make up a greater portion of total living expenses. To maximize these benefits, decarbonization efforts should be targeted in

disadvantaged communities with sufficient support to avoid adding additional burden from the costs of implementing the decarbonization measures in these buildings.

GHG Reductions

GHG emission reductions were not quantified for this strategy.

Cost

Implementers of these decarbonization strategies will face many costs associated with pursing all viable decarbonization projects, starting with the updated assessment and audit process which will be the basis for determining the highest impact projects. The projects themselves will range from less complex and least expensive such as lighting retrofits, to more complex energy efficiency projects and the implementation of energy efficiency strategies. In the long term, electrification at the scale suggested in this action will be very costly from the replacement of non-electric equipment to the necessary upgrades to the local grid and interconnections to allow for the high electricity demands of electrified buildings.

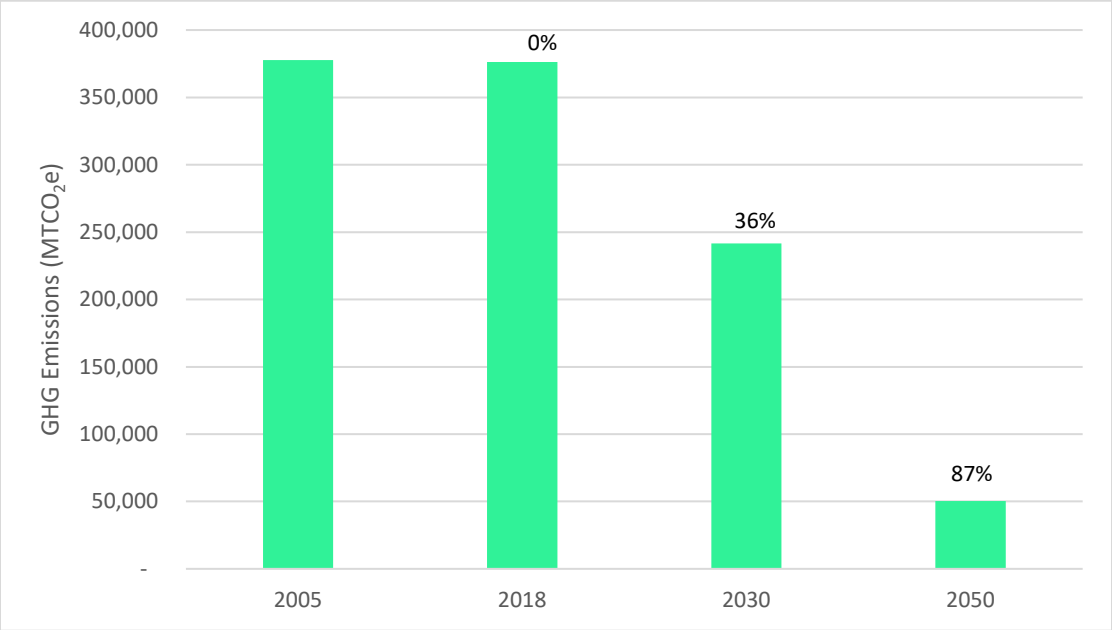
Transportation

The transportation sector includes three priority strategies addressing on-road GHG emissions:

- T-1: Reduce vehicle miles traveled (VMT)
- T-2: Accelerate the deployment of electric and alternative fuel vehicles
- T-3: Reduce City fleet fuel consumption and increase alternative fuel use in line with the City Alternative Fuel Policy

These strategies will result in a 36% reduction in GHG emissions by 2030 and an 87% reduction in GHG emissions by 2050 as compared to the 2005 base year (see Figure 8). As of 2018, GHG emissions were equal to 2005 GHG emissions for on-road transportation. While development and growth occurred in the region during this time, vehicle efficiency improvements and management of VMT likely contributed to holding emissions stable.

Figure 8. Transportation GHG Emissions Under the GHG Reduction Pathway



Consideration of Metropolitan Washington Council of Governments and Transportation Planning Board's 2030 GHG Goals

In 2021, the National Capital Region Transportation Planning Board (TPB) conducted a scenario study to assess ways to reduce GHG emissions in the on-road transportation sector. The study assessed the types of transportation-related actions, and their levels of implementation, that might be needed to reduce GHG emissions to meet regional goals of 50% reduction by 2030 and 80% reduction by 2050 as compared to a 2005 baseline. The results of this study and options for GHG reduction goals for the on-road transportation sector were discussed at a May 18, 2022, TPB meeting and working session. Three goal options for on-road transportation were considered, including 1) an aspirational goal (50% reduction by 2030) identical to the region's overall (non-sector-specific) goal, 2) an aspirational goal (32% reduction by 2030) that would achieve the region's overall goal, assuming other sectors achieve reductions consistent with the 2030 Climate and Energy Action Plan, and 3) A pragmatic goal (23-29% reduction by 2030), based on GHG reduction strategies that appear to be supported by the TPB in a member survey. The TPB decided to adopt first option, an aspirational GHG reduction goal. As indicated by in the memo "Clarifications Regarding On-Road Transportation Greenhouse Gas (GHG) Reduction Goals and Strategies," dated June 3, 2022, none of the scenarios analyzed as part of the 2021 study, including the most aggressive combinations of strategies, could achieve close to this aspirational goal. The most aggressive scenario analyzed illustrated a maximum GHG reduction of 33-36% reduction from 2005 GHG levels by 2030. This modeling was conducted at the regional level, however if Alexandria were to work towards achieving the aspirational goal set by the TBP of a 50% reduction in GHG emissions by 2030, additional technology, policy, and other advancements would need to occur, beyond what is considered available based on today's current technology understanding and policy and regulatory constructs. For example, this would likely require a combination of:

- Very rapid shifts to move the fleet toward zero emissions vehicles, so that nearly all new vehicles sold in the next few years would be electric or other zero emissions (beyond the level of the aggressive EV sales targets in California)
- Incentives for residents to get rid of their personal vehicles or trade in existing vehicles for zero emissions vehicles to more rapidly remove conventional vehicles from the fleet
- Dramatic reductions in vehicle travel through aggressive strategies beyond

T-1: Reduce vehicle miles traveled (VMT)

Through this strategy the City will implement several actions to reduce overall vehicle miles and accelerate the implementation of the *Alexandria Transit Vision and Mobility Plan* and the *Bike Master Plan*. This strategy includes the following actions:

- **T-1.A:** Implement strategies from the Alexandria Transit Vision and Mobility Plans.
- **T-1.B:** Land use changes focused on redistribution of future growth to activity centers and areas better served by transit across jurisdictions
- **T-1.C:** Advocate for reduced transit fares and parking pricing in workplaces
- **T-1.D:** Support telework policies
- **T-1.E:** Promote a job/housing balance by focusing on-site affordable housing units near transit, jobs, and amenities (Language from OTN SAP)

Strategy T-1 Modeling Results

Total GHG Emissions Reduced from BAU

30,000 $MTCO_2e$ (2030)

50,000 $MTCO_2e$ (2050)

Interactions with Other Strategies

Strategy T-1 will support strategy T-3 (Reduce City fleet fuel consumption and increase alternative fuel use) by reducing miles traveled for city fleet, in addition to other vehicles. It will also support strategy T-2 (Accelerate the deployment of electric and alternative fuel vehicles) by making electric and alternative fuel vehicles more accessible to those with concerns about long commuting distances with limited charging infrastructure.

Equity

Reducing vehicle miles traveled (VMT) will have notable impacts across all three indicated areas of equity indicators. Related to economic impacts, this action lowers the transportation cost burden, reduces energy usage per capita, and reduces employment barriers related to commuting for marginalized communities. This action will provide significant health benefits by limiting harmful pollutants generated from burning transportation fuel, especially for sensitive populations. Also, reducing vehicle miles encourages more active modes of transportation (e.g., walking, biking) providing additional health benefits.

GHG Reductions

GHG emission reductions for reducing VMT is expected to be 30,000 $MTCO_2e$ below BAU levels in 2030 and 50,000 $MTCO_2e$ in 2050. This corresponds to a 12% VMT reduction in 2030 and a 15% VMT reduction in 2050.

Cost

The costs associated with strategy are high and fall more heavily on companies and businesses than the City. The most significant cost comes from land purchase, land use change, and infrastructure development needed to create communities designed for low-emissions transit (e.g., walking, biking, public transportation). Additionally, to make these communities equitable, the inclusion of affordable housing will lower developers return on investment. For the City, however, some of these investments will recoup costs overtime (e.g., low O&M costs associated with electric bus fleets). Other lower costs include investment in technology to support telecommunications and creation and distribution of advocacy materials.

T-1.A: Implement strategies from Alexandria Transit Vision and Mobility Plan

Description	The Alexandria Transit Vision **(ATV)** Plan is a collaboration between the City of Alexandria and DASH to design a future bus network. The ATV plan recommends coordinating with the Washington Metropolitan Area Transit Authority (WMATA) and Arlington for route responsibility and coordination and expansion of key bus infrastructure such as bus bays, additional vehicles, and speed and reliability investments along key corridors. The plan also recommends securing funding from the City, the extent of changes depends on the budget allocation DASH receives. The Alexandria Mobility Plan (AMP) is a strategic update to the 2008 transportation master plan. Along with the expanded transit network outlined in the ATV plan, the AMP seeks to build out the city's priority transitway corridors and identify improvements on congested, high ridership corridors to reduce travel times, improve reliability, transition bus fleets to electric zero-emission vehicles, improve rider experience from trip planning (e.g., accessing stops, riding the bus, and arriving at destinations). It also recommends evaluating fare-free service and continuing to explore low-income WMATA fares, supporting a better-c**onnected** regional transit network, and modernizing the paratransit program for the city's aging population.

Equity Impacts and Implementation Considerations	Impacts: An expanded transit network allows for underserved communities to have expanded access to mobility options and an increased ability to benefit from opportunities not previously reachable without the use of a person vehicle. Eliminating or reducing transit fares would have the greatest economic benefit on low-income populations. Modernizing the paratransit program would improve access and reliability for elderly individuals. Implementation: As the strategies from the Alexandria Transit Vision and Mobility Plan move from planning to implementation stages, considerations of how to guide the strategies toward the greatest outcomes for disadvantaged populations.
Cost Considerations	The largest costs to implement this strategy are connected to the expansion of infrastructure, such as bus depots, street improvements for bus reliability and improved priority transit corridors. Additionally, the strategy of electrifying the bus fleet has high initial costs from the purchase of new vehicles but will likely recoup those costs with reduced O&M costs for the fleet.
Risks and Uncertainties	Much of the strategies laid out in the two plans rely on infrastructure investments that do not currently have guaranteed sources of funding, expanded transit networks will not be able to operate with the required capacity and reliability without sufficient infrastructure investment.
City Staff Resources	
Lead Implementer(s)	

Stakeholders and Partners	
Milestones and Next Steps	**Status**
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T-1.B: Land use changes focused on redistribution of future growth to activity centers and areas better served by transit across jurisdictions

Description	To allow for greater use of transit systems where currently active or planned expansion areas, transit-oriented development (TOD) should be encouraged. In other words, the focus of development should be access to current and future transit availability. This can be supported through land use change policies, allowing for more dense housing infrastructure, encouraging the development of mixed-used neighborhoods, supporting TOD efforts, and/or reducing or eliminating parking minimums in specific areas.
Equity Impacts and Implementation Considerations	Impacts: The development of new housing opportunities can provide economic drivers for all three areas of equity indicators. The focus on transit availability reduces VMT which lowers the transportation cost burden, reduces energy use, reduces employment barriers related to commuting for marginalized communities. Reduced VMT additionally has the potential to impact air quality, limiting harmful pollutants and improving health outcomes, especially in sensitive populations. Implementation: Any policy regarding land use change should be considered with the lens of equity considerations forefront to ensure that the maximum positive impact will be had for disadvantaged populations and that those groups are not left out of the benefits from new development.
Cost Considerations	The costs stemming from promoting land use change land mostly on developers who will enact the vision that land use change policy seeks to accomplish.
Risks and Uncertainties	For developers, guidance will need to be offered to ensure that development does not fall squarely into the highest profit development, without adequate guidelines there will likely be an imbalance in the groups who benefit from new development. The city must ensure that new developments have significant impacts on disadvantaged communities while still working towards profitable developments that developers are willing to take on.
City Staff Resources	
Lead Implementer(s)	
Stakeholders and Partners	

Milestones and Next Steps	**Status**

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T-1.C: Advocate for reduced transit fares and parking pricing in workplaces

Description	Reduced transit fare and parking pricing in workplaces can lift barriers to those seeking to live and work within Alexandria. Along with that reduction comes the potential for reduced VMT with the reduction of distance of commutes and the increased use of public transit options.
Equity Impacts and Implementation Considerations	Impacts: Encouraging the increased use of transit and reducing the cost of commuting by personal vehicles work toward positive economic outcomes by reducing the barrier to employment related to commuting costs. While encouraging the use of transit additional reduced VMT, leading to better health outcomes from the reduction of pollutants, and the encouragement of more active commuting methods, reducing parking prices in workplaces has the opposite effect, encouraging the use of personal vehicles and increasing VMT in the area which have negative health outcomes, especially for populations sensitive to criteria pollutants. Implementation: The focus on partnerships with transit authorities should be on reducing the burden of ridership for those most disadvantaged communities, especially if reduced transit fares are not universal. For parking pricing reduction, especially in cases where partners are employers, outreach should be directed to those businesses where a significant part of the employee base is from one of the equity populations to maximize impacts for those communities.
Cost Considerations	The costs would stem from the creation of advocacy materials and the distribution of this material to the businesses that could implement these benefits. This action does not require any funds from the jurisdiction to run the program outside of offering those benefits to city employees.
Risks and Uncertainties	Because this action deals with advocacy and not the requirement for business to offer transit benefits, it is likely out of control of the City how widespread these benefits become.
City Staff Resources	
Lead Implementer(s)	

Stakeholders and Partners	
Milestones and Next Steps	**Status**
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T-1.D: Support telework policies

Description	Telework has become increasingly popular as both a necessary way to continue work throughout the COVID-19 pandemic and as a choice by many employees. Supporting telework policies for City employees and private business can reduce VMT, especially in areas not well served by current or future transit options.
Equity Impacts and Implementation Considerations	Impacts: This action allows workers more freedom of choice in where they choose to live and work. It may also reduce the use of or need for a personal vehicle to commute to an office. The need for home working setups may not allow everybody to take advantage of teleworking opportunities, and not all business can realistically support telework. Implementation: Promoting telework policies, especially in cases where partners are private employers, outreach should be directed to those businesses where a significant part of the employee base is from one of the equity populations to maximize impacts for those communities.
Cost Considerations	For the City, setting up the proper infrastructure to support teleworking of city employees will need to be set up, if not already done through 2022. Advocacy for teleworking policies in businesses will need to be conducted through the creation of advocacy materials and outreach efforts from city staff.
Risks and Uncertainties	The need for home working setups may not allow everybody to take advantage of teleworking opportunities, and not all business can realistically support telework.
City Staff Resources	
Lead Implementer(s)	
Stakeholders and Partners	

Milestones and Next Steps	Status
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T-1.E: Promote a job/housing balance by focusing on-site affordable housing units near transit, jobs, and amenities

Description	Actively seeking the development of affordable housing units near transit, jobs, and amenities promotes the creation of areas of mixed-use building types and uses with varied housing options, multi-modal transportation availability, and easy access to both residential and commercial activities. These diverse areas reduce the need for person use vehicles and reduced VMT in Alexandria and allow for more opportunity of access for necessities and jobs for all members of the community.
Equity Impacts and Implementation Considerations	Impacts: Reduced VMT and emissions will improve air quality and health outcomes. Greater access to retail leads to better nutritious food availability, and more opportunities for work without the need for a personal vehicle can lead to greater economic prospects. Implementation: During the design of programs to promote on-site affordable housing units near transit, jobs, and amenities, the City should ensure the equity considerations are prioritized to ensure that the maximum benefits are generated for disadvantaged communities. For affordable housing projects, ensuring that a large enough portion of developments are affordable, and that those who need affordable housing have first access to these new developments is likely to be an important factor.
Cost Considerations	Those costs to purchase land in desired areas will be considerable for those companies that would develop in the areas where the development of affordable housing will have greater access to transit, jobs, and amenities. Incentivizing the development of affordable housing beyond what may be required by law may prove costly given the lower return on investment (ROI) compared to market-rate developments.
Risks and Uncertainties	The availability of land to develop into affordable housing where there will be most access to transit, jobs, and amenities is low in a previously developed city. Opposition from those who do not support affordable housing projects may make approval of developments more difficult.

City Staff Resources	
Lead Implementer(s)	
Stakeholders and Partners	

Milestones and Next Steps	**Status**
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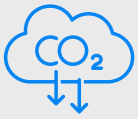
T- 2: Accelerate the deployment of electric and alternative fuel vehicles

Through this strategy, the City will expand accessibility to and public awareness of electric and alternative fuel vehicles. Emissions from charging are built into the transportation sector estimates using assumptions about grid emissions factors and energy efficiency (kWh/mi) for different vehicle classes. This strategy also includes reductions associated with changes to fuels to offroad vehicles and aviation operations.

Strategies T-2 and T-3 Modeling Results



Total GHG Emissions Reduced from BAU

41,000 $MTCO_2e$ (2030)

240,000 $MTCO_2e$ (2050)

This strategy includes the following actions:

- T-2.A: Implement recommendations that support EV charging infrastructure development, including addressing gaps in meeting charging demand
- T-2.B: Provide education and outreach to the community about EVs and available state and national incentives
- T-2.C: Advocate with Dominion and regulators for fee-based EV charging; educate the community about these options
- T-2.D: Transition public fleets to electric (DASH)

- T-2.E: Connect private fleets with partners and opportunities to educate and incentivize electrification

Interactions with Other Strategies

Strategy T-2 will be supported by strategy T-1 (Reduce VMT) by making electric and alternative fuel vehicles more accessible to those with concerns about long commuting distance with limited charging infrastructure. It will also be supported by RE-1 (support implementation/acceleration of the VCEA by increasing solar deployment within the City) by electrifying and transitioning the transportation sector to alternative fuels.

Equity

Deploying electric and alternative fuel vehicles reduces GHG emissions and harmful pollutants from burning fossil fuels, thus improving air quality, particularly for sensitive populations. This action will also aim to increase access to EVs for marginalized populations, who currently cannot afford new EVs. This trend is due to higher sticker prices, limited access to expensive charging infrastructure, lack of information on low-carbon vehicles, and other socio-economic barriers. Supporting the expansion of EV charging infrastructure may also generate new low-carbon construction jobs.

GHG Reductions

When combined with the actions under strategy T-3 (Reduce City fleet fuel consumption and increase alternative fuel use in line with the City Alternative Fuel Policy), GHG emission reductions for the transportation sector are expected to be 41,000 $MTCO_2e$ below BAU levels in 2030 and 240,000 $MTCO_2e$ in 2050.

Cost

The costs associated with Strategy T-2 are moderate to high and fall both on the Alexandria public and the City. Most of the costs will come from the purchase of electric and alternative fuel vehicles and the installation of charging infrastructure. Even with incentives like rebates for purchasing low-emission vehicles and installing chargers, the upfront costs are higher than those associated with an internal combustion engine (ICE) vehicle. Both public and private entities will have to determine the cost-efficiency of switching over from ICE vehicles. This switch will likely be more cost-efficient overtime though because electricity is cheaper than fossil fuels. Other lower costs associated with the strategy include new fees for public charge stations and creating and distributing advocacy materials.

T-2.A: Implement recommendations that support EV charging infrastructure development, including addressing gaps in meeting charging demand

Description	In the aim of increasing the use of EVs, developing a robust charging infrastructure is a necessity to ease the barrier that people have in switching to an EV. Having reliable access to charging when needed can become increasingly difficult as the adoption of EVs continues to increase as other incentives drive people toward EV adoption. Implementing recommendations for new developments to have a requirement on EV charging spots where parking infrastructure is developed or encouraging city owned property or local businesses to install charging infrastructure are effective actions that can be taken to make more robust EV charging infrastructure that is prepared for the growing populations of electric vehicles in Alexandria. This action is consistent and complementary to Alexandria's EVRS.
Equity Impacts and Implementation Considerations	Impacts: Increasing the use of electric vehicles reduces GHG and harmful pollutant emissions that are currently emitted from the burning of fossil fuel. This improves air quality, especially for sensitive populations. Reducing the energy consumption per capita, electric and alternative fuel vehicles will decrease the transportation cost burden as the price of fossil fuels increase. This action will also increase access to low-carbon vehicles for marginalized populations as most are currently used by affluent communities. This trend is due to limited access to expensive charging infrastructure, information on low-carbon vehicles, and other socio-economic barriers. Supporting the expansion of EV charging infrastructure will also contribute new low-carbon construction jobs. Implementation: The City should work to expand charging infrastructure in low-income areas to make electric and alternative fuel vehicles more accessible as they become less expensive. The expansion of charging infrastructure in public locations will be crucial to this effort as most chargers are currently located in private residences and businesses.
Cost Considerations	The installation of electric vehicle charging is a moderately expensive infrastructure project which can range in cost depending on the need for the jurisdiction to develop the infrastructure versus private businesses being incentivized to develop their own EV charging infrastructure projects. The largest costs are to the community as they will need to be the ones to make the individual choice to purchase and electric vehicle. Currently the costs of EVs are much greater than a comparable ICE vehicle, even with current incentives for people to purchase an EV.

Risks and Uncertainties	Charging infrastructure will only be needed if the demand is great enough to warrant large expansions of EV charging infrastructure. Currently EVs are much more expensive compared to ICE vehicles and it depend on the market, along with any federal, state, or local incentives to bring the costs to a comparable level with ICE vehicles. This is not a certainty, and projects expanding on EV charging infrastructure will not move forward if the demand for EVs is not similarly rising.
City Staff Resources	
Lead Implementer(s)	
Stakeholders and Partners	

Milestones and Next Steps	**Status**
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T-2.B: Provide education and outreach to the community about EVs and available state and national incentives

Description	One of the main barriers to the adoption of EVs and alternative fuel vehicles is the cost to the individual consumer. There are state and national incentives that help bring the costs to be more comparable to ICE vehicles. Some of these incentives are not well known or well understood by the public and efforts from Alexandria to increase awareness and provide education about these incentives can lead to the greater adoption of EVs and alternative fuel vehicles.
Equity Impacts and Implementation Considerations	Impacts: Increasing the use of electric vehicles reduces GHG and harmful pollutant emissions that are currently emitted from the burning of fossil fuel. This improves air quality, especially for sensitive populations. Reducing the energy consumption per capita, electric, and alternative fuel vehicles will decrease the transportation cost burden as the price of fossil fuels increase. This action will also increase access to low-carbon vehicles for marginalized populations as most are currently used by affluent communities. This trend is due to limited access to expensive charging infrastructure, information on low-carbon vehicles, and other socio-economic barriers. One concern with the incentive programs relates to tax-based incentives where only those affluent enough to wait on receiving the incentive and have enough taxes owed to make full use of the incentive will have the most benefit from these incentive programs. Implementation: Ensure that educational opportunities are accessible in several forms (e.g., offering virtual and in-person meetings) to reach the most community members. A notable access constraint is limited Internet availability in marginalized communities.
Cost Considerations	The costs would stem from the creation of advocacy materials and the distribution of this material to the community where the increased awareness and understanding of incentives can help drive people to make the switch to an EV or alternative fuel vehicle.
Risks and Uncertainties	Even with the incentives that are offered, EVs and alternative fuel vehicles are likely to remain at a greater cost compared to and ICE vehicle, this is especially true in relation to tax incentives where not everybody can benefit.
City Staff Resources	
Lead Implementer(s)	
Stakeholders and Partners	

Milestones and Next Steps	Status
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T-2.C: Advocate with Dominion and regulators for fee-based EV charging; educate the community about these options

Description	Fee-based EV charging would result in users paying a fee to use public charging infrastructure, comparable to what private charging stations already charge. This will increase accessibility of chargers, and private and public chargers would cost similar amounts. The resulting funds could be reinvested in the community by improving/expanding EV charging infrastructure or funding other actions that can help support Alexandria's climate goals.
Equity Impacts and Implementation Considerations	Impacts: Increasing the use of electric vehicles reduces GHG and harmful pollutant emissions that are currently emitted from the burning of fossil fuel. This improves air quality, especially for sensitive populations. Reducing the energy consumption per capita, electric and alternative fuel vehicles will decrease the transportation cost burden as the price of fossil fuels increase. This action will also increase access to low-carbon vehicles for marginalized populations as most are currently used by affluent communities. This trend is due to limited access to expensive charging infrastructure, information on low-carbon vehicles, and other socio-economic barriers. Supporting the expansion of EV charging infrastructure will also contribute new low-carbon construction jobs. Implementation: Ensure that educational opportunities are accessible in several forms (e.g., offering virtual and in-person meetings) to reach the most community members. A notable access constraint is limited Internet access (?) and availability in marginalized communities.
Cost Considerations	The main cost will be the users of EVs who may have previously been using free public EV chargers would have to pay a fee, increasing the cost of owning an EV in Alexandria. There would be little to no cost for the City to implement this action.

Risks and Uncertainties	The increased costs of EV ownership due to the fee-based EV charging has the potential to disincentivize the community from adopting EVs, even if the potential savings compared to an ICE vehicle are still happening. This could work against other goals that support the adoption of EVs in the community.
City Staff Resources	
Lead Implementer(s)	
Stakeholders and Partners	

Milestones and Next Steps	**Status**
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T-2. D: Transition public fleets to electric (DASH)

Description	The EAP stated the intent to develop a plan to acquire zero-emissions buses on rapid transit routes and covert the DASH fleet to zero emissions vehicles. The City's vehicle fleet contains a small amount of EVs currently. Transitioning the vehicle fleets of the police and sheriff's department to zero emission vehicles will vastly reduce overall emissions. The majority of emissions from the police fleet occur from idling when officers are out on patrol and the transition to electric vehicles will eliminate this main source of emissions
Equity Impacts and Implementation Considerations	Impacts: Deploying electric and alternative fuel vehicles reduces GHG emissions and harmful pollutants from burning fossil fuels, thus improving air quality, particularly for sensitive populations. Implementation: In the implementation of the transition of the DASH fleet to electric, considerations should be made to transition buses that cover areas where there is a larger proportion of people from disadvantaged communities. This then increases the potential localized air quality improvements to those areas where air quality improvements will lead to the largest health outcome improvements.

Cost Considerations	Electric vehicles, especially larger vehicles like buses come at a significantly higher cost than an ICE bus. There are incentives for electric vehicles, especially for the transition to electric public transportation that can help alleviate these costs but there is still likely to be additional costs in purchasing electric buses over ICE alternatives. Over time, the lower cost of electricity versus fossil fuel will make the fleet more economically viable which larger organizations can more easily take into account when deciding to upgrade their fleet.
Risks and Uncertainties	The risk of transitioning to an electric fleet comes with how the transition takes place, by gradually replacing the fleet at buses reach the end of their service life the risk of not having adequate capacity to run service effectively while the role of the bus network is being expanded is mitigated.
City Staff Resources	
Lead Implementer(s)	
Stakeholders and Partners	

Milestones and Next Steps	**Status**
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T-2. E: Connect private fleets with partners and opportunities to educate and incentivize electrification

Description	Education and outreach combined with voluntary incentive programs can accelerate the adoption of electric vehicles in private fleets.
Equity Impacts and Implementation Considerations	Impacts: The deployment of electric and alternative fuel vehicles reduces GHG emissions and harmful pollutants from burning fossil fuels, thus improving air quality, particularly for sensitive populations. However, this action will have a limited impact on other indicators of equity for the broader community due to the size of private fleets compared to all vehicles in Alexandria. Implementation: This action is unlikely to have equity impacts during the implementation of the action.
Cost Considerations	Alternative fuel and electric vehicles are currently significantly more expensive than traditional ICE vehicles, especially for larger vehicles such as trucks. While there are incentives to reduce this barrier, it does not fully alleviate the additional costs for alternative fuel and electric vehicles, and it will be a consideration for private fleets to ensure it is economically viable to switch to electric or alternative fuel fleets.
Risks and Uncertainties	This action would be more effective with the reduction in cost of alternative fuel and electric vehicles. While the costs are expected to decrease over time, this is not something that private fleet owners can affect, as prices are determined by market forces, and the level of incentivization offered by federal and state legislation.
City Staff Resources	
Lead Implementer(s)	
Stakeholders and Partners	

Milestones and Next Steps	**Status**
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T-3: Reduce City fleet fuel consumption and increase alternative fuel use in line with the City Alternative Fuel Policy

This strategy includes the following actions:

- T-3.A: Reduce vehicle size of City fleet
- T-3.B: Increase average fuel economy of City fleet
- T-3.C: Reduce VMT through various best practices (i.e., teleconferencing, limited idling, alternative modes of transportation, optimized routes, centralized meeting locations)
- T-3.D: Purchase vehicles with highest emissions certification standards
- T-3.E: Increase use of alternative fuel vehicles and equipment (i.e., electric and hybrid vehicles)

Strategies T-2 and T-3 Modeling Results

Total GHG Emissions Reduced from BAU

Included in T-2

Interactions with Other Strategies

Strategy T-3 will support strategy T-1 (Reduce vehicle miles) by implementing best practices like teleconferencing and incentivizing alternative modes of transportation, among others. Additionally, expanding alternative fuel City vehicles will affect the amount of renewable energy needed by the city to achieve Strategy RE-2 (Transition all applicable Alexandria government facilities to 100% renewable energy). Strategy T-3 also be supported by RE-1 (support implementation/acceleration of the VCEA by increasing solar deployment within the City) by electrifying and transitioning the transportation sector to alternative fuels.

Equity

This action will reduce GHG emissions and harmful pollutants from burning fossil fuels, thus improving air quality. Over time, this also will likely reduce costs as alternative fuel sources fall in price while fossil fuel prices increase. However, this action will have a limited impact on other indicators of equity for the broader community.

GHG Reductions

GHG emission reductions for this strategy are included in the reductions for T-2.

Cost

The costs associated with Strategy T-3 are moderate to high and mostly fall on the City. Alternative and electric vehicles cost more compared to ICE vehicles, even after incentives. Purchasing these vehicles will be a significant, but necessary, cost to the City to achieve a lower average fuel economy and improved emissions standards across their fleet. However, the lower cost of electricity versus fossil fuel will make the fleet more economically viable overtime. The City may also need to invest in additional technology to reduce VMT by means like teleconferencing, but these costs should be relatively low. Finally, by reducing the size of the fleet, the City is expected to reduce O&M costs for their fleet.

T-3.A: Reduce vehicle size of City fleet

Description	Emissions can be reduced by decreasing the vehicle size of the City fleet to the extent possible.
Equity Impacts and Implementation Considerations	Impacts: The reduced VMT from the city fleet will lead to reduced air pollution from the burning of fossil fuels, improving air quality. However, this action will have a limited impact on other indicators of equity for the broader community due to the size of the city fleet compared to all vehicles in Alexandria. Implementation: This action is not expected to have significant equity impacts during the implementation of the action.
Cost Considerations	By reducing the size of the fleet, the City is expected to reduce O&M costs for their fleet. This is especially effective when a fleet of vehicles comes to the end of its service life and rather than being replaced with a new vehicle, has its function replaced with an existing vehicle in the fleet.
Risks and Uncertainties	A thorough review of the uses and potential overlap in uses for the City's fleet is needed to ensure that if a vehicle is phased out, there are no likely scenarios where the City cannot accomplish the task performed by that vehicle. This becomes especially important to consider in scenarios where the fleet is currently out under stress and is used near capacity.
City Staff Resources	
Lead Implementer(s)	
Stakeholders and Partners	

Milestones and Next Steps	**Status**
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T-3. B: Increase average fuel economy of City fleet

Description	This includes increasing the use of alternative fuel vehicles and equipment (i.e., electric and hybrid vehicles).
Equity Impacts and Implementation Considerations	Impacts: The reduced fuel usage from the city fleet will lead to reduced air pollution from the burning of fossil fuels, improving air quality. However, this action will have a limited impact on other indicators of equity for the broader community due to the size of the city fleet compared to all vehicles in Alexandria. Implementation: This action is not expected to have significant equity impacts during the implementation of the action.
Cost Considerations	To increase the average fuel economy of the City fleet, new vehicles will have to be purchased. Higher efficiency vehicles, especially alternative fuel and electric vehicles are more costly than ICE vehicles, even with incentives. This requires a significant investment in the fleet from the city to drive up the average fuel economy of the City fleet.
Risks and Uncertainties	This action would be more effective with the reduction in cost of alternative fuel and electric vehicles. While the costs are expected to decrease over time, this is not something the City can affect, as prices are determined by market forces, and the level of incentivization offered by federal and state legislation. Additionally, not all vehicles in the city fleet can be replaced with an electric or alternative fuel option, replacing a vehicle with a more fuel-efficient option may not be worth the cost of replacement, and if new vehicles allow for a switch to and EV or alternate fuel option, they are likely to be significantly more expensive than current ICE vehicles.
City Staff Resources	
Lead Implementer(s)	
Stakeholders and Partners	

Milestones and Next Steps	Status
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T-3.C: Reduce VMT through various best practices

Description	Work to reduce VMT of the City fleet by implementing best practices such as teleconferencing, limited idling, alternative modes of transportation, optimized routes, and centralized meeting locations.
Equity Impacts and Implementation Considerations	Impacts: The reduced VMT from the city fleet will lead to reduced air pollution from the burning of fossil fuels, improving air quality. However, this action will have a limited impact on other indicators of equity for the broader community due to the size of the city fleet compared to all vehicles in Alexandria. Implementation: The actions being implemented should be designed in a way to ensure that behavioral changes and technology changes to how business is conducted by the City do not lead to further barriers for disadvantaged communities to participate in City businesses, such as public meetings that are held virtually, which some people may not have adequate technology to attend.
Cost Considerations	Most of these best practices come at little cost to the City to implement. The main costs come from ensuring that there is adequate technology available to implement teleconferencing successfully in a way that does not cut off access to meeting to those who do not have access to technology that allows them to participate.
Risks and Uncertainties	If people do not have access to the requisite technology to participate in teleconferencing, there could be unintended barriers to participation in City politics. This can also be said for centralized locations for meetings as a lack of transit options or length of commute may become a barrier for those who wish to participate if not managed thoughtfully.
City Staff Resources	
Lead Implementer(s)	

Stakeholders and Partners	

Milestones and Next Steps	**Status**
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T-3.D: Purchase vehicles with highest emissions certification standards

Description	The City will review purchases for the city fleet to ensure that any vehicles that do partly or fully use fossil fuels will meet the highest emission certification standards to limit the emission of GHG and other criteria pollutants.
Equity Impacts and Implementation Considerations	Impacts: Vehicles with higher emission certificate standards are more fuel efficient and will reduce GHG emissions along with air pollution, improving air quality. However, this action will have a limited impact on other indicators of equity for the broader community due to the size of the city fleet compared to all vehicles in Alexandria. Implementation: This action is not expected to have significant equity impacts during the implementation of the action.
Cost Considerations	Vehicles that meet higher emissions certification standards, especially those that go significantly beyond federal, or state standards are likely to be more costly compared to other vehicles.
Risks and Uncertainties	The continued use of ICE vehicles in the City fleet does not fully align with other recommended actions, driving the transition to EVs and alternative fuel vehicles. Additionally, the increased costs for the vehicles that meet the highest emissions certification standards may not be justified for the emission reductions compared to vehicles that do not meet the highest emissions certification standards.
City Staff Resources	
Lead Implementer(s)	
Stakeholders and Partners	

Milestones and Next Steps	**Status**

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T-3.E: Increase use of alternative fuel vehicles and equipment (i.e., electric and hybrid vehicles)

Description	Work toward the transition of vehicles and equipment toward alternative fuel options, especially EV and hybrid vehicles. This transition is in alignment with the City's alternative fuel policy.
Equity Impacts and Implementation Considerations	Impacts: This action will reduce GHG emissions and harmful pollutants from burning fossil fuels, thus improving air quality. Overtime, this also will likely reduce costs overtime as alternative fuel sources fall in price while fossil fuel prices increase. However, this action will have a limited impact on other indicators of equity for the broader community. Implementation: This action is not expected to have significant equity impacts during the implementation of the action.
Cost Considerations	Alternative fuel vehicles are currently significantly more expensive than traditional ICE vehicles, especially for larger vehicles such as trucks. While there are incentives to reduce this barrier, it does not fully alleviate the additional costs for alternative fuel and electric vehicles.
Risks and Uncertainties	This action would be more effective with the reduction in cost of alternative fuel and electric vehicles. While the costs are expected to decrease over time, this is not something the City can affect, as prices are determined by market forces, and the level of incentivization offered by federal and state legislation.
City Staff Resources	
Lead Implementer(s)	
Stakeholders and Partners	

Milestones and Next Steps	**Status**
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Renewable and Clean Electricity

The City is prioritizing two strategies to increase the availability of clean and renewable electricity within the City:

- RE-1: Support implementation and acceleration of the VCEA by increasing solar deployment within the City
- RE-2: Transition all applicable Alexandria government facilities to 100% renewable energy for all energy-use needs

The emission reductions associated with the increased availability and use of renewable and clean electricity in Alexandria is modeled and represented within the buildings and transportation sector results. GHG reductions presented within this section are for informational purposes only, to help facilitate the understanding of the role of lower and zero carbon electricity in meeting the City's GHG reduction goals.

RE-1: Support implementation/acceleration of the VCEA by increasing solar deployment within the City

VCEA establishes a 100% clean energy target for the state's largest utility (and the utility serving Alexandria) by 2045 and for the rest of the state by 2050. The City and its stakeholders can help support the implementation and acceleration of achieving the VCEA's clean electricity goals through a series of actions:

Strategy RE-1 Modeling Results (Informational)

Total GHG Emissions Reduced from BAU

370,000 $MTCO_2e$ (2030)

None (2050)

- **RE-1. A:** Increase on-site renewable deployment within the City through SolarizeAlexandria, Solar Equipment Tax Exemption, Green Building Policy (new construction), and low- and moderate-income programs
- **RE-1.B:** Support deployment of battery storage through promoting community ownership, incentives, and pairing with onsite renewables
- **RE-1.C:** Explore municipal aggregation
- **RE-1.D:** Encourage large-scale offsite renewable energy through working with businesses and other organizations within the City to procure through PPAs

Unlocking a clean, reliable electricity grid is arguably the most critical aspect of achieving the City's climate goals. Not only will grid decarbonization immediately result in lower carbon intensities for current electricity uses, but it can also accelerate and amplify additional reductions through 2050 and beyond as different end uses (e.g., cars, building heating systems, appliances) electrify. Within this plan, a low or no carbon electric mix will further support GHG reductions within the Buildings Energy and Transportation Sectors, and more specifically as the City pursues actions to electrify both buildings and the transportation sector.

Within the modeled pathway towards carbon neutrality, the achievement of the 2045 carbon-free grid is assumed.

Interactions with Other Strategies

Strategy RE-1 will contribute to achieving the goals of strategies B-2 and B-3, contributing to decarbonization of buildings and increasing the GHG reductions seen from electricity use in new and existing buildings. In addition, strategy RE-1 will also support achieving the goals of strategies T-2 and T-3 of electrifying and transitioning the transportation sector to alternative fuels.

Equity

Installation of distributed renewable energy (e.g., solar panels) within the City is not expected to tangibly address inequities such as regional air quality improvements and related public health impacts. However, equity is a key consideration in the design of programs and policies that support the deployment of renewable energy within the City and for access to renewable energy through other means including municipal aggregation or PPAs. For those that install panels onsite or are a part of potential large-scale or aggregated buying structures, energy costs can be reduced over time, but these types of actions require upfront financial investments and education. People who live in multi-family buildings where there is limited control over energy choices typically are not able to install solar panels. Additionally, disproportionate actions from higher income homes and businesses could increase electricity rates, creating a disproportionate impact on lower income utility customers.

GHG Reductions

GHG emission reductions associated with increased renewable and clean electricity in Alexandria are included in building and transportation sector results. The contribution of a municipal aggregation program is expected to result in emissions reductions of 370,000 $MTCO_2e$ below BAU levels in 2030 and none in 2050.

Cost

Although the capital costs of developing renewable energy and energy storage projects may be significant, the investment generally decreases future energy costs to energy users. This is true for both grid-scale facilities as well as for rooftop solar projects at the individual customer level. It's important to note that the upfront capital cost of renewable energy and storage continues to fall, and that tax credits also provide a financial incentive to install renewable energy installations.

RE-1.A: Increase on-site solar deployment within the City through SolarizeAlexandria, Solar Equipment Tax Exemption, Green Building Policy (new construction), and low- and moderate-income programs

Description	Install onsite solar at select facilities throughout the City to increase the share of renewable electricity supply throughout the City over time. These actions from the EAP include: • By FY2023, ensure that direct purchasing of offsite renewable electrical energy accounts for at least 50 percent of electrical energy use at all City-operated facilities. The remainder will be made up by Renewable Energy Certificate (REC) purchases and onsite renewable electrical energy generation to achieve a 100 percent renewable energy supply. • By FY2028, ensure that direct purchasing of offsite renewable electrical energy accounts for at least 80 percent of electrical energy use at all City-operated facilities. Ensure it is from a regional source that contributes to the growth of renewable energy capacity in the region. Onsite renewable electricity generation and REC purchases will make up the remainder, to achieve a 100 percent renewable electrical energy supply.
Equity Impacts and Implementation Considerations	Impacts: Installation of on-site renewable energy is unlikely to address inequities associated with regional air quality and public health impacts. Inequities may be exacerbated if the transition to a renewable energy system results in disproportionate actions from higher income homes and businesses increasing electricity rates for lower income utility customers. However, increased deployment of affordable solar energy throughout the community will reduce the energy burden on communities as a relatively cheap energy source that continues to decline in cost overtime. Implementation: This action will have a limited impact on other indicators of social equity for the broader community.

Cost Considerations	The upfront capital cost associated with grid-scale or behind-the-meter renewable energy projects can be significant. These costs are decreasing, as the industry matures and costs decrease (e.g., decreasing price of solar panels). In addition, tax credits offset some of the upfront capital costs. Lastly, energy costs over tie are lower with renewable energy projects compared to fossil fuel power generation, resulting in significant energy cost savings over time.
Risks and Uncertainties	Deployment of on-site renewables should be considered in parallel to energy storage systems in order to provide electricity to end users when the renewable energy resources are unavailable (i.e., when the sun isn't shining or the wind isn't blowing). In addition, consideration should be given to electrical grid impacts including grid interconnection issues.
City Staff Resources	
Lead Implementer(s)	
Stakeholders and Partners	

Milestones and Next Steps	**Status**
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RE-1.B: Support deployment of increased battery storage for on-site solar through promoting community ownership, incentives, and pairing with onsite renewables

Description	This action supports the increased deployment of battery storage through promotion of community ownership, incentives, and paring with onsite renewables. The installation and operation of behind-the-meter batteries can support distributed renewable energy generation efforts and improve resilience of local properties.

Equity Impacts and Implementation Considerations	Impacts: The deployment of battery storage to pair with onsite renewables will contribute to GHG remissions reductions and improved regional air quality. However, similar to RE-1.A, this action is unlikely to address inequities associated with regional air quality and public health impacts. Implementation: Renewable energy projects combined with battery storage, if strategically located to benefit disadvantaged neighborhoods, could have a beneficial impact and improve resilience.
Cost Considerations	Although battery costs are decreasing, they still require an upfront capital expenditure that can be prohibitive. Tax credits help offset the upfront capital cost, and a battery paired with a renewable energy system contribute to long term energy cost savings.
Risks and Uncertainties	Battery technology is evolving. Lithium-ion batteries currently dominate the market, and other energy storage alternatives are being explored and deployed (e.g., hydrogen, zinc-ion, redox flow). These alternatives may have properties that are more aligned with the user's needs, such as long-duration storage. Investing in a battery technology now may lock-in the user for decades to come. The City can support battery storage through a technology agnostic approach.
City Staff Resources	
Lead Implementer(s)	
Stakeholders and Partners	

Milestones and Next Steps	**Status**
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RE-1.C: Consider implementation of municipal aggregation program

Description	A municipal aggregation program would enable the City to purchase renewable electricity in bulk from an electricity supplier on behalf of the City residents and businesses.
Equity Impacts and Implementation Considerations	Impacts: Should the municipal aggregation program result in procurement of renewable energy resources that displaces fossil fuel energy, this will reduce GHG emissions and thus improve air quality while reducing energy costs for the government. However, this action will have a limited impact on other indicators of social equity for the broader community. Implementation: Renewable energy projects combined with battery storage, if strategically located to benefit disadvantaged neighborhoods, could have a beneficial impact and improve resilience.
Cost Considerations	Although there is a cost associated with procuring energy on behalf of customers, this cost is ultimately born by the customer. The costs associated with administering a municipal agreement program would need to be explored and considered by the City.
Risks and Uncertainties	Although Virginia has legislation enabling municipal aggregation models, there is the risk that any program could be challenged in court and implementation held up in court proceedings. In addition, there is also the risk of push-back from traditional utilities that would face potential new competition.
City Staff Resources	
Lead Implementer(s)	
Stakeholders and Partners	

Milestones and Next Steps	**Status**
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RE-1.D: Encourage large-scale offsite renewable energy by working with businesses and other organizations within the City to procure through PPAs

Description	Large businesses and organizations operating in Alexandria could participate in utility-scale power purchase agreements (PPAs) and procure renewable energy. Encouraging pursuit of large-scale PPAs could be achieved through a regional or local framework or program that coordinates PPAs. This could include the City educating businesses and organizations on PPAs, facilitating introductions between interested parties, and helping potential partners identify and address challenges.
Equity Impacts and Implementation Considerations	Impacts: While the use of renewable energy will have an impact on the national, regional, or global GHG emissions, PPAs for renewable energy in areas far from Alexandria will not have an impact on regional air quality and the health benefits associated with reducing fossil fuel combustion. Implementation: Renewable energy projects combined with battery storage, if strategically located to benefit disadvantaged neighborhoods, could have a beneficial impact and improve resilience.
Cost Considerations	The cost to the City for encouraging large-scale offsite renewable energy projects through PPAs is nominal relative to the cost of the business or organization securing the PPA.
Risks and Uncertainties	As part of encourage a PPA program, there should be an evaluation of the energy loads of participating businesses and organizations and the carbon content of delivered power. This could potentially be an issue if the energy load does not correspond to when the renewable energy is generated.
City Staff Resources	
Lead Implementer(s)	
Stakeholders and Partners	

Milestones and Next Steps	**Status**
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RE-2: Transition all applicable Alexandria government facilities to 100% renewable energy for all energy-use needs

Alexandria is leading by example and committing 100% renewable energy across all government facilities. Action the City can take to help achieve this goal includes:

- **RE-2.A:** Implement government operations renewable electricity actions from the EAP 2040

Interactions with Other Strategies

Transitioning all government facilities to 100% renewable energy for all energy-use needs can in part be supported by financial support for building decarbonization (B-1) and through implementation of all-feasible decarbonization measures for City-owned buildings (B-2). In addition, increasing alternative fuel City vehicles and associate charging infrastructure (T-3) will impact the amount of renewable energy needed by the City. Lastly, increasing solar deployment through the City (RE-1) will be complementary to this strategy.

Equity

Installation of distributed renewable energy (e.g., solar panels) within the City is not expected to tangibly address inequities such as regional air quality improvements and related public health impacts. However, equity is a key consideration in the design of programs and policies that support the deployment of renewable energy within the City and all for access to renewable energy through other means including municipal aggregation or PPAs. For those that install panels onsite or are a part of potential large-scale or aggregated buying structures, energy costs can be reduced over time, but these types of actions require upfront financial investments and education. People who live in multi-family buildings where there is limited control over energy choices typically are not able to install solar panels. Additionally, disproportionate actions from higher income homes and businesses could increase electricity rates, creating a disproportionate impact on lower income utility customers.

GHG Reductions

GHG emission reductions were not quantified for this strategy.

Cost

The cost of transitioning all of Alexandria's government facilities to 100% renewable energy will include a sizeable upfront capital investment with long-term energy cost savings. These costs can be dampened through tax credits and financing arrangements to spread the costs out over the lifetime of the renewable energy installation.

RE-2.A: Implement government operations renewable electricity actions from the EAP 2040

Description	The EAP2040 details actions and milestones for transitioning government operations to renewable energy. This includes increasing REC purchases, developing a renewable energy supply strategy for the City, and reaching 100% electrical energy use at City-operated facilities.
Equity Impacts and Implementation Considerations	Impacts: Installation of on-site renewable energy is unlikely to address inequities associated with regional air quality and public health impacts. Implementation: Renewable energy projects combined with battery storage, if strategically located to benefit disadvantaged neighborhoods, could have a beneficial impact and improve resilience.
Cost Considerations	
Risks and Uncertainties	
City Staff Resources	
Lead Implementer(s)	
Stakeholders and Partners	

Milestones and Next Steps	**Status**
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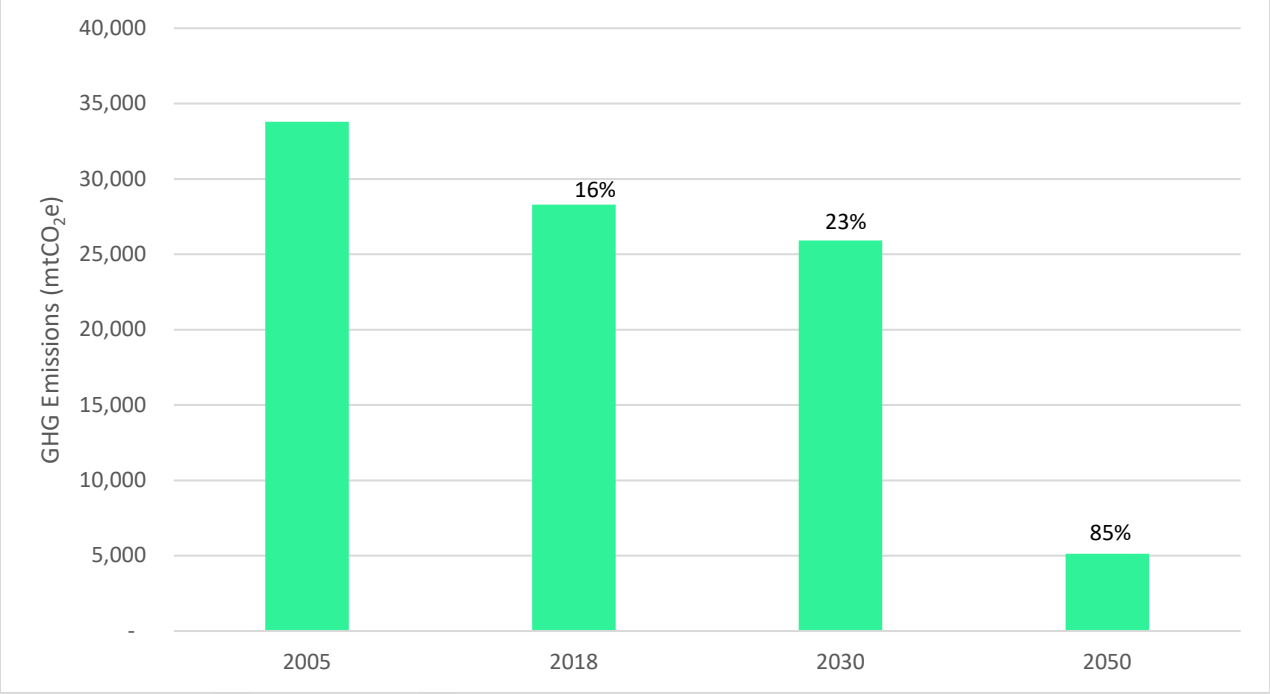
Waste

The waste sector includes two priority strategies:

- W-1: Recover resources and reduce GHG emissions and other forms of pollution by optimizing and safely handling the collection and processing of solid waste
- W-2: Reduce total solid waste collected from City-served residential customers

These strategies will result in a 23% reduction in waste sector GHG emissions by 2030 and an 85% reduction in GHG emissions by 2050 as compared to the 2005 base year (see Figure 9). As of 2018, GHG emissions were reduced by 16% as compared to 2005, due to the various programs and policies the City has developed around recycling and resource management.

Figure 9. Waste GHG Emissions under the GHG Reduction Pathway



W-1: Recover resources and reduce GHG emissions and other forms of pollution by optimizing and safely handling the collection and processing of solid waste

The City's waste policy is guided by the Alexandria WasteSmart strategic plan. The plan focuses on reducing GHG emissions from waste and a shift toward waste disposal practices that optimize the collection and processing of solid waste. This can be done by separating waste and recycling products like glass from the single stream recycling system, creating education campaigns for the community to be more conscious of how they dispose of solid waste, and reviewing the state of current solid waste treatment options to see where processes can be improved to reduce GHG emissions from the processing of solid waste.

Strategies W-1 and W-2 Modeling Results

Total GHG Emissions Reduced from BAU

8,900 $MTCO_2e$ (2030)

39,000 $MTCO_2e$ (2050)

- **W-1.A:** Continue to implement actions defined in the EAP 2040 addressing resource recovery and GHG emissions

Interactions with Other Strategies

The reduction in solid waste being generated from city residents in strategy W-2 will allow for further reductions in GHG emissions due to a lower amount of waste that would need to be processed.

Equity

Diverting waste can lead to better health outcomes, especially for communities that are located near such facilities which have historically been the most adversely effected from the emissions from waste disposal and processing. Program implementation must allow for programs to increase ease of access to recycling and resource recovery. Programs should also be implemented along with education in areas where the economic incentive for right recycling practices and the diversion of waste from landfills will have the greatest impact.

GHG Reductions

When combined with the actions under strategy W-2 (Reduce total solid waste collected from City-served residential customers) GHG emission reductions for new and existing buildings are expected to be 8,900 $MTCO_2e$ below BAU levels in 2030 and 39,000 $MTCO_2e$ in 2050. Overall strategies W-1 and W-2 combined are expected to result in a 23% reduction from base year 2005 GHG emissions in 2030 and an 85% reduction from base year emissions in 2050.

Cost

The costs to the City include the costs to provide the infrastructure and to run the programming for initiatives intended to have residents recycle more and in more appropriate ways to maximize the potential for resource recovery.

W-1.A: Implement actions defined in the EAP 2040 addressing resource recovery and GHG emissions

Description	Per the EAP 2040 guidance on resource recovery, there are short-term and medium-term actions that help reduce GHG emissions including: • Glass-only recycling receptacles at all recycling drop off centers and the phase-out of glass in single stream recycling • Educational campaigns to promote and define recycling best practices • Update recycling ordinances to reflect changes in the global recycling market • Review commercial recycling requirements to improve resource recovery in the commercial sector. • Evaluate for recycling capacity, convenience, signage, number and type of recyclables required to be recycled, education, outreach, and information required for Recycling Implementation Plan form
Equity Impacts and Implementation Considerations	Impacts: Diverting waste from facilities can lead to better health outcomes, especially for communities that are located near waste disposal facilities. Implementation: Program implementation must allow for programs to increase ease of access to recycling and resource recovery. Programs should also be implemented along with education in areas where the economic incentive for right recycling practices and the diversion of waste from landfills will have the greatest impact.
Cost Considerations	The costs to the City include the costs to provide the infrastructure and to run the programming for initiatives intended to have residents recycle more and in more appropriate ways to maximize the potential for resource recovery.
Risks and Uncertainties	The risk associated with the EAP 2040 guidance is tied to the volatility of the global recycling market and the value of resource recovery versus disposal. Without proper education there is a risk that the infrastructure put in place to allow for better recycling practices will go underutilized.
City Staff Resources	
Lead Implementer(s)	

Stakeholders and Partners	
Milestones and Next Steps	**Status**
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W-2: Reduce total solid waste collected from City-served residential customers

W-2.A: Implement actions defined in the EAP 2040 that will reduce solid waste from City-served residents. The EAP recommends short-, mid-, and long-term actions that include actions such as creating a registry for reuse, donation, and repair to encourage waste prevention and reuse of existing materials, implementing variable rate pricing for solid waste collection service, encouraging the use of reusable bags over disposable plastic bags, and supporting the reduction, reuse, and recovery of building material.

Interactions with Other Strategies

The strategies in W-1 to encourage more thoughtful consideration in what waste should be disposed of and what can be sent for recycling or for reuse will further reduce the waste generated by city-served residential customers.

Equity

Diverting waste from facilities like landfills can lead to better health outcomes, especially for communities that are located near waste disposal facilities which have historically been the most adversely effected from the emissions from waste disposal and processing facilities. Programs, especially those that increase the costs to the community should be carefully considered to ensure that an undue burden is not placed on communities without proper support.

GHG Reductions

GHG emission reductions for this strategy are included in the reductions for W-1.

Cost

The costs of this action for the City comes from studies and staff time used to implement programs, provide community outreach, and prepare legislation.

The cost to the community comes from potential additional costs associated with solid waste, either through additional charges for using plastic bag or from the variable rate pricing.

W-2.A: Implement actions defined in the EAP 2040 that will reduce solid waste from City-served residents

Description	The EAP 2040 plan lays out way to reduce solid waste generated by City residents including: • Creating a registry for reuse, donation, and repair to encourage waste prevention and reuse of existing materials. • Implement variable rate pricing for solid waste collection services. • Encourage the use of reusable bags over disposable plastic bags. • Support the reduction, reuse, and recovery of building material.
Equity Impacts and Implementation Considerations	Impacts: Diverting waste from facilities like landfills can lead to better health outcomes, especially for communities that are located near waste disposal facilities. Implementation: Programs, especially those that increase the costs to the community should be carefully considered to ensure that an undue burden is not placed on communities without proper support.
Cost Considerations	The costs of this action for the City comes from studies and staff time used to implement programs, provide community outreach, and prepare legislation. The cost to the community comes from potential additional costs associated with solid waste, either through additional charges for using plastic bag or from the variable rate pricing.
Risks and Uncertainties	Passing legislation that has the potential to increase costs in the community is not certain to be enacted. Outreach and education efforts to change behaviors are also not guaranteed to drive significant change in behavior.
City Staff Resources	
Lead Implementer(s)	
Stakeholders and Partners	

Milestones and Next Steps	**Status**
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Other GHG Strategies

Additional GHG reduction strategies are necessary to achieve the EAP's 2050 targets. Remaining emissions are present in all sectors, but in relatively small amounts. Some of these areas, such as aviation, refrigerants, and SF_6, may be addressed in partnership with federal government. Alexandria can participate by supporting federal action such as the Sustainable Aviation Fuel Act.

To fully achieve the City's GHG reduction goals other GHG reduction strategies will need to be used. This ECCAP prioritizes one specific strategy to address fugitive methane emissions from the gas system and one strategy that recognizes there will be a role for adopting future technologies as they become more developed and economically feasible.

- **O-1:** Address fugitive gas system leaks
- **O-2:** Recognize and understand the role of future technologies as they continue to be developed

O-1: Address fugitive gas system leaks

Fugitive emission from distribution systems can be a substantial source of GHG emissions. By requiring Washington Gas to report the level of leaks in the Alexandria distribution system and upstream piping system feeding into the Alexandria system, a better handle on the full emissions from Alexandria can be known and action can be taken to address leaks or to have more data to advocate for changes from Washington Gas. To ensure that the resources are available for Washington Gas to reduce leaks from their system, the Steps to Advance Virginia's Energy (SAVE) rider was implemented. The efficacy of this rider should be examined to determine if any adjustments should be made to allow for the program to work effectively for reducing fugitive methane emissions from natural gas distribution systems.

Strategy O-1 Modeling Results

Total GHG Emissions Reduced from BAU

620 $MTCO_2e$ (2030)

1,500 $MTCO_2e$ (2050)

- **O-1.A:** Set requirements for Washington Gas to report level of leaks in Alexandria distribution system and upstream piping systems serving Alexandria
- **O-1.B:** Analyze whether the state-approved SAVE rider provides for a fair recovery of pipeline infrastructure upgrades needed to reduce leaks

Interactions with Other Strategies

Transitions to renewable energy (RE-1, RE-2), and building electrification and decarbonization (B-1, B-2, B-3, and B-4) will reduce the need for natural gas distribution in the city, this will lead to less natural gas leakage as well as reduce the amount of natural gas pipe in the city, both of which will lead to smaller overall emissions from the distribution of natural gas.

Equity

Reduced GHG emissions from the pipeline system can lead to better air quality, especially for those from sensitive populations. Additionally, lower waste from natural gas distribution systems can lead to lower energy costs, alleviating the energy burden for disadvantaged populations. If effort is undertaken to have a better understanding of the fugitive emissions from distribution systems, efforts should be made to help pass savings along to consumers, especially for disadvantaged populations.

GHG Reductions

Over half of emissions from gas systems occur during storage or transportation of gas in pipelines. With increased servicing and better storage technology, fugitive emissions can be significantly reduced. The contribution of reducing fugitive gas system leaks is expected to result in emissions reductions of 620 $MTCO_2e$ below BAU levels in 2030 and 1,500 $MTCO_2e$ in 2050.

Cost

The costs to set requirements for Washington Gas is relatively small, and it is likely that Washington Gas can gather the data without significant investments in their systems. To evaluate the efficacy of the SAVE rider the costs will stem from the costs to commission the analysis.

O-1.A: Set requirements for Washington Gas to report level of leaks in Alexandria distribution system and upstream piping systems serving Alexandria

Description	Fugitive emission from distribution systems can be a substantial source of GHG emissions. By requiring Washington Gas to report the level of leaks in the Alexandria distribution system and upstream piping system feeding into the Alexandria system, a better handle on the full emissions from Alexandria can be known and action can be taken to address leaks or to have more data to advocate for changes from Washington Gas.

Equity Impacts and Implementation Considerations	Impacts: Reduced GHG emissions from the pipeline system can lead to better air quality, especially for those from sensitive populations. Lower waste from natural gas distribution systems can lead to lower energy costs, alleviating the energy burden for disadvantaged populations. Implementation: If effort is undertaken to have a better understanding of the fugitive emissions from distribution systems, efforts should be made to help pass savings along to consumers, especially for disadvantaged populations.
Cost Considerations	The costs to set requirements for Washington Gas is relatively small, and it is likely that Washington Gas can gather the data without significant investments in their systems.
Risks and Uncertainties	Washington Gas may oppose any legislation setting this type of requirement or may not have the ability to track leaks at the level required to be useful for making further decisions and taking further actions.
City Staff Resources	
Lead Implementer(s)	
Stakeholders and Partners	

Milestones and Next Steps	**Status**
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O-1.B: Analyze whether the state-approved SAVE rider provides for a fair recovery of pipeline infrastructure upgrades needed to reduce leaks

Description	The SAVE rider allows for Washington Gas to take on projects that replace current infrastructure given they improve reliability and reduce GHG emissions. An analysis of this program seeks to determine if the program provides a fair recovery of pipeline infrastructure upgrades needed to reduce leaks.

Equity Impacts and Implementation Considerations	Impacts: Reduced GHG emissions from the pipeline system can lead to better air quality, especially for those from sensitive populations. Lower waste from natural gas distribution systems can lead to lower energy costs, alleviating the energy burden for disadvantaged populations. Implementation: If effort is undertaken to have a better understanding of the fugitive emissions from distribution systems, efforts should be made to help pass savings along to consumers, especially for disadvantaged populations.
Cost Considerations	Working with consultants to perform the analysis will be the bulk of the costs associated with the analysis.
Risks and Uncertainties	Even after an analysis is conducted there is no guarantee that action will be taken to improve conditions, allowing for more work to be done to reduce leaks.
City Staff Resources	
Lead Implementer(s)	
Stakeholders and Partners	

Milestones and Next Steps	**Status**
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O-2: Recognize and understand the role of future technologies as they continue to be developed

The strategies modeled in this ECCAP demonstrate the pathway the City can take to meet its 2030 and 2050 GHG reduction goals. To accelerate climate action and go beyond the City's goals, additional strategies could be explored. These strategies could include:

(a) Existing technologies that may be costly

(b) Yet to be developed technologies

(c) Accelerated action

Strategy O-2 Modeling Results

Total GHG Emissions Reduced from BAU

None (2030)

190,000 $MTCO_2e$ (2050)

Specifically, these additional strategies could encompass technologies such as carbon capture, utilization, and storage, advanced batteries, and very rapid shifts to move the fleet toward zero emissions vehicles. In addition, further reducing single occupancy vehicle trips and VMT could be achieve through cordon pricing, VMT pricing, or other policy constructs that are feasible but do not yet exist.

Interactions with Other Strategies

These future technologies have the potential to interact with many of the existing strategies. For example, acceleration of EV adoption may be supported by T-1 (Reduce VMT) by making EVs more accessible to those with concerns about long commuting distance with limited charging infrastructure. It will also be supported by RE-1 (support implementation/acceleration of the VCEA by increasing solar deployment within the City) by providing electricity to a bigger fleet of vehicles.

Equity

Equity impacts will depend on the future technology adopted. They could be positive, for instance, if a cordon pricing policy decreases ICE traffic in disadvantaged communities leading to better air quality. Conversely, the deployment of a CCS facility near a disadvantaged community may not drastically improve air quality in that community, rendering no change to the status quo.

GHG Reductions

This strategy is not contributing emissions reductions to the 2030 goal since the other ECCAP strategies cumulatively achieve the City's 2030 goal. By 2050, emissions reductions from future technologies are expected to be 190,000 $MTCO_2e$ below BAU levels in 2050.

Cost

The costs to deploy this strategy are high. Widespread adoption of existing technologies such as EVs or efficient appliances is feasible with significant subsidies or incentives. Yet-to-be discovered technologies need the research and development investment, and then the commercial scale-up, which can both be capital intensive investments.

Climate Impacts and Adaptation Strategies

Climate Change Impacts and Vulnerabilities

The City is seeing the impacts of warming global temperatures on critical infrastructure and public health outcomes across the community. The Metropolitan Washington region has warmed 2° F over the past century, leading to more frequent hot days and heavy rainstorms.[6] Future temperature increases will exacerbate extreme heat, drought, flooding, and extreme storm conditions, including hurricanes and tropical storm events. Already, the Potomac River is rising by nearly one inch every eight years, and is exacerbating stormwater flooding throughout Alexandria.[7] Additionally, climate change will pose a threat to low-lying wetlands along the Potomac River and its tributaries due to exacerbated flooding conditions.

GHG Emissions and Climate Hazards

The magnitude of local changes in climate hazards – including extreme heat, flooding, storms, and extreme winter conditions – over the coming decades will depend on the rate of future global GHG emissions.

Mitigation of GHG emissions is imperative, however, the region is facing impacts from climate change now and will continue to experience these impacts over the next 20-30 years because of GHGs that have already been emitted. Adaptation and resilience measures are important to undertake to minimize impacts to the

The impacts of climate change will not be felt uniformly across all of Alexandria's community. Vulnerable populations including elderly, youth, low-income, and disabled community members are at the highest risk of negative impacts associated with climate change.[8]

The Metropolitan Washington Council of Governments' (MWCOG) Metropolitan Washington 2030 Climate and Energy Action Plan quantifies the probability, consequences, and risks of climate change-driven impacts on the greater Washington D.C. metropolitan area, including Alexandria.[9]

[6] U.S. Army Corps of Engineers Baltimore District, "Metropolitan Washington District of Columbia Coastal Storm Risk Management Feasibility Study," May 2022, https://www.nab.usace.army.mil/Media/News-Releases/Article/3051747/army-corps-releases-draft-report-environmental-assessment-for-metro-dc-coastal/.

[7] U.S. Army Corps of Engineers Baltimore District, "Metropolitan Washington District of Columbia Coastal Storm Risk Management Feasibility Study."

[8] IPCC, "Summary for Policymakers of IPCC Special Report on Global Warming of 1.5°C Approved by Governments," Accessed April 8, 2022, https://www.ipcc.ch/2018/10/08/summary-for-policymakers-of-ipcc-special-report-on-global-warming-of-1-5c-approved-by-governments/.

[9] MWCOG, "Metropolitan Washington 2030 Climate and Energy Action Plan," Accessed April 8, 2022, https://www.mwcog.org/documents/2020/11/18/metropolitan-washington-2030-climate-and-energy-action-plan/.

The impacts of climate change will not be felt uniformly across all of Alexandria's community. Vulnerable populations including elderly, youth, low-income, and disabled community members are at the highest risk of negative impacts associated with climate change.[10]

The Metropolitan Washington Council of Governments' (MWCOG) Metropolitan Washington 2030 Climate and Energy Action Plan quantifies the probability, consequences, and risks of climate change-driven impacts on the greater Washington D.C. metropolitan area, including Alexandria.[11] In this study, risk is calculated as a product of the probability and consequence of each climate hazard type. Flooding and extreme heat present the greatest risk, ahead of drought, extreme thunder and lightning storms, and extreme winter conditions (Figure 10).

Figure 10. MWCOG Risk Level of Hazards in Metropolitan Washington [12]

Hazard	Probability	Consequence	Risk
Extreme Heat	3	3	9
Drought	2	3	6
Flooding (Flash and Riverine)	3	3	9
Coastal Flooding	3	2	6
Lightning/Thunderstorm	3	2	6
Extreme Winter Conditions	2	3	6

Note: In the MWCOG study, risk from each hazard is rated as the product of the probability and consequence of that hazard, each rated on a scale of 1 (low) to 3 (high). For Alexandria, the risk of coastal flooding may also be considered high due to the tidal characteristics of the Potomac River.

Additionally, the 2017 Northern Virginia Hazard Mitigation Plan analyzed hazards and risk levels for the City, further highlighting the importance of flooding as an area of major concern (Figure 11).[13] This hazard mitigation plan also identifies wind, tornados, and winter weather as high-risk hazards.

[10] IPCC. "Summary for Policymakers of IPCC Special Report on Global Warming of 1.5°C Approved by Governments." Accessed April 8, 2022. https://www.ipcc.ch/2018/10/08/summary-for-policymakers-of-ipcc-special-report-on-global-warming-of-1-5c-approved-by-governments/.

[11] MWCOG. "Metropolitan Washington 2030 Climate and Energy Action Plan." Accessed April 8, 2022. https://www.mwcog.org/documents/2020/11/18/metropolitan-washington-2030-climate-and-energy-action-plan/.

[12] The risk of coastal flooding for the City may see a risk value as high as 9 due to the tidal characteristics of the Potomac River.

[13] Northern Virginia Mitigation Advisory Committee, "Northern Virginia Hazard Mitigation Plan," Accessed April 19, 2022, https://media.alexandriava.gov/docs-archives/fire/info/hazmit-final-draft-8.24.17.pdf.

Figure 11. Northern Virginia Hazard Mitigation Plan, Hazard Rankings for Alexandria

Hazard	Flood	Wind	Tornado	Winter Weather	Drought	Earthquake	Landslide	Wildfire	Karst
Ranking	High	High	High	High	Med-High	Med	Low	Med-Low	Med-Low

The City also led several Community Workshops to gather a holistic understanding of climate vulnerabilities and impacts to the community. During a Workshop on March 1st, 2022, participants identified the following climate vulnerabilities from most concerning to least: Extreme Heat/Urban Heat Island, Extreme Precipitation/Inland Flooding, Extreme Storms, Sea Level Rise/Waterfront Flooding, Drought, Wildfires, Extreme Cold, and Other (Figure 12).[14] The City is committed to engaging with the community and understanding the impacts of climate risk as it relates to resident and energy community perspectives.

Figure 12. City Climate Vulnerabilities, ECCAP Community Engagement Workshop #2

This ECCAP focuses on the potential impacts of flooding and extreme heat throughout the City, including within various neighborhoods and demographic groups. These two hazards were selected because they represent the highest priority risks to the City based on the findings of the studies described above and the community priorities gathered from workshops and engagement activities. The plan addresses ongoing initiatives by the City to combat these hazards. The plan lays out potential planning and adaptation strategies the City may undertake in the future to expand existing initiatives or adopt new approaches to reduce and adapt to the impacts of climate change.

[14] City of Alexandria, VA, "Energy and Climate Change Action Plan, Community Engagement Workshop 1," March 1, 2022, https://www.alexandriava.gov/sites/default/files/2022-03/MentimeterPollResults03012022_0.pdf.

Flooding

The City of Alexandria is located along the tidal Potomac River which is included in the Virginia Coastal Zone Management Area (CZM), which encompasses more than 5,000 miles of shorelines.[15] Virginia's CZM experiences different threats than non-coastal communities.

The City experiences a variety of flooding types, including:

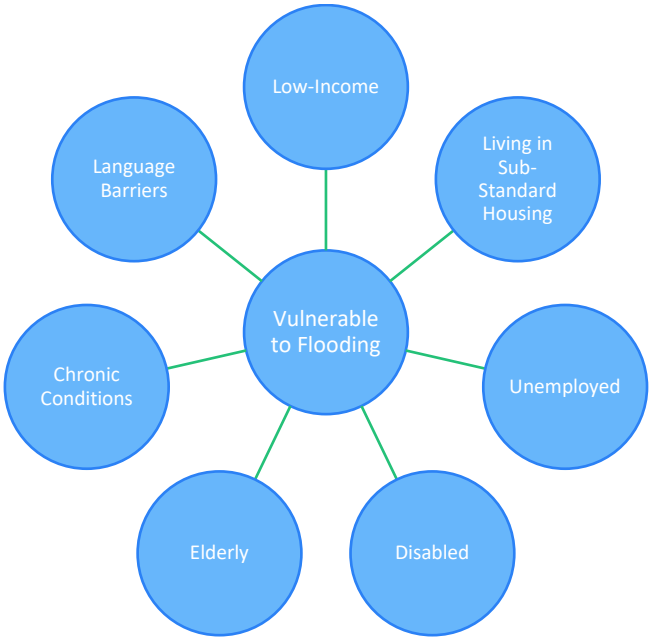
- **Tidal flooding** from the Potomac, generally caused by a higher-than-average high tides, which may be compounded by heavy rainfall across the region. Sea level rise caused by global climate change is increasing the frequency of these high tide events.
- **Riverine flooding** events occur when water levels rise enough to overtop riverbanks and are due to one or more events such as excessive rain from tropical storm systems, persistent thunderstorms over the river's watershed for an extended period, as well as combined rainfall and snowmelt.
- **Stormwater flooding, or inland flooding,** takes place when intense rainfall that occurs over a relatively short period, often 6 hours or less, overwhelms storm sewer infrastructure and results in flooding of alleys, streets, buildings, and streams. This type of flooding also leads to infiltration and inflow (I&I) into the City's sanitary sewer system which causes sanitary sewer backups.

Recent flood events, such as those caused by Hurricane Isabel in 2006, Hurricane Irene in 2011, Tropical Storm Lee in 2011, and the more recent, severe flash flooding events of July 2019, July and September 2020, and August and September 2021, illustrate the impacts of these flood events. For example, flooding could endanger public health and may impair continuity of transportation and business operations, emergency response services, and the functions of sanitary sewers. Demographics of communities particularly vulnerable to the socio-economic impacts caused by flooding are shown in Figure 13..[16]

[15] Virginia Department of Environmental Quality, "Coastal Zone Management," Accessed August 10, 2022, https://www.deq.virginia.gov/coasts/coastal-zone-management.

[16] Metropolitan Washington Council of Governments, 2020.

Figure 13. Demographic Characteristics that Contribute to Flooding Vulnerability

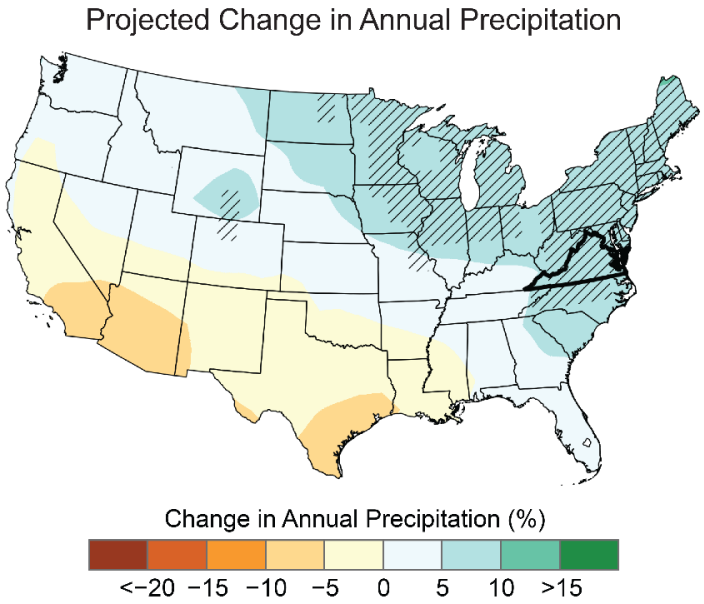


The City of Alexandria and the continental United States are already experiencing increases in annual precipitation and heavy rainfall. Overall annual precipitation in the mid-Atlantic is projected to increase by 5-10% by the middle of the 21st century based on historical observations, and may come in the form of more frequent and intense heavy rainfall events (Figure 14).[17]

Figure 14. Virginia is expected to see increases in average annual precipitation through 2050 and beyond. The hatch mark area represents areas with a statistically significant change in precipitation.

[17] K.E. Kunkel, "State Climate Summaries 2022," Accessed April 8, 2022, https://statesummaries.ncics.org/chapter/va/.

Source: NOAA National Centers for Environmental Information, State Climate Summaries 2022, Virginia.



Increasing annual precipitation and heavy rainfall places significant structural and functional burdens on combined sewer and stormwater infrastructure. Additionally, historic architecture and landmarks within Old Town are at risk of damage due to overbank flooding from the Potomac River. Sewage overflows to the Potomac River, flood damage to properties, and the impacts of tropical storms will continue to worsen city-wide disruptions, damage, and injury.

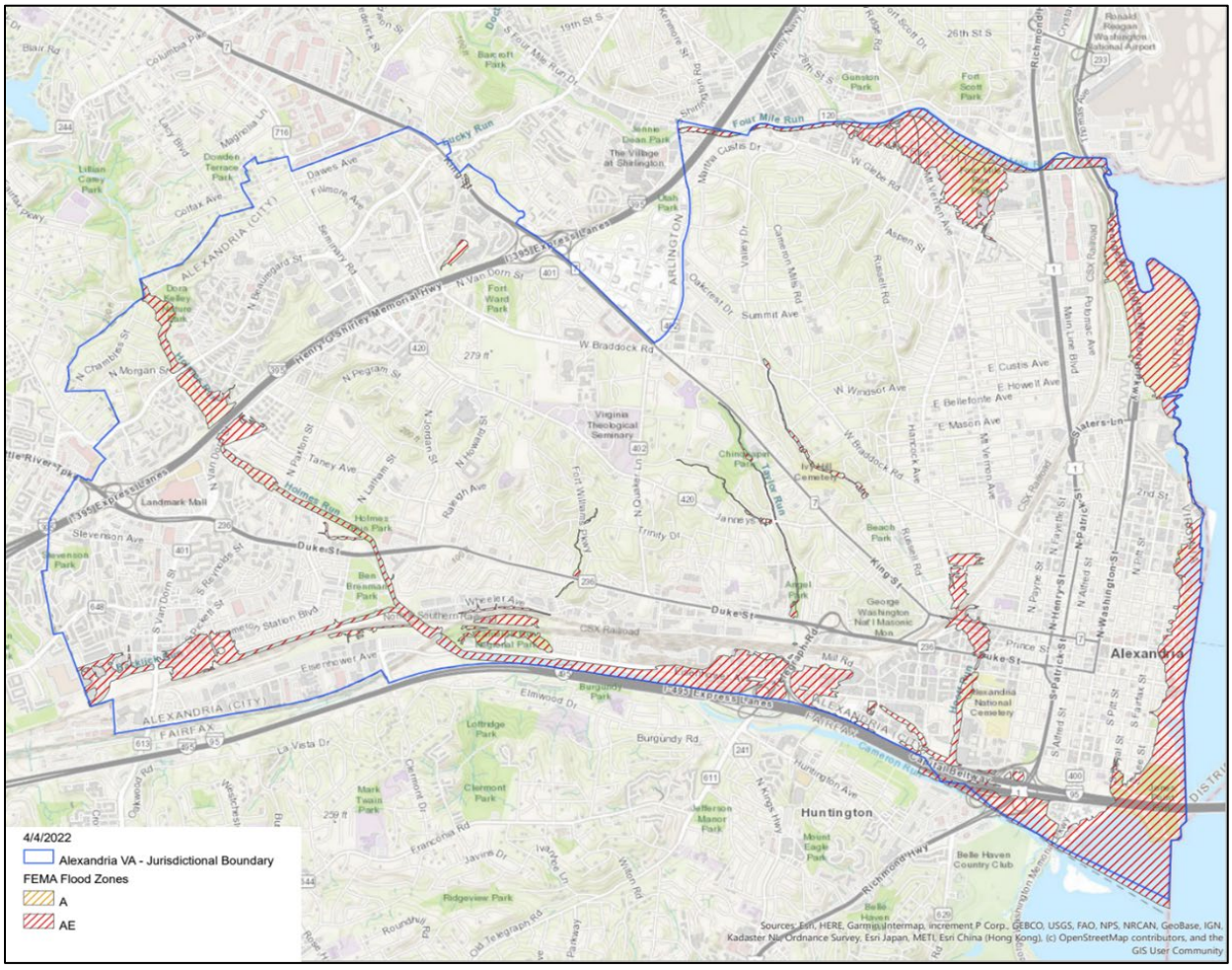
As of 2022, nearly 20% of the city is mapped in the Federal Emergency Management Agency (FEMA) floodplain (Figure 15).[18] The majority of these areas are in Zone AE, which depicts flood zone areas that historically have a 1% annual chance of flooding (or a 26% chance of flooding at least once over the life of a 30 year mortgage).[19] The FEMA floodplain maps for Alexandria were last updated in 2011, and the FEMA floodplain updates presented to the community of Alexandria in 2020 will take effect the Fall of 2022.

It is important for residents and business owners to know current flood risks if residences or businesses are in a FEMA floodplain, or property is susceptible to damage from any type of flooding that may occur. Residents and business owners can take steps to protect themselves and their property by understanding where they are situated within the floodplain, their risk of flooding impacts, and what mitigating resources are available.

[18] City of Alexandria, VA, "Flood Map," Accessed April 8, 2022, https://www.alexandriava.gov/FloodMap.

[19] FEMA, "Glossary," Accessed April 22, 2022, https://www.fema.gov/about/glossary.

Figure 15. FEMA Flood Zones; Alexandria, VA



The FEMA 100-year floodplain shown in Figure 15 only displays the mapped floodplain and does not represent all areas of the City that may be exposed to, or experience flooding. FEMA floodplains are based on historical data associated with water bodies (streams, rivers, etc.) and do not account for increased precipitation, sea level rise, or aging infrastructure so the FEMA floodplain does not depict all flooding concerns. A complete list of current and planned actions is summarized under Existing Adaptation and Resilience Activities below. Highlights include:

- Through the Flood Action Alexandria program, the City is currently undertaking several activities to further assess flood risks and take action to reduce those risks.
- The City's combined sewer system, which extends over 500 acres of Old Town Alexandria, is presently being rehabilitated through a public-private partnership known as the River Renew program. This program which will reduce the number of and volume of potential sewage overflows to the system.

- The City's Waterfront Mitigation Plan will reduce nuisance flooding by building a six-foot bulkhead along the waterfront.[20]

Extreme Heat

Extreme heat is another priority risk for the City's focus, with impacts to public health and infrastructure. Extreme heat is a leading cause of weather-related deaths and illness in the U.S.[21] The City has historically experienced temperatures exceeding 95°F, on average, nearly 8 days per year. However, depending on future emissions, the number of days in Alexandria with such temperatures is projected to increase to 19-20 days by 2030 and 26-33 days by 2050, respectively.

Figure 16. Number of days per year in Alexandria with maximum temperatures exceeding 90°F, 95°F, and 100°F (under high emissions scenario RCP 8.5 and low emissions scenario RCP 4.5)

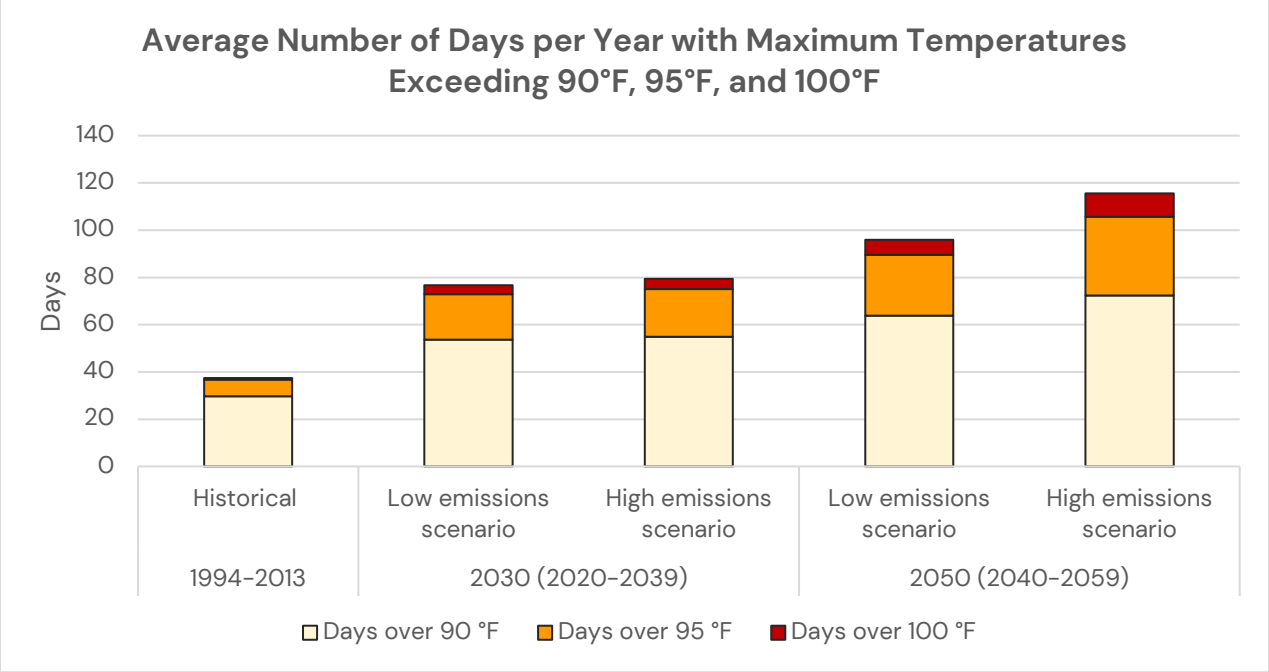


Figure 16 shows the number of days per year above 90 °F, 95 °F, and 100 °F under low and high emissions scenarios.

[20] U.S. Army Corps of Engineers Baltimore District, "Metropolitan Washington District of Columbia Coastal Storm Risk Management Feasibility Study," May 2022. https://www.nab.usace.army.mil/Media/News-Releases/Article/3051747/army-corps-releases-draft-report-environmental-assessment-for-metro-dc-coastal/.

[21] National Weather Service, Natural hazard Statistics, "Weather Related Fatality and Injury Statistics, 2020," Accessed May 26, 2022, https://www.weather.gov/hazstat/.

Figure 17. Number of Days per Year in Alexandria with Maximum Temperatures Exceeding 90°F, 95°F, and 100°F (under high emissions scenario RCP 8.5)

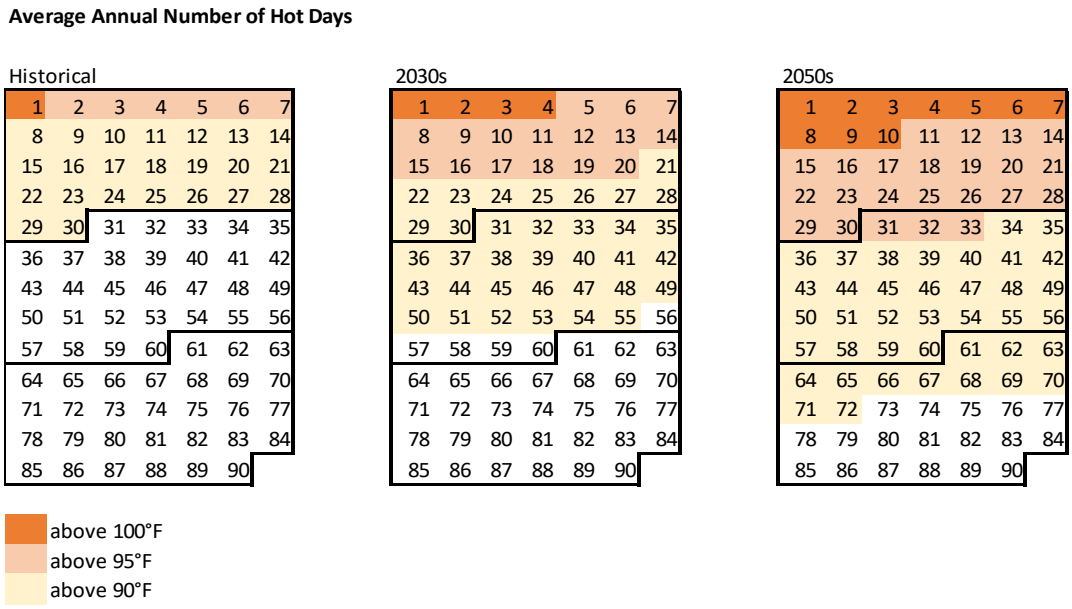


Figure 17 shows the average annual number of hot days above 90°F, 95°F, and 100°F over a period of 90 days, or the average length of the summer season for the region. Historically, such conditions are only experienced during 30 of the 90 day of a typical summer season. As we approach mid-century projections, over 10 out of 90 days of the summer season will be above 100°F, 22 days will be above 95°F, and almost 80% of all summer days will be above 90°F.

Extreme heat can have cascading impacts on public health and the livelihoods of Alexandria's inhabitants. Extreme heat disproportionately increases adverse health effects on children under five years of age, people aged 65 and older, individuals with obesity, asthma, and chronic obstructive pulmonary disease (COPD), and individuals with underlying chronic illnesses.[22]

[22] Health Matters Alexandria, "Number of Extreme Heat Days," Accessed April 8, 2022, https://www.healthmattersalexandria.org/indicators/index/view?indicatorId=8677andlocaleId=2967.

Figure 18. Demographic Characteristics that Contribute to Heat Vulnerability

Additionally, extreme heat can damage overhead electrical transmission wires, buckle rail lines, and impact Alexandria's transportation and other critical infrastructure. The MWCOG Transportation Planning Board is leading a resilience study to address major issues related to transportation resilience.

Heat Vulnerability Assessment

Methodology Overview

As a part of the ECCAP, the City of Alexandria has conducted a heat vulnerability assessment to provide a foundational understanding of increasing heat's impact on the Alexandria community, and to identify preliminary opportunities to address challenges related to extreme heat.

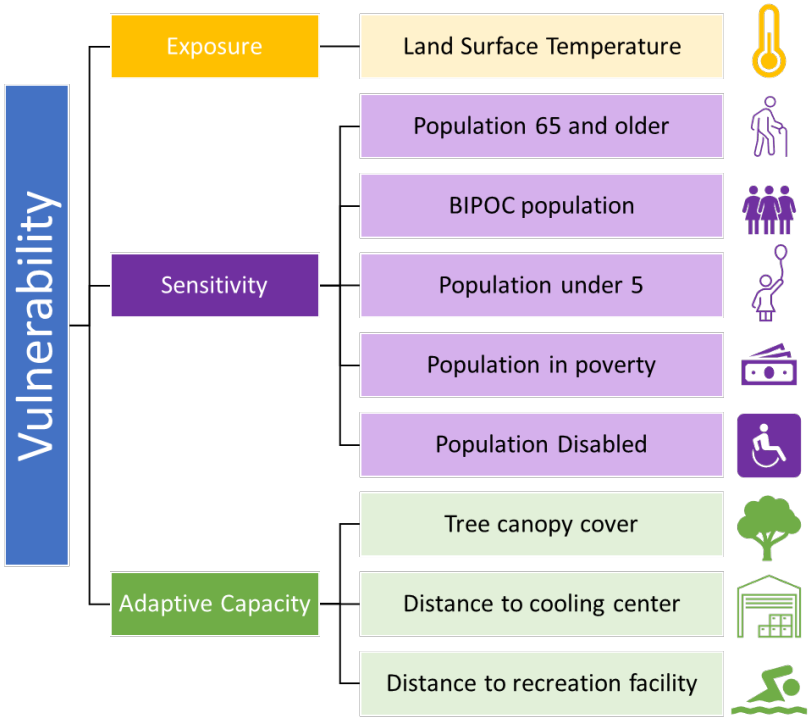
The heat vulnerability assessment uses data on sociodemographic and physical features (e.g., tree canopy cover) to determine areas of the City where populations are more vulnerable to extreme heat.[23] The assessment is based on indicators of the three components of vulnerability: **exposure** (i.e., locations expected to experience the most heat), **sensitivity** (i.e., populations most likely to experience adverse impacts from extreme heat), and **adaptive capacity** (i.e., the ability to cope with and recover from heat impacts) at a neighborhood scale for the City. A heat vulnerability index (HVI) score is calculated for each Census block group, based on the sum of scores for each of these three vulnerability components. The HVI ranks each neighborhood's susceptibility to extreme heat events in relation to the rest of the City.

[23] Nayak et al., "Development of a heat vulnerability index for New York State," 2017, https://doi.org/10.1016/j.puhe.2017.09.006.

The HVI can be used to identify neighborhoods and groups most vulnerable to heat, so that short-term and long-term planning and programs can be prioritized to combat heat related illnesses, death, and impacts among highly vulnerable populations.

Figure 19 summarizes the vulnerability indicators and data sources used in the Heat Vulnerability Assessment. Additional methodology details are found in Appendix F.

Figure 19. Variables included in the HVI



Results

Figure 20 shows results of the heat vulnerability assessment, including the cumulative HVI score, as well as the individual components that contribute to vulnerability: exposure, sensitivity, and adaptive capacity. The results showcase a strong relationship between all three components.

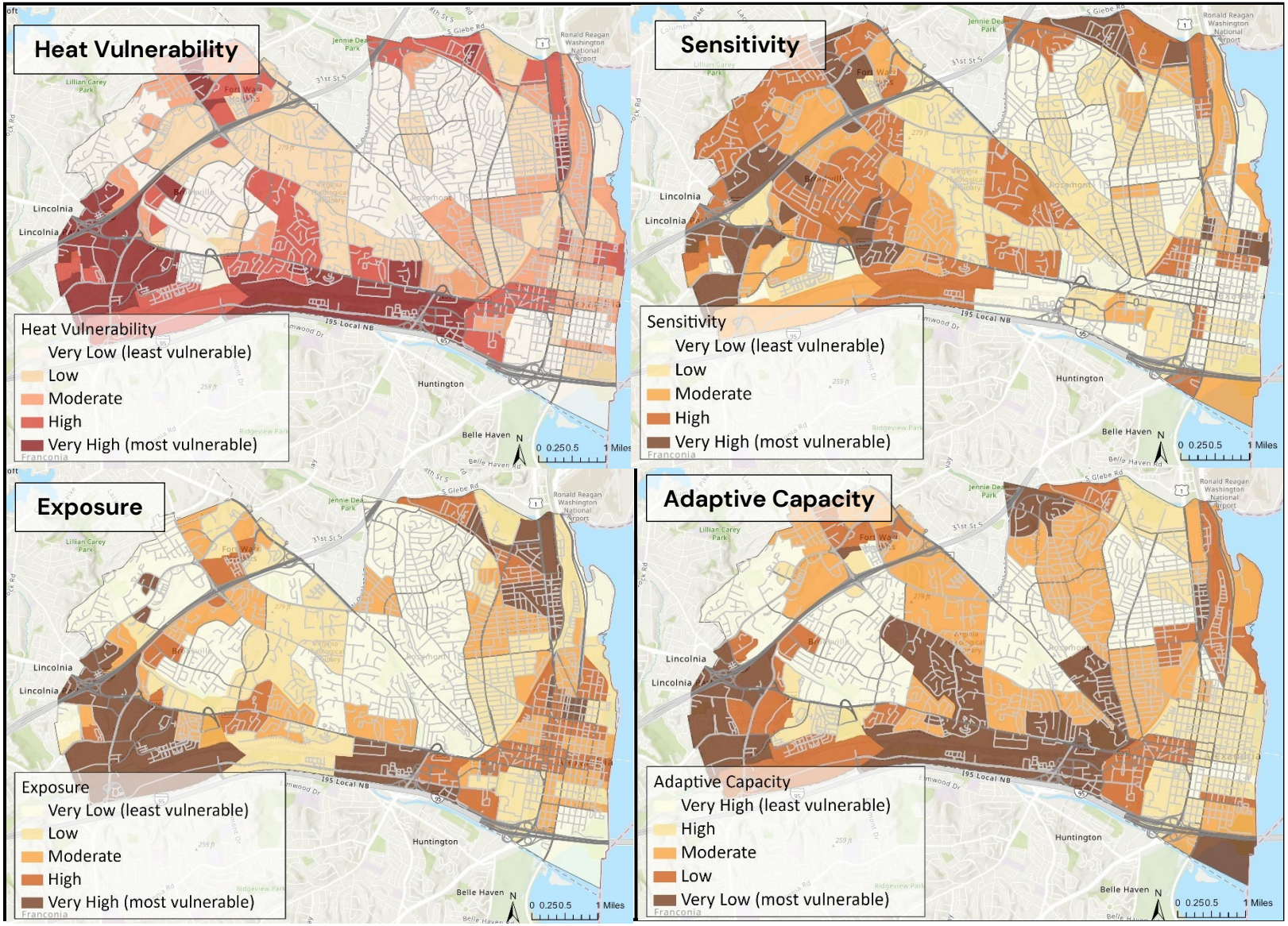


Figure 20. Results for the heat vulnerability assessment. Heat vulnerability (top left) is composed of separate scores for sensitivity (top right), exposure (bottom left), and adaptive capacity (bottom right).

The results of the Heat Vulnerability Assessment can also be viewed in an interactive map available on the City's website.

Overall, the neighborhoods of Landmark/Van Doren, Potomac Yard, Eisenhower Valley, and portions of the West End and Beauregard have the highest vulnerability, driven by high relative temperatures/urban heat island, high concentrations of sensitive populations, and less tree canopy cover. This indicates that these areas would benefit most from heat reduction and management strategies executed by the City.

Additional details on the drivers of heat vulnerability in Alexandria are provided below.

Exposure

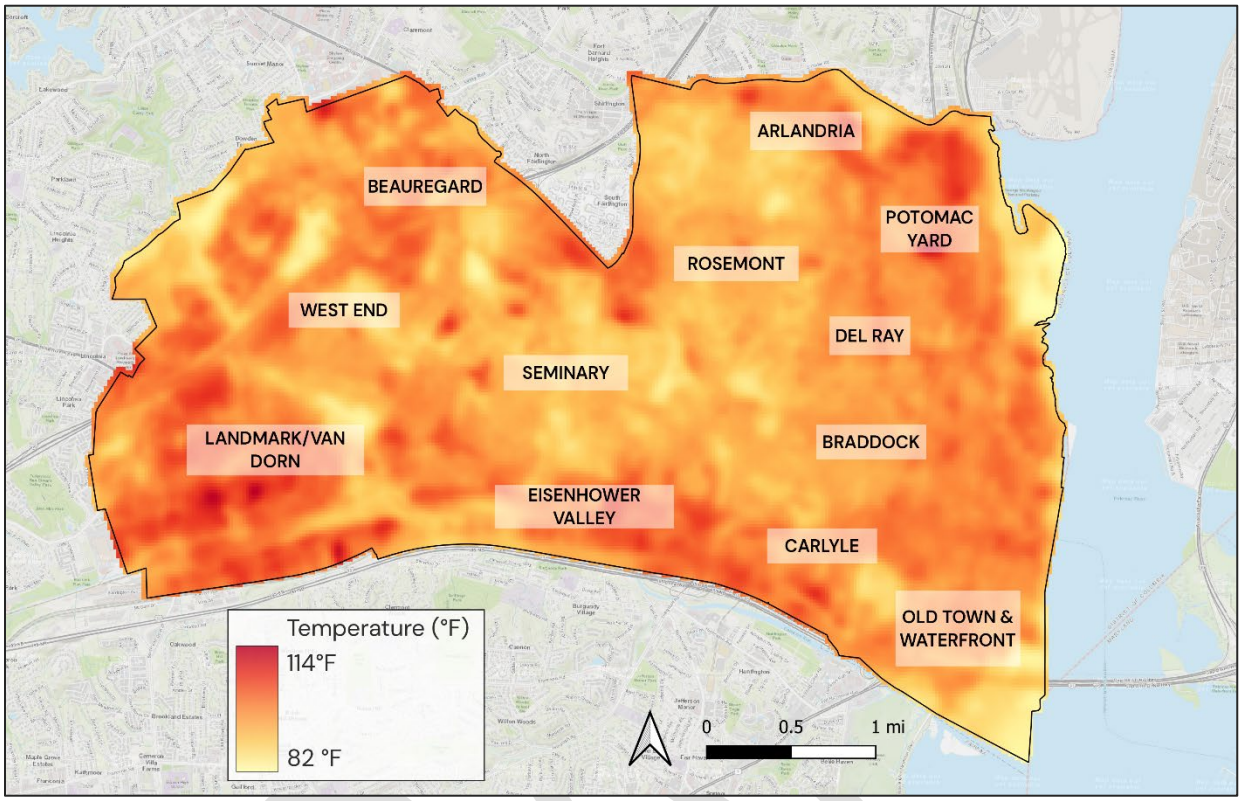
Exposure represents which areas of the City are most likely to experience extreme heat (Figure 20, top right), determined by land surface temperatures from two hot summer days in 2020 and 2021 (Figure 21). Block groups that are warmer than the City average have higher exposure scores.

Cooler areas of Alexandria largely overlap with parks since vegetation and trees provide passive cooling and shade (Figure 21).[24]

The hottest areas of the city are in the Landmark, Van Dorn, Carlyle, Arlandria, and Potomac Yard neighborhoods. These locations may be good candidates for urban heat island reduction strategies such as enhancing green space, tree planting, shading, or cool roofs. Old Town, Beauregard, and Del Ray are cooler because of existing parks and tree canopy coverage that help mitigate heat. Additional data analysis could offer additional insights for adaptation planning, as discussed further in this report.

[24] Wong, et al., "Greenery as a mitigation and adaptation strategy to urban heat," Nat Rev Earth Environ 2, 166–181 (2021), https://doi.org/10.1038/s43017-020-00129-5.

Figure 21. Relative Summer Land Surface Temperatures in Alexandria



Sensitivity

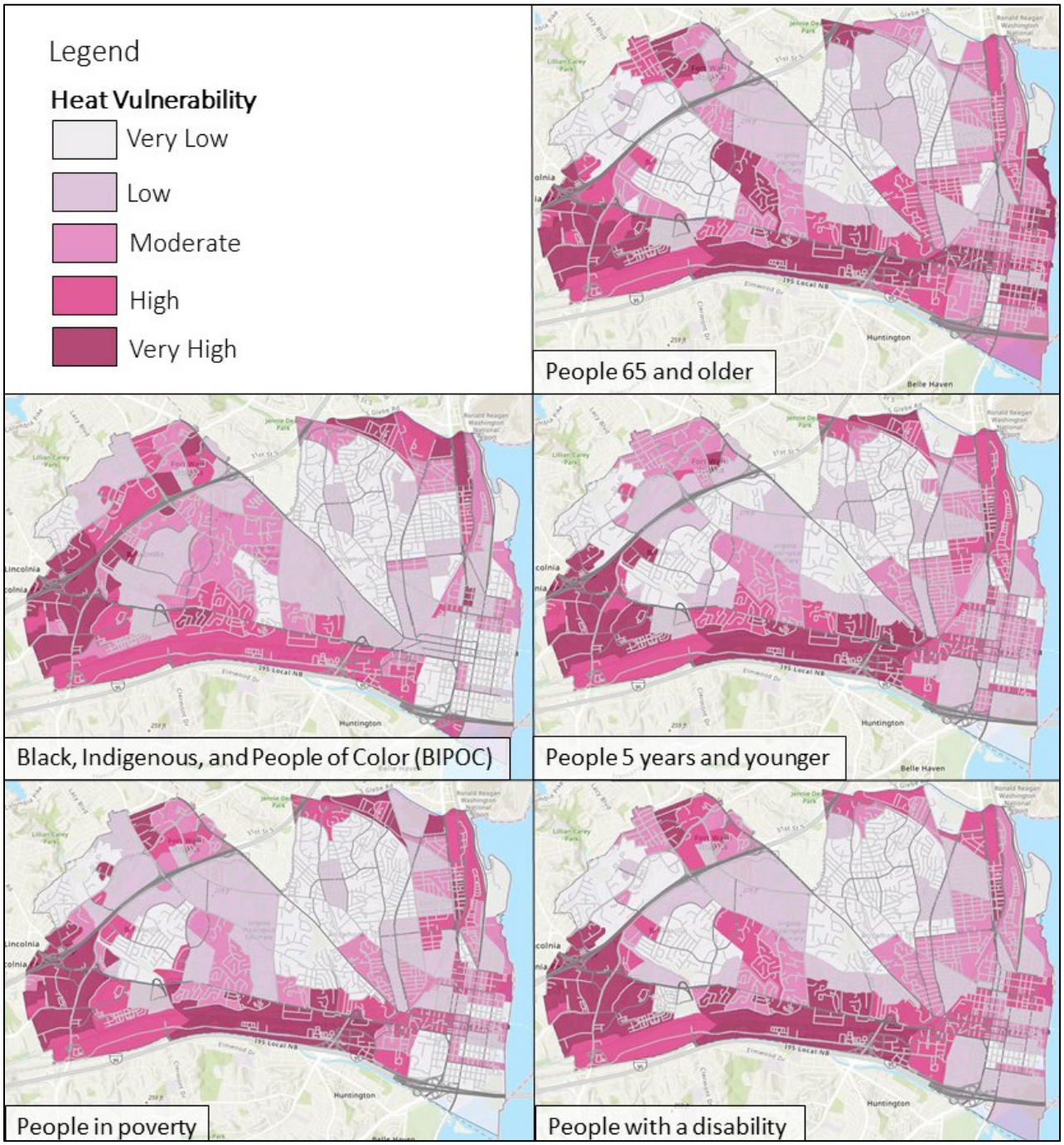
Sensitivity captures populations most likely to experience negative impacts such as health or financial burdens because of extreme heat. For example, lower income households may not be able to afford air conditioning units or associated utility expenses to enable options for reducing the impact of extreme heat. Disabled and older residents may have underlying health issues that increase their susceptibility to heat and have limited mobility to transport themselves to cooling centers. Black, Indigenous, and People of Color (BIPOC) have experienced higher mortality rates during heat events than white individuals.[25]

The City used Census data to determine the percentage of each block group with a disability; under the age of five; 65 and older; in poverty; and identifying as Black, Indigenous, or People of Color (BIPOC) to estimate sensitivity. In the future, other demographic or socioeconomic groups could be included. The variables were added and averaged to determine the overall sensitivity score (Figure 22, bottom left). Overall, sensitivity is highest in the western half of the city.

[25] EPA, "Climate Change and Social Vulnerability in the United States: A Focus on Six Impacts," 2021, https://www.epa.gov/system/files/documents/2021-09/climate-vulnerability_september-2021_508.pdf.

The methods the City will employ to combat urban heat will vary depending on the demographics of vulnerable populations and their immediate needs. For example, enhancing education and outreach efforts may be most effective in minority communities that have minimal access to the knowledge or resources that assist with extreme heat events, while increasing the number of emergency responders may be most effective for neighborhoods with large elderly and disabled populations that are likely to need emergency care. Figure 22 shows individual HVI for each of the five socio-demographic variables used in the sensitivity score. The variables were isolated and combined with exposure and adaptive capacity to help the City identify at-risk neighborhoods and to consider options to tailor potential solutions to specific vulnerable populations. For example, disabled residents, residents over 65, and residents under five are particularly vulnerable to heat in the southern and southwestern sections of the City. Increasing the amount of green space and parks in these areas could give young children an area to play while lowering air temperatures. Addressing the mobility needs of disabled populations to get to and from cooling centers would be an effective strategy for locations with a high concentration of disabled persons. Additionally, cooling centers and areas of congregation during climate hazards should be equipped with precautions to prevent the spread of air-borne and vector-borne diseases, so that accessibility for individuals with disabilities is preserved.

Figure 22. Heat Vulnerability Indices for Separate Vulnerable Population Groups



Adaptive Capacity

For the heat vulnerability assessment, adaptive capacity was defined as the ability to cope with and recover from heat impacts.[26] Existing features that facilitate cooling and other ways to alleviate heat were considered in the adaptive capacity score. These include the total tree canopy cover over each block and the proximity of each block group to recreation facilities (including parks and green space) and cooling centers. A cooling center

is a location with air conditioning designated to provide respite and safety from extreme heat. Recreation facilities included tennis and basketball courts, parks, playgrounds, swimming pools, picnic areas, and dog parks from the City's recreation facilities data. Adaptive capacity is lowest in areas with low tree canopy and parks, which are also areas of high heat. Neighborhoods with low adaptive capacity include Eisenhower Valley, Landmark, Van Dorn, parts of Beauregard, and parts of Arlandria (see Figure 20, bottom right).

Existing Adaptation and Resilience Activities

The City has already begun planning and implementing strategies to address the expected impacts of climate change.

Flooding

The City's Capital Improvement Program plan for fiscal years 2023–2032 includes over $256 million dollars funding to support the City's Flood Action initiative. This funding will support stormwater sewer system improvements identified, in part, by the 2016 City of Alexandria Storm Sewer Capacity Analysis (CASSCA). This funding will also support service requests through Alex311 during large storm events, and the related investigations, maintenance, and other key program areas to help mitigate the impacts of flooding.

Flood Hazard Mitigation Projects Underway

The City is actively implementing several flood hazard mitigation projects, as identified in the City ECCAP and the Flood Action Alexandria Master Schedule Project Tracker.[27] For example, the heavy cleaning and rehabilitation of the Hooff's Run Culvert completed in 2021 restored stormwater conveyance and reduced local flooding. Additionally, the Commonwealth Avenue, East Glebe Road, and Ashby Street flood mitigation projects will result in the implementation of storage, capacity, and green infrastructure solutions to provide flood mitigation within Four Mile Run Watershed.[28]

The City is also undertaking a program to develop the Flood Mitigation Implementation Project along the City's Waterfront. The project will mitigate tidal flooding experienced along the Potomac River at Queen Street, Duke Street, and Union Street. Tidal flooding has significantly disrupted movement of residents, business-owners, and visitors through the

[26] M. Guardaro, et. al., "Adaptive capacity to extreme urban heat: The dynamics of differing narratives," *Climate Risk Management*, Volume 35, 2022, 100415, ISSN 2212-0963, https://doi.org/10.1016/j.crm.2022.100415.

[27] City of Alexandria, VA, "Flood Action Alexandria, Project Implementation Schedule," Accessed April 8, 2022, https://www.alexandriava.gov/sites/default/files/2022-03/baseline%20schedule.pdf.

[28] City of Alexandria, VA, "Flood Action Alexandria, Flooding and Drainage Projects," Accessed April 8, 2022, https://www.alexandriava.gov/flood-action/flooding-and-drainage#CityFloodingandDrainageProjects.

area, and has also damaged homes, businesses, and infrastructure. The project will investigate and implement a combination of engineered solutions, including a bulkhead designed to keep Potomac River's waters from entering the City, a bypass storm sewer system to increase capacity and divert stormwater flows, and the potential for pump stations to alleviate stormwater overflows and localized flooding.[29]

[30]

Stormwater Utility Fee

In 2018, the City adopted a Stormwater Utility Fee to serve as an equitable, dedicated revenue stream for the stormwater management program, which includes new capital projects to reduce sediment and nutrient pollution to the Potomac River and, more recently, address flooding through improved stormwater conveyance capacity .[31]

Community Rating System

The City continues to maintain a Class 6 Community Rating System (CRS) for flood insurance.[32] The CRS Program rates communities on a 1 to 10 scale, with Class 1 receiving a 45 percent premium discount, and Class 10 receiving no discount. The CRS is a voluntary incentive program that encourages individuals situated within the floodplain to develop best practices that exceed the requirements of FEMA's National Flood Insurance Program (NFIP) based on their compliance with the requirements of the NFIP and the community's CRS credit points.[33]

Extreme Heat

Extreme heat is increasingly a cause of concern for individuals across the region living in dense, urban areas. The City has launched several programs that attempt to provide cooling measures and mitigation programs to combat mortality and injury related heat incidences.

[29] City of Alexandria, VA. 2018. *Alexandria Waterfront: Flood Mitigation Implementation: Master Storm Water Management Plan*. https://media.alexandriava.gov/docs-archives/special/waterfrontplan/info/20181116=awf-stantec-mswmp=-akrf-soc.pdf.

[30] City of Alexandria, VA, *Alexandria Waterfront: Flood Mitigation Implementation: Master Storm Water Management Plan*, 2018, https://media.alexandriava.gov/docs-archives/special/waterfrontplan/info/20181116=awf-stantec-mswmp=-akrf-soc.pdf.

[31] City of Alexandria, VA, "Stormwater Utility Fee," Accessed April 8, 2022, https://www.alexandriava.gov/stormwater-management/stormwater-utility-fee.

[32] City of Alexandria, VA, *Environmental Action Plan 2040*, 2018, https://media.alexandriava.gov/docs-archives/tes/eap2040v25.pdf.

[33] FEMA, *Community Rating System*, https://www.fema.gov/floodplain-management/community-rating-system.

Emergency Response and Energy Assistance

The City has focused its attention on emergency response efforts by providing cooling centers in recreation centers, libraries, and schools across the City.[34] Moreover, the City continues to engage with the ECCTF to understand the community perspective as it relates to heat emergencies and ever-increasing seasonal temperatures. The City has also launched and supported several financial aid programs related to cooling resources, such as the Senior Cool Care Program and the Virginia Energy Assistance Cooling Program, which has provided cooling apparatus as well as rebates to compensate residents for the increased energy burdens of residential cooling.[35]

Increasing Tree Canopy and Enhancing Open Space

Complementing these efforts, the City has proposed several key recommendations in the 2009 Urban Forestry Master Plan, which will serve to increase tree canopy through improved maintenance of existing trees and a thorough assessment of available land for new tree plantings. Recommendations include the planting of 400 additional trees per year adjacent to school grounds and public spaces, the development of master landscaping, planting, maintenance plans for all public properties, and providing and promoting incentives to plant trees and implement projects to preserve and enhance the tree canopy on institutional and semi-public sites, such as hospitals and faith-based establishments.[36]

In addition, the Alexandria City Council unanimously adopted the updated 2040 Environmental Action Plan (EAP), which includes short, medium, and long-term goals for open space and land use objectives relating to preserving existing and increasing new tree canopy by maintaining a ratio of 7.3 acres of publicly available accessible open space per 1,000 residents with approximately 40% total tree canopy cover across the City. The City has also committed to maintaining and enhancing stream valleys located throughout the City through the implementation of ecological and recreational improvements. Finally, the City, by 2028, would seek to create publicly accessible open space opportunities in unconventional spaces, such as public alleys, conservation easements, public rights-of-

[34] City of Alexandria, VA, "Summer Cooling Options for Alexandria Residents and Seniors," Accessed April 8, 2022, https://www.alexandriava.gov/dchs-connect/2021-10-01/summer-cooling-options-for-alexandria-residents-and-seniors.

[35] City of Alexandria, VA, "Seasonal and Emergency Warming and Cooling Options," Accessed April 8, 2022, https://www.alexandriava.gov/homeless-services/seasonal-and-emergency-warming-and-cooling-options.

[36] City of Alexandria, VA, *Urban Forestry Master Plan*, 2009, https://media.alexandriava.gov/docs-archives/planning/info/masterplan/mpa200900012.pdf.

way, parking lots, and through the careful assessment of new developments and vacant lots.[37]

Adaptation and Resilience Strategy Recommendations and Next Steps for Planning

Building on the City's existing activities as well as a greater understanding of climate risks, this ECCAP, and complementary efforts undertaken by the City, will serve to provide strategies in the expansion of existing efforts, and will provide new adaptation and resilience strategies to be executed by the City.

These actions are grouped into three categories:

4. Activities to integrate climate change risk and resilience considerations into existing municipal decisions and activities;
5. Specific activities to reduce, manage, and coordinate a response to impacts from increasing temperature and extreme heat;
6. Specific activities and next steps to continue to reduce, manage, and coordinate a response to impacts from flooding.

[37] City of Alexandria, VA, *Environmental Action Plan 2040*. https://media.alexandriava.gov/docs-archives/tes/eap2040v25.pdf.

Integrating Climate Change in Municipal Decisions and Activities

An important step to building climate resilience in Alexandria is to ensure climate change resilience and equity are considered as a matter of course in all municipal decisions and activities.

This report proposes five primary actions, shown in Figure 23, in which the City may integrate climate change into municipal decisions and activities. Each of these actions will be underpinned by active efforts to address climate equity and prioritize increased resilience among vulnerable populations.

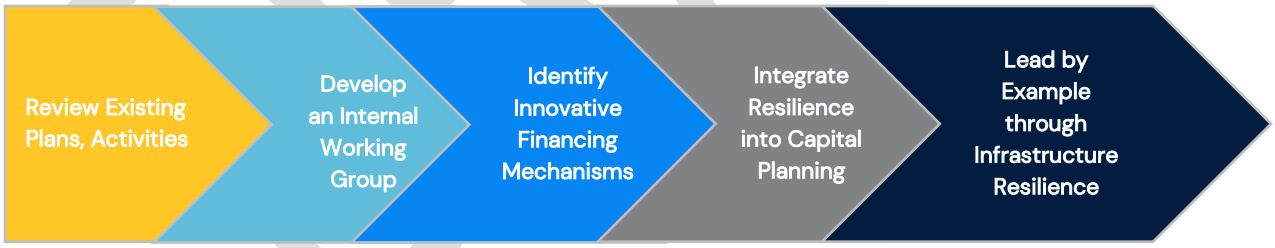
Enhancing Equity in Climate Resilience Planning & Actions

It is essential to consider social equity when planning and implementing resilience strategies because members of the community will experience climate change impacts unevenly. Municipal plans and operations can proactively address systemic inequities by considering both *communities at greatest risk* and *distribution of resources* related to climate resilience.

The City of Alexandria will incorporate equity into their climate resilience planning process using the following guiding principles:

- Focus on the Root Causes of Inequity
- Balance Power Dynamics Among the City, Stakeholders, and Residents

Figure 23. Primary Actions to Integrate Climate Change into Municipal Decisions and Activities



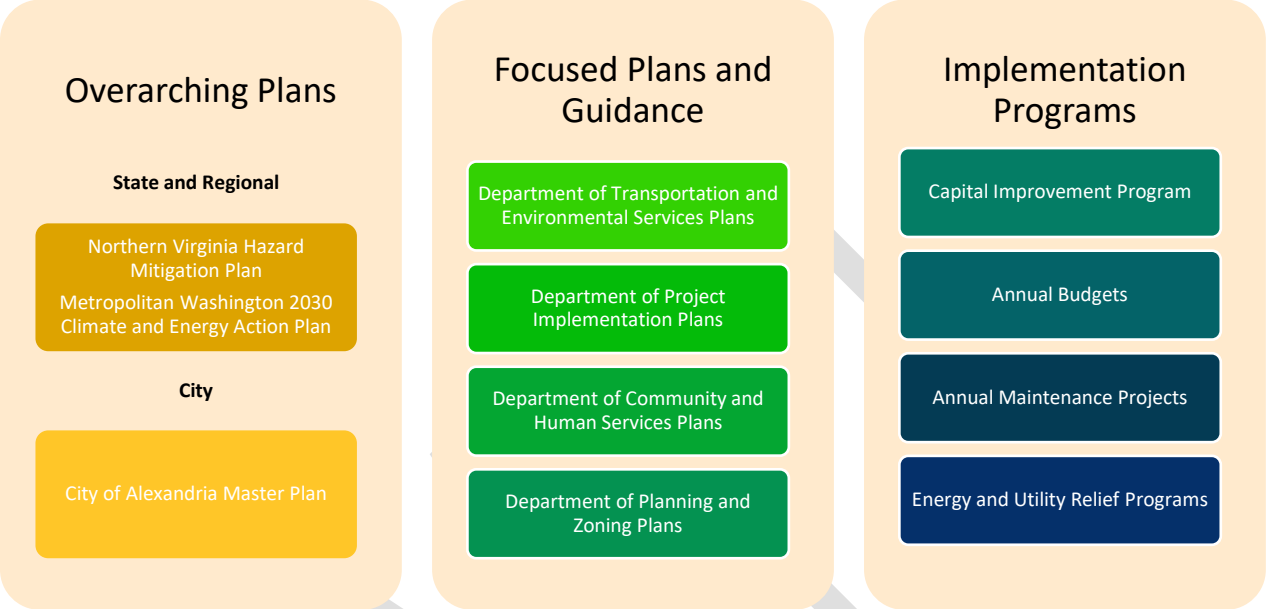
Review Existing City and State Plans, Programs, and Activities

The City will first review existing Alexandria and state-wide resilience plans, as well as department-specific plans and guidance and the City's ongoing implementation programs, to identify additional needs for targeted resilience analyses across City departments and functions.

Figure 24 shows examples of existing high level statewide planning documents and City plans. These plans can inform focused plans and guidance for Alexandria departments, and subsequent implementation programs that could increase resilience.

Plans, like the Northern Virginia Hazard Mitigation Plan, the MWCOG 2030 Climate and Energy Action Plan, and the City of Alexandria's master plan provide actions taken on a broader scale for the region and the City at-large. These types of plans help to inform the development of the ECCAP. Furthermore, this ECCAP outlines the elements of a Flood Resilience Plan (FRP).

Figure 24. Examples of the City's Plans and Programs that may Enhance Climate Resilience



Implementation programs will introduce a variety of adaptation and resilience strategies in combatting climate change. Four key areas have been identified in integrating climate change to City implementation programs:

- The City will review **Capital Improvement Programs** to assess whether climate resilience initiatives may be folded into these programs. Additional details regarding the integration of resilience into capital planning are described below in the "Integrating Resilience into Capital Planning" section of this report.
- City departments will review **annual budgets**, including those allocated to Alexandria City Public Schools (ACPS), to accommodate climate resilience needs, such as those related to awareness and educational programs to inform community members of priority climate hazard impacts and resources. For example, the ACPS could reinstate their sustainability ambassadors program, which could focus on increasing climate resilience and suitability within each school and across the school-system.
- **Annual maintenance projects**, like annual sidewalk and paving programs, may benefit from expanded budgets to include heat mitigating pavement treatments and additional tree planning provisions. This work currently is coordinated and managed by T&ES Public Works Service (PWS).
- **Energy and utility relief programs,** as well as social aid programs that indirectly alleviate the financial burden of internal heating, cooling, and weatherization costs on residents, may be expanded and improved to target a greater number of specifically

vulnerable residents. This expanded program could potentially be managed through the Alexandria Redevelopment and Housing Authority.

Develop a Multi-Department Working Group for Climate Resilience

Climate change will affect all sectors in the City and affect the work of nearly all City departments. An internal working group will identify specific activities each department will need to undertake to integrate resilience into their decision-making processes, and coordinate actions citywide.

The multi-department working group may focus their attention on **improving cross-departmental collaboration, long term capital planning efforts, external cooperation with city-wide stakeholder groups, and developing short term strategies** to address impacts of primary climate hazards like flooding and extreme heat. Through the development of this working group, City departments **will build capacity regarding climate change risks** so that they are better equipped during early project development to identify marginal add-on opportunities to reduce risks and enhance resilience.

Table 4 establishes a roadmap of priority actions for the City's internal working group.

Table 4. Priority Actions Roadmap of City Internal Working Group

Priority Action	How will the Internal Working Group achieve this priority action?
Cross-Collaboration across City Departments	• Meet quarterly to focus attention on relevant City departments and their climate resilience roles and responsibilities • Draw on the ECCAP and regional climate resilience plans to establish quarterly and annual objectives for city departments to report on
Review of Capital Improvement Plans to Determine Gaps	• Review capital improvement plans and identify areas in which climate resilience could be incorporated • Provide recommendations for City Council to address these gaps, and provide early notice of adaptations or changes to long-range capital improvement plans
Establish a Framework for External Collaboration	• Incorporate external stakeholders at quarterly meetings from city-wide non-profits, organizations, public programs, or other relevant stakeholders • Circulate a report on updated City initiatives regarding climate hazards to relevant stakeholders and community members for public comment

Develop Short-Term Adaptation Strategies	• Implement short-term adaptation projects to deal with extreme heat, such as expansion of cooling centers and shade structures • Develop adaptation projects and relief programs for prioritized environmental justice communities as identified in this report's heat vulnerability assessment

Once the working group has been established, the City can then begin to identify innovative financing mechanisms to execute the climate adaptation strategies.

Identify Innovative Financing Mechanisms

Upfront capital investments to effectively combat climate change can be costly, due to the intensive planning, designing, engineering, and construction necessary. There are positive benefits associated with investing in climate resilience efforts. The National Institute of Building Sciences found that natural hazard mitigation saves $6 on average for every $1 spent.[38] Approaching the City's governing bodies with creative and innovative financing mechanisms can ensure that projects directly and indirectly addressing climate resilience are implemented.

The City will work to **identify key decision makers** in order to further its climate adaptation and resilience initiatives. City departments, internal stakeholders, and the community can most effectively advance climate action when they are directly engaged with key decision makers responsible for approving projects and programs.

The City will also **seek opportunities to engage with external stakeholders** who could help identify options for private investment and sponsorship of climate resilience and adaptation projects suggested in this plan. The City has developed several public-private partnerships and has benefited from these relationships within energy and waste management, arts and culture, expansion of transit opportunities, and publicly guided private development. Public-private partnerships are contractual arrangements between public and private sectors that allow for a combination of the financial and knowledge-based strengths of the private sector with public sector interests. These partnerships may enable new feasibility of high-impact and high-cost infrastructure and community development projects.

Articulating the costs and savings of climate resilience and adaptation projects will increase transparency to the community and key-decision makers that financial contributions to such projects are being utilized effectively. The City will **conduct ROI analyses** that consider future climate projections and evaluate the upfront costs of implementation with the climate resilience benefits among all project alternatives. An ROI analysis would effectively

[38] Federal Insurance Mitigation Administration, *Natural Hazard Mitigation Saves Interim Report*, 2018, https://www.fema.gov/sites/default/files/2020-07/fema_mitsaves-factsheet_2018.pdf.

weigh the up-front costs in constructing assets and infrastructure which are resilient to climate change over their useful lives with the long-term benefits of reductions in extensive repeat maintenance and repairs after extreme weather events.

The analysis can also be extended to showcase the potential reductions in property damage and loss of life as a benefit of climate-resilient assets or infrastructure. The City would develop a list of climate resilience projects to **articulate the cost savings of climate adaptation and resilience infrastructure and programs** to City Council on an annual basis.

Integrate Resilience into Capital Planning

For Alexandria to adequately prepare for the long-term impacts of climate change across a range of sectors, the City will need to ensure its infrastructure investments today and in the coming decades are made in consideration of climate change—both in identifying and prioritizing project needs, and in evaluating and designing projects.

The City invests in municipal infrastructure through its Capital Improvement Program (CIP). The City will **consider climate resilience in planning for capital investments** throughout the CIP development process**.** Entry points for climate resilience at each stage within the CIP process are described below.

Identifying project needs: The CIP is informed by the needs within Alexandria, such as the need for additional cooling centers; the development of additional open and green space; or the rehabilitation of stormwater infrastructure. Climate changes should be considered in identification and prioritization of project needs, such as in the following ways:

- ***Identify whether projected climate changes and impacts may create a need for new capital investments*** – For example, new cooling centers may need to be established to meet increasing needs for relief in parts of the City not previously experiencing intense urban heat island effects, or new flood mitigation projects may be necessary in parts of Alexandria that have not historically flooded in the past but will under future climate conditions.
- ***Identify whether climate change may increase the future costs of assets***– If an existing asset has needed more maintenance over the past few years following extreme weather impacts, there may be a cost-effective solution to accelerate the upgrade of such assets within the CIP pipeline, in order to allay future costs of recurring damage to the asset.
- ***Consider impacts of the project on climate resilience as part of the project prioritization process*** – The City will continue to have a range of capital needs, some of which will and will not relate to climate change impacts. The City will review its project prioritization process and evaluate whether it may be valuable to place additional priority on any projects that would enhance climate resilience (regardless of whether they were initially designed for that purpose).

- *Consider impacts to and needs of vulnerable populations in project identification and prioritization* – Prioritizing projects based on areas of vulnerability will increase the influence on overall equity in project selection and implementation. For example, the creation of cooling centers and new heat mitigation infrastructure may need to be constructed first in areas of highest vulnerability and high extreme heat, as identified in the Heat Vulnerability Assessment, rather than areas where extreme heat is highest overall.
- *Identify opportunities for projects in coordination with regional partners* – The City may identify areas where climate hazards should be addressed in which external stakeholders hold influence or assets. For example, climate impacts often cross jurisdictional boundaries and capital investments in resilience measures may be more cost-efficient if jointly implemented. An example is a large-scale flood mitigation projects that protects public and private property across two or more municipalities.

Evaluating and designing capital projects: All capital investments should be reviewed to ensure they are maximizing opportunities to reduce climate risks, regardless of the project. The City will develop a high-level screening guidance or tool to help project managers identify whether the capital project could face climate risks and whether the project could feasibly incorporate increased climate resilience in its design or implementation. These screening tools may be particularly helpful for projects that have a long expected useful life—for example, new buildings or other long-lived infrastructure.

The City will also work to **develop climate resilience design guidelines and general standards** related to best practices and opportunities to integrate adaptation strategies for existing or new capital projects. Such resources could be referred to if the screening process flags a project for climate risk. The City will coordinate with and monitor neighboring jurisdictions such as via the NVRC working group to keep abreast of related regional efforts.

Lead by Example in Infrastructure Resilience

The City will **lead by example through the integration of climate resilience** into all facets of annual maintenance and infrastructure rehabilitation. The City will accomplish their "lead by example" initiative through the following principles in infrastructure resilience projects (Table 5).

Table 5. Example Areas for the City to Lead by Example in Infrastructure Resilience Investments

Example Activities	How will the City Lead by Example within Infrastructure Resilience Projects?
Annual Roadway Maintenance	• When resurfacing roads, the City could consider using **materials that are less likely to buckle or soften** due to extreme heat or choose **materials that are more reflective** to reduce the urban heat island effect.

	○ **Example:** The City can improve this initiative by targeting road replacement in particularly hot areas of the City where vulnerable communities live.
Building Rehabilitation and Renovations	• When installing new roofs, **incorporate white or light sealant options** to reduce radiative heating of building and extreme heat impacts. ○ **Example:** The City can improve this initiative through the prioritization of new roofs on schools, libraries, and other critical public facilities with particularly vulnerable patrons such as young children and the elderly. • When implementing new public facilities, the City of Alexandria will not construct within 100-year or 500-year floodplains as feasible.
Rehabilitating Stormwater Infrastructure	• When installing or replacing stormwater infrastructure, the City may **consider the projected increase in storm intensity and include it in the design process**. ○ **Example:** The City can improve this initiative by prioritizing infrastructure rehabilitation in areas where floods impact critical facilities, commerce, emergency response, and healthcare facilities.
Budgeting for O&M of Public Facilities	• The City will **consider implications to budgets for O&M** of capital assets. ○ **Example:** The City can consider greater attention and larger O&M budget for capital assets that, should they fail or become damaged, could put vulnerable populations at the highest risk. For example, maintenance of storm drains could be emphasized in areas prone to flooding during severe storms.

The City will promote awareness around the impacts of climate change on public facilities and communicate the effects of activities in Table 5 which will serve as an example for private property owners and businesses. The spotlighting of infrastructure resilience improvements on public facilities and properties can be utilized as a tool to convince private stakeholders, property owners and property developers to increase resilience to climate hazards. This will translate to a city-wide effort to increase climate resilience on all public and private assets, facilities, and properties.

Flooding Adaptation Strategies

The City of Alexandria is already undertaking several flooding adaptation strategies. Climate impacts are projected to worsen, however, and flooding is already becoming a more frequent occurrence throughout the City. Residents, property owners, and city officials need to be prepared to respond to flooding and implement new adaptation strategies. The

City's recommendations are presented in the context of the development of a Flood Resilience Plan (FRP) as a framework to improve flood resilience across the City. The execution of the FRP will enable estimation and reduction of flood risk, development of initiatives for flood preparedness and response, and technical support for implementation of mitigation measures. The FRP will include the following elements:

1. Hazard identification and information dissemination
2. Flood mitigation
3. Flood preparedness and response
4. Land development policies and regulations
5. Financing strategy

Subsequent sections describe components of these elements of the FRP.

Hazard Identification and Information Dissemination

The City of Alexandria was founded in 1749 and has many historic neighborhoods all with unique characteristics and varying ages of infrastructure. The topography in Alexandria is such that the 'low lying' neighborhoods are closer to the Potomac River in the older areas of the City. The City is almost 50 percent impervious which means that stormwater does not soak into the ground but runs off into the City's stormwater system into local waterways. Approximately 500-acres in Old Town are served by a combined sewer system that travels to AlexRenew to be treated. During storm events, the combined sewer system overflows into local waterways. Severe storm events cause sanitary sewer backups as water enters the system through 'infiltration and inflow' or I&I. Developing a deep understanding of the City's sewer infrastructure system and the impacts of severe storms on the system can enable staff to identify areas that would benefit from increased conveyance or storage. Current design standards focus on creating and maintaining infrastructure for a 10-year 24-hour storm, but storms are becoming more severe and causing significant flooding. It is imperative to help think through scenarios that will help create a more flood resilient Alexandria.

Update Stormwater Models

Finalized in 2016, CASSCA analyzed the City's current storm sewer system and provided the following major outcomes: (1) the identification of problem flooding areas and (2) the development and prioritization of solutions for these areas. The study showed that approximately 22 percent of the system may experience flooding and 16 percent may have a water level within 2 feet below the surface -- referred to as insufficient freeboard -- at some point during the storm. Also 16 percent of the system may be surcharged such that the water completely fills the storm sewer causing system backups. Overall, 90 problem areas were identified across the City with an estimated cost of $61 million (in 2016 dollars). The estimated cost focused solely on construction cost and was used for planning purposes only. Actual implementation costs were not included in the scope of CASSCA and include costs associated with feasibility study, design, utility coordination, property

acquisition, permitting, construction management and inspection. The City will **update CASSCA with the latest data, including updated climate change models**.

Identify Vulnerable Neighborhoods and Populations

During and directly after severe flooding events, residents use the Alex311 request system to inform the City of flooding in their neighborhoods. This data, combined with the CASSCA update and information gained from other inputs such as emergency services, cameras, and rain and stream gauges help inform the **development of flood vulnerability maps**. Combined with social and equity indicators, these maps will help the City prioritize areas for infrastructure improvements and outreach on flood mitigation efforts.

Engage the Public in Flood Resilience

To help the public understand the impacts from severe storms and changes in the Potomac River due to climate change, the City will **develop an online interactive platform** to help engage and inform the public about flood hazards across the City. This platform will rely on the updated CASSCA study; new flood vulnerability maps; and will help better inform the public, and particularly vulnerable communities, about flood hazards. The City will **develop a flood resilience engagement program** to help disseminate this critical information across the City.

Flood Mitigation

Flood mitigation efforts are underway in the City through the implementation of several large capacity projects, which improve the conveyance of the storm sewer system, as well as "spot improvement" projects that help reduce flooding at the neighborhood scale. These smaller projects may include for example, increasing the size of inlets to convey flood waters into the sewer system more quickly.

Formulation of Solutions

To continue mitigating the effects of flooding, the City will formulate strategies and projects that reduce the occurrence and severity of flooding throughout the City. In addition to the large capacity projects and spot improvements mentioned above, other projects may include deployment of flood barriers; acquisition and elevation of buildings; and flood proofing infrastructure and buildings. Projects under consideration will be based on climate change projections, will be evaluated on their long-term cost/benefit ratios, and will be prioritized based on the findings from the updated CASSCA and the flood vulnerability maps.

The City's storm sewer drainage network follows watershed contours and, as such, should be managed in a way that considers the entire watershed. Projects proposed upstream may impact residents downstream; therefore, solutions must be formulated at a watershed-scale.

Assistance for Property Owners, Businesses, and Residents

In addition to developing and implementating flood mitigation projects, the City also will continue to **encourage property owners to mitigate flooding through various methods including financial incentives and technical assistance**.

Flood Preparedness and Response

Monitoring and regular data collection of all flooding impacts and sea level rise over time will help inform the City's current development and future planning of infrastructure improvements.

Monitor and Prepare for Sea Level Rise

The City will **monitor readings from the Washington, D.C. National Oceanic and Atmospheric Administration (NOAA) tide gauge, in order to understand better how sea level rise may exacerbate tidally influenced riverine flooding**.[39] As the city monitors sea level rise over time and considers future projections in sea level rise by mid-century, the City will incorporate additional design and engineering parameters to negate flooding and inundation to city-wide utilities.

Enhance Local Flood Warnings

Warnings at a hyper-local scale will benefit the entire City. Therefore, the City will **expand its flood warning procedures** from radio and television stations to incorporate the use of Alex311, reverse 911 calls, and social media to announce flash and riverine flooding events through multi-lingual and multi-media platforms to City residents. Providing the public with information and timely warnings about storm events and forecasted flooding will improve preparedness and the protect the safety of residents. The City may also choose to continue to implement remote sensors on roadways and within culverts to provide specific roadway flooding warnings to drivers and nearby property owners. The City will also begin to connect its remote sensor network and rain gauges to regional networks.

Enhance the City's Internal Flood Response Mechanisms

The City will **integrate flood vulnerability maps into the City's flood readiness and response plans** and **adjust and coordinate inter-departmental response plans** including notification procedures and continuity-of-operations to also include utility companies and service-providers whose services may be impacted by flooding.

Regional Stakeholder Coordination

The City will continue to **coordinate with stakeholders and adjacent agencies to build institutional capacity and share data**. The City will plan to meet on a quarterly basis with Fairfax County and Arlington County under the guidance of the Northern Virginia Regional Commission (NVRC). The City will also coordinate with the Metropolitan Washington

[39] NOAA, Tides and Currents, Accessed April 27, 2022, https://tidesandcurrents.noaa.gov/map/index.html.

Council on Governments (MWCOG), District of Columbia Flood Task Force and other non-Virginia entities such as Montgomery County and Prince George's County, Maryland. Coordination with these regional partners can identify and establish best practices from around the region and may aid in efforts to solicit and facilitate additional state and federal financing for flood adaptation strategies.

Land development policies and regulations

The City's current population is 165,000 and is expected to increase significantly over the next few decades as outlined in this Action Plan. Most of the City's development is considered re-development, and replacing older development with new development based on current stormwater quality and quantify standards will improve the City's resilience to flooding. However, looking into the future of development, the City will benefit from a thorough review and analysis on the current land development regulations. This analysis may include reviewing the building requirements and waiver process. The City will also review stormwater management rules that regulate development and consider updates to the size of disturbance, location of disturbance, and stormwater volumes to manage on site. Updates to these factors will consider climate change impacts.

Update Policies for Flood Resilience

The City will **review current policies and regulations** that are impacted by stormwater and rising tides including how land use is managed within the FEMA-regulated floodplain. Based on this review, the City will develop watershed-based standards to improve flood resilience.

Financing Strategy

The creation of the Flood Action Alexandria program coincided with a doubling of the local Stormwater Utility Fee and a shift in resources to develop the Stormwater Management 10-Year Plan to focus on flood mitigation capital projects and related programs. Grants have allowed the City to further accelerate capital projects to begin the design and construction to mitigate flooding impacts. The City has been awarded approximately $5.5 million to help accelerate capital projects to bring relief to the community even faster than previously planned.

Seek External Funding Sources

The City will continue to **seek adaptation funding** to help supplement City-funding for implementation such as grants and public-private partnerships.

Extreme Heat Adaptation Strategies

Extreme heat will have a wide range of impacts across the City and will primarily jeopardize the health of vulnerable residents. The City's strategies to address extreme heat have been organized into three categories: heat reduction, management, and coordination strategies.[40]

Heat Reduction

Heat reduction strategies will serve to reduce additive heat contributions by the built environment. The built environment contributes to the urban heat island effect and extreme heat in a variety of ways. Waste heat generated by buildings, an abundance of impervious surfaces, and a lack of vegetation all contribute to extreme heat throughout the City. Several areas of intervention exist to promote heat reduction.

Establish Cool Roof and Pavement Programs

Traditional and dark roof and paving materials trap heat from solar radiation and release it into back into the surrounding environment. Cool roofs may be achieved using high solar reflectance and high thermal emittance materials in place of traditional roof sealants. Cool roofs absorb less heat and have been shown to stay nearly 50-60°F cooler than conventional materials during peak heat conditions.[41]

The expansion of cool roof programs throughout Alexandria could therefore have major benefits in reducing the urban heat island effect and the impacts of extreme heat. The City of Alexandria will consider utilizing **regional and State collaborations to create new financing mechanisms, like grants, low-interest loans, etc.** for cool roof implementations on private properties.

> **Example Program: The New York City CoolRoofs Program** *offers financing of cool roofs and provides New Yorkers with paid training and work experience installing cool roofs on private properties.*

The City of Alexandria will work with the State of Virginia and adjacent municipalities to expand financing and will leverage the findings of MWCOG's 2030 Climate and Energy Action Plan and the Northern Virginia Hazard Mitigation Plan as evidence that such a program should exist.

The City will also **work to promote and implement lighter paving materials** to increase solar reflectance and thermal emittance of publicly owned roadways and parking lots throughout the City. As identified above, these efforts will culminate to a series of "Leading by Example" initiatives undertaken by the City to mitigate extreme heat and spread awareness of this

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[40] American Planning Association, *PAS Report 600, Planning for Urban Heat Resilience,* 2022, https://planning-org-uploaded-media.s3.amazonaws.com/publication/download_pdf/PAS-Report-600-r1.pdf.

[41] EPA, Reducing urban heat islands: Compendium of strategies, 2008, https://www.epa.gov/heat-islands/heat-island-compendium.

climate hazard. The City will rely on data before and after implementation of these new roofs, roadways, and parking lots to showcase reductions in extreme heat, and construct a narrative and model for private property owners to consider and implement themselves.

> **Example Program: The City of Cambridge, MA Piloted a Pavement Surface Treatment** *to reduce the urban heat island effect at a municipal parking lot in a dense, vulnerable neighborhood.*[42]

Expand Waste Heat Reduction Programs

Industrial and commercial properties contribute to extreme heat primarily through the creation of waste heat during their use of high volumes of energy. The City will **plan and implement programs in which industrial and commercial sites will reduce waste heat through heat recovery technology**, as well as improved HVAC controls and the use of on-site renewable energy and battery storage. The City will **develop a plan to engage with industrial and commercial property owners** to assess a combination of energy efficiency building retrofits in tandem with waste heat reduction improvements.

Expand and Incentivize Urban Greening

The City will continue to **expand its efforts to increase the number of trees throughout the City**, as identified in its Urban Forestry Master Plan. The City, through its identification of heat vulnerable areas with relatively low access to parks and open space, will work to implement new vegetated parks and open space. The City will also review ongoing development plans for parks and open spaces, and will **incorporate shade structures and water features**, to enable additional heat reduction around the City.

The City will work to **incentivize urban greening initiatives** by residents and developers through assistance through the continuation of its Green Building Policy, as well as the development of financial incentives to support residents in purchasing and planting trees in on their properties.

> ***Example: Montgomery County gives away free shade trees*** *to individuals who reside in particularly heat vulnerable areas throughout the County.*[43]

The City will seek out the potential for **establishing public-private partnerships to expand urban greening**. The City will complement these efforts with a rigorous O&M plan to ensure newly planted trees thrive and provide established shade canopies to combat heat.

> ***Example Program: Sacramento Tree Foundation and Sacramento Municipal Utility District Partnership.*** *Private contributions, like those provided by the Sacramento Tree Foundation to the Sacramento Municipal Utility District to plant over 350,000*

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[42] City of Cambridge, MA, The Works, *City Pilots Pavement Surface Treatment to Reduce Urban Heat Island Effect, 2021,* .

[43] Montgomery County, *Free Shade Trees,* .

shade trees, can assist in providing the incentives and materials needed to robustly expand tree canopy throughout the City.[44]

The expansion of urban greening can also occur through other methods, like the implementation of green stormwater infrastructure within city streets and parks. Green infrastructure utilizes soil and plants, permeable pavements, and natural systems to store, retain, and infiltrate stormwater. Such infrastructure is co-beneficial to reducing the volume of stormwater in underground utilities, and provides an environment for trees, vegetation, and habitat to flourish. The City will **assess all city streets, public ways, and parks for the installation of green infrastructure**, especially within districts that are highly vulnerable to both heat and flooding.

Heat Management

Heat management strategies will serve to equip residents with the financial and physical resources necessary to grapple with extreme heat events. Heat management strategies will work to address energy use during extreme heat events, understand personal exposure to heat, mitigate negative public health outcomes, and increase overall emergency preparedness of residents.

Expand Heat Relief Programs for Vulnerable Residents

One of the primary ways in which individuals protect themselves and their families from extreme heat is via internal cooling methods, such as air conditioning and electric fans. Vulnerable residents, however, are often individuals with smaller relative disposable income, and may not be able to keep up with the costs of operating such cooling appliances throughout the hot summer months. The City already provides energy assistance cooling programs to income-eligible households comprised of elderly, young, and disabled individuals. The City will work to **expand and tailor these energy assistance services** to vulnerable neighborhoods, and will utilize the Heat Vulnerability Assessment to guide this process. Additionally, the City will work to **provide energy efficient air conditioning (AC) units** to vulnerable residents in order to replace outdated cooling appliances or provide new means of cooling for residents.

Expand Cooling Centers for Residents

The City will utilize the findings of its Heat Vulnerability Assessment to **identify new cooling centers** and **extend existing cooling center hours**, while prioritizing the new implementation and expansion of hours of cooling centers situated in heat vulnerable neighborhoods. The City will engage with the community to raise awareness of these services, and will **conduct a resident survey** to understand the needs of vulnerable residents during extreme heat. The survey will include questions relating to the need for transportation to and from cooling

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[44] Sacramento Municipal Utility District (SMUD). *Shading Sacramento.* Accessed on April 27, 2022, .[46] City of Alexandria, *ResilientALX Charter*, 2020, *https://media.alexandriava.gov/docs-archives/tes/stormwater/resilientalxcharterfinal20210108.pdf*.

centers for residents with disabilities, as well as the location and services offered at cooling center locations.

Address Personal Exposure to Heat

Individuals will be impacted by heat outside of their homes and during times when they are unable to access cooling centers. The City will address personal exposures to heat across multiple sectors, including schools, occupational settings, and transportation systems. The City will **identify schools throughout the City that are deficient in adequate cooling mechanisms** for students and staff and work with the Alexandria Public School system to address financial or logistical gaps in providing these appliances. The City will **incorporate training programs for City staff working outdoors** and will provide educational materials to businesses and firms to inform them of National Institute for Occupational Safety and Health standards. The City will **identify public transportation hubs and facilities that require additional cooling mechanisms** such as on-board AC systems, shaded transit stops, and the addition of drinking fountains and misting stations along walking, biking, and transit routes.

Heat Coordination

Heat coordination strategies will enable the City and its departments to facilitate focused preparedness and response programs to support heat reduction and heat management strategies, while providing a focused set of roles and responsibilities for City staff and emergency response personnel.

Establish a Heat Preparedness Program

The City will **establish a heat preparedness program**. The goal of the heat preparedness program is to increase community participation in preparing for and spreading awareness of extreme heat throughout the City. The program will be staffed by relevant city department staff and neighborhood leaders.

> **Example Program: The City of Philadelphia's Beat the Heat Toolkit** was developed through the coordination of city departments and neighborhood groups to combat and increase community resilience to extreme heat.[45] The program included the elements shown in *Figure 25*.

Figure 25. Elements of the Philadelphia Beat the Heat Toolkit

[46] City of Alexandria, *ResilientALX Charter*, 2020, https://media.alexandriava.gov/docs-archives/tes/stormwater/resilientalxcharterfinal20210108.pdf.

The City will work with public and community stakeholders, including the Virginia Department of Health, ACPS, neighborhood groups, and other relevant boards and commissions to identify leaders of this Heat Team. A city survey will aid in understanding knowledge around extreme heat, and what proposed improvements can be made to address its impacts. Community events will spread awareness and increase participation within the Heat Team and will allow for the election of Heat Ambassadors who may represent specific neighborhoods around the City. Heat Ambassadors will function as a liaison of their neighborhood community's needs and concerns related to extreme heat. Effectively, this process will simultaneously spread awareness of heat impacts, and assist the community in preparing for extreme heat.

Develop an Extreme Heat Incident Response Plan

The adaptive capacity to deal with extreme heat events is reliant on the City's ability to streamline emergency response services to residents in need. The City will begin the **creation of an extreme heat incident response plan**, which will serve to define the roles and responsibilities of city departments and public service agencies in responding to extreme heat events. Roles and responsibilities, and the commitment of the City to conduct assessments of community preparedness and resilience, are mentioned within the ResilientALX Charter and may be stewarded by the Citizen Corps Council.[46] The goal of the Extreme Heat Incident Response Plan will be to foster a coordinated and tailored response to heat emergencies, while building the City's internal capacity and understanding of extreme heat impacts on residents. The Extreme Heat Incident Response Plan may incorporate the following elements.[47]

Defining Roles and Responsibilities: City departments, such as the Alexandria Fire Department, Police Department, and Emergency Services Department, DCSH, should understand their response to extreme heat and how they can best serve the needs of their residents.

Worker Safety: The City may review the impact of heat on workers in both indoor and outdoor settings, with special attention given to workers spending the majority of their time in outdoor settings. A review of resources available to the Department of Public Works staff, City construction workers, crossing guards, and any other relevant personnel should be undertaken by the City and adjusted to ensure adequate cooling and emergency response plans are in place.

[46] City of Alexandria, *ResilientALX Charter*, 2020, *https://media.alexandriava.gov/docs-archives/tes/stormwater/resilientalxcharterfinal20210108.pdf*.

[47] Arizona Department of Health Services, *Extreme Heat Incident Annex*, 2021, https://www.azdhs.gov/documents/preparedness/emergency-preparedness/response-plans/extreme-heat-incident-annex.pdf.

Identifying Response to Vulnerable Residents: The City should work with the Department of Community and Health Services and the Office of Emergency Management to create plans for regular check-ins with community members who are disabled, unhoused, or particularly vulnerable to extreme heat.

Coordinate Communications Strategies: The City has resources available to assist residents during times of extreme heat. The City will work to expand its communication strategies through the use of coordinated public broadcasts, multi-lingual and multi-platform alert systems, and through the establishment of resident led buddy programs for vulnerable residents.

Coordinate Regionally

The City will coordinate with regional partners, such as the District of Colombia's Ready D.C. program, to share experiences and strategies in reducing and managing heat impacts to Alexandria. The City of Alexandria will consider joining a regional working group to address the impacts of extreme heat in Northern Virginia communities. The City may request the support of the Northern Virginia Planning District Commission to serve as a steward of such meetings.

Implementation and Next Steps

Recommendations for Further Action and Funding

Achieving the ambitious goals laid out in this plan will require that the Alexandria community comes together across sectors to work collaboratively to achieve this vision for the City's future. However, there are tangible next steps for the City and stakeholders alike to take that will ensure that these plans translate into impactful actions. These span continual communications and engagement with the community and stakeholders, establishing protocols for demonstrating accountability and progress, tracking progress through established transparent metrics, and seeking and securing funding (e.g., from the Infrastructure and Investment Jobs Act (IIJA) and the Inflation Reduction Act (IRA)).

Community and stakeholder resources for continued action vary from Federal, State, regional, and local resources. These resources are listed below by sector.

Building Energy

- Weatherization Assistance Program (DOE)
- Database of State Incentives for Renewables and Efficiency
- Commercial Property Assessed Clean Energy (C-PACE) Program
- 2019 Green Building Policy
- Virginia Clean Energy Act 2020, Emissions Reductions Strategies and Actions

Transportation

- Federal EV Tax Credits

- DOE Alternative Fuels Data Center
- GO Alex

Renewable and Clean Electricity

- VA Database of State Incentives for Renewables and Efficiency
- Alexandria Community Renewable Energy Resources
- Northern Virginia Solar Map
- Solarize Virginia

Waste

- Purple Can Club (glass recycling)
- Alexandria Food Waste Composting Stations
- Alexandria Recycling
- Alexandria Green Stormwater Infrastructure (utility fee credit)

In addition, Federal funding exists to support the City in implementation of actions within this ECCAP through the IIJA and IRA (see text boxes below).

IIJA

In November 2021, Congress passed the IIJA—also known as the Bipartisan Infrastructure Act—which includes $550 billion in federal funding to grow a more sustainable economy. The act aims to create new jobs and invest in sustainable infrastructure ranging from bridges and roads to broadband internet. Notably, IIJA focuses on investments designed to create a more climate-friendly energy and transportation sector. This includes—but is not limited to—the expansion of EV infrastructure, deployment of clean energy, and creation of a new Grid Development Authority for sustainable electrification of the power grid. As of December 2021, Virginia is projected to receive over $8 billion in infrastructure funding over five years as a result of IIJA (Transportation Today).

This funding will go towards various grants for new and existing energy programing to achieve the following:

- Reduce the energy burden in low-income and marginalized communities;
- Expand access to energy efficiency solutions for families, communities, and businesses (like electrification and low-carbon technologies for building retrofitting);
- Increase the generation of reliable, clean, and affordable power; and
- Deploy EV charging infrastructure.

IRA

The IRA of 2022 is the largest federal clean energy and climate investment to date. While the IRA will not singlehandedly accomplish current U.S. climate commitments, the bill is projected to cut GHG emissions by between 37-41% below 2005 levels by 2030. The act includes $369 billion for climate and energy investment and tax breaks (The National Law Review, "What's In the Inflation Reduction Act?" August 24, 2022, https://www.natlawreview.com/article/what-s-inflation-reduction-act). These are mostly comprised of expanded tax credits and funding programs to promote the following goals that align with the ECCAP priorities:

- Deployment and generation of clean energy and fuels;
- Electrification and resiliency improvements to existing electrical grids;
- Low-carbon technologies and materials for homes and buildings; and
- EV adoption.

The City can take advantage of the community benefits reaped by promoting these tax credits to Alexandria citizens while also considering the following direct funding opportunities provided in the IRA, such as:

- Block grants from the Department of Housing and Urban Development for projects addressing affordable housing and climate change issues;
- Grants from the Department of Energy for local government to implement greener energy codes (2021 International Energy Conservation Code for residential, ANSI/ASHRAE/IES Standard 90.1—2019 for commercial);
- Clean Heavy-Duty Vehicle program covering incremental costs of zero-emissions school buses, garbage trucks, and transit buses;
- Low Emission Electricity program funding and providing technical support to reduce GHG emissions, particularly in low-income and disadvantaged communities;
- Greenhouse Gas Reduction Fund financing zero-emissions technology deployment (including community solar) with 60% of funds to go towards low-income and disadvantaged communities; and
- Improving Energy Efficiency or Water Efficiency or Climate Resilience of Affordable Housing grant program which helps cover the cost of efficiency upgrades (including electrification).

Office of Climate Action, Ongoing Community Engagement and Communications

[Overview of Office of Climate Action, Ongoing Community Engagement, and Communications]

Next Steps, Evaluating Progress, and Continual Planning

In addition to the action plans and commitments made in this report, the City will strive to ensure that such actions have positive impacts on the Alexandria community and the environment at large. Tracking these impacts through the course of planned action is critical to ensuring the efficacy of these efforts. Clear qualitative and quantitative metrics for impacts in areas like environmental health, economic growth, and equity considerations, among others, will be tracked throughout the lifetime of a project or action. The City will partner with community stakeholders and subject matter experts to provide collect and analyze impact data to produce accurate and substantive impact reports.

Follow up action plans, policy changes, and future impact reports will play a key role in fulfilling the City's climate goals in the long term, beyond the scope of this report alone. These future accountability measure taken by the City will demonstrate their commitment to continuously shaping a greener, thriving Alexandria.

The City made the commitment in its 2040EAP to continuously update goals, programming actions, and plans every five years to meet the evolving needs of the community. This schedule will keep the City on track to achieve their ambitious sustainability goals while being responsive to changes in technology advances, fiscal constraints, and impactful global occurrences.

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Appendix B: Acronyms

AIM	American Innovation & Manufacturing
ATV	Alexandria Transit Vision plan
AMP	Alexandria Mobility Plan
BAU	Business-as-usual
BIPOC	Black, Indigenous, and People of Color
BRT	Bus Rapid Transit
CAV	Connected/automated vehicles
CBECS	Commercial Building Energy Survey
CIP	Capital Improvement Program
CRS	Community Rating System
CZM	Coastal Zone Management
DASH	Driving Alexandria Safely Home
DSP	Development Site Plan
DSUP	Development Special Use Permit
EAP	Environmental Action Plan
ECCAP	Energy and Climate Change Action Plan
ECCTF	Energy and Climate Change Task Force
EPC	Environmental Policy Commission
EUI	Energy use intensity
EV	Electric vehicle
EVRS	Electric Vehicle Charging Readiness Strategy
FEMA	Federal Emergency Management Agency
FTA	Federal Transit Authority
HVI	Heat vulnerability index
I&I	Infiltration and inflow
ICE	Internal combustion engine
IPCC	Intergovernmental Panel on Climate Change
IWG	Internal Working Group
LEAP	Local Energy Alliance Program
LED	Light-emitting diode

LiDAR	Light Detection and Ranging
LMI	Low and moderate income
MWCOG	Metropolitan Washington Council of Governments
NFIP	National Flood Insurance Program
NIOSH	National Institute for Occupational Safety and Health
NOAA	National Oceanic and Atmospheric Administration
NVRC	Northern Virginia Regional Commission
O&M	Operations and Maintenance
PCA	Principal component analysis
PPA	Power purchase agreements
PWS	Public Works Service
REC	Renewable Energy Certificate
RECS	Residential Energy Consumptions Survey
RNG	Renewable natural gas
ROI	Return on investment
SAVE	Steps to Advance Virginia's Energy
TMP	Transportation Management Plan
TOA	Top of atmosphere
TOD	Transit-oriented development
TPB	Transportation Planning Board
TSMO	Transportation systems management and operations
TSP	Transit vehicle signal priority
USDN	Urban Sustainability Directors Network
VCEA	Virginia Clean Economy Act
VMT	Vehicle miles traveled
WAP	Weatherization Assistance Program
WMATA	Washington Metropolitan Area Transit Authority

Appendix C: Glossary

Adaptation—The process of adjusting to new or changing climate conditions to reduce or avoid negative impacts to valued assets and take advantage of emerging opportunities

Adaptive management—An iterative risk management approach. As conditions change, adaptive management suggests using adaptation actions that address current risks and preparing for variable future changes. This approach provides flexibility to assess continuously changing risks and undertake appropriate actions to mitigate those risks.

Business-as-usual Scenario (BAU)—A climate modeling tool used to project potential climate impacts based on current GHG emissions, energy consumption rates, population growth, and other factors contributing to climate change.

Climate equity—The result of efforts to alleviate negative climate change impacts that disproportionately fall on vulnerable and marginalized populations.

Decarbonization—Efforts to reduce or eliminate carbon emissions resulting from a particular activity.

Electrification—Converting energy infrastructure to run on electricity rather than burned fossil fuels for the purpose of increased energy efficiency and accessibility to low- or zero-emissions energy sources

Environmental justice (EJ)—The fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income, with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies.[48]

Energy consumption—End-use consumption of energy fuels and electricity in Alexandria's residential, commercial, industrial, and transportation sectors.

Energy burden—The percentage of gross household income spent on energy costs. The national average energy burden for low-income households is 8.6% and can be as high as 30%.[49]

Energy efficiency—The use of less energy to perform the same function or action.

Energy generation—Grid-connected electricity generating units located in Alexandria or other generation sources located in Alexandria facilities.

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[48] EPA, "Environmental Justice," August 5, 2022, https://www.epa.gov/environmentaljustice.

[49] Office of Energy Efficiency and Renewable Energy, "Low Income Community Energy Solutions," Accessed August 31, 2022, https://www.energy.gov/eere/slsc/low-income-community-energy-solutions#:~:text=Energy%20burden%20is%20defined%20as,which%20is%20estimated%20at%203%25.

Green bank—A financial institution (generally public or quasi-public) using financing techniques and market development tools to accelerate deployment of clean energy

Green buildings—Building structures (residential, commercial, or otherwise) that use energy sources, building materials, and other low-carbon technologies to reduce GHG emissions and other negative environmental impacts, e.g., human or environmental exposure to toxic substances, across a building's lifespan.

Greenhouse gases (GHG)—Gases that trap heat in the atmosphere, contributing to global warming and climate change. Common GHGs include carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and fluorinated gases.

GHG reductions—Reducing the emissions of heat-trapping greenhouse gases into the atmosphere

Impacts—Refers to the effects of a climate hazard, e.g., potential impacts of warmer temperatures include health risks on hot days.

Resilience—The capacity of a community, business, or natural environment to prevent, withstand, respond to, and recover from disturbances, while retaining the basic functions of the system.

Risk— The chance of a climate hazard with cause harm. Risk is a function of the likelihood of an adverse climate impact occurring and the severity of its consequences (e.g., Risk = Likelihood x Consequence).

Transportation cost burden—The percentage of gross household income spent on transportation costs.

Vulnerable populations— Populations more likely to experience adverse impacts from exposure to climate hazards because of demographic factors (e.g., race, gender, sexual orientation), socio-economic status, and life-or livelihood-sustaining needs (e.g., dependence on electricity for critical medical care).[50]

[50] EPA,"EJ 2020 Glossary," 2020, https://www.epa.gov/environmentaljustice/ej-2020-glossary.

Appendix D: Community Engagement

The ECCAP's development has included a focus on engaging with the Alexandria community and stakeholders in five primary ways: convening of the Energy and Climate Change Task Force (ECCTF), Community Engagement Workshops, Directed outreach, Commission engagement, and Public Comment.

Energy and Climate Change Task Force (ECCTF)

The members of the Energy and Climate Change Task Force (ECCTF) serve as representatives of the Alexandria community. The Task Force is comprised of 13 members appointed by the City Manager, and includes general community representation; environmental advocates; energy, climate, and related technical experts; representatives from Alexandria's youth and representing equity issues; and those representing engagement with Alexandria's businesses and institutional partners. The Environmental Policy Commission (EPC) has designated their own representative.

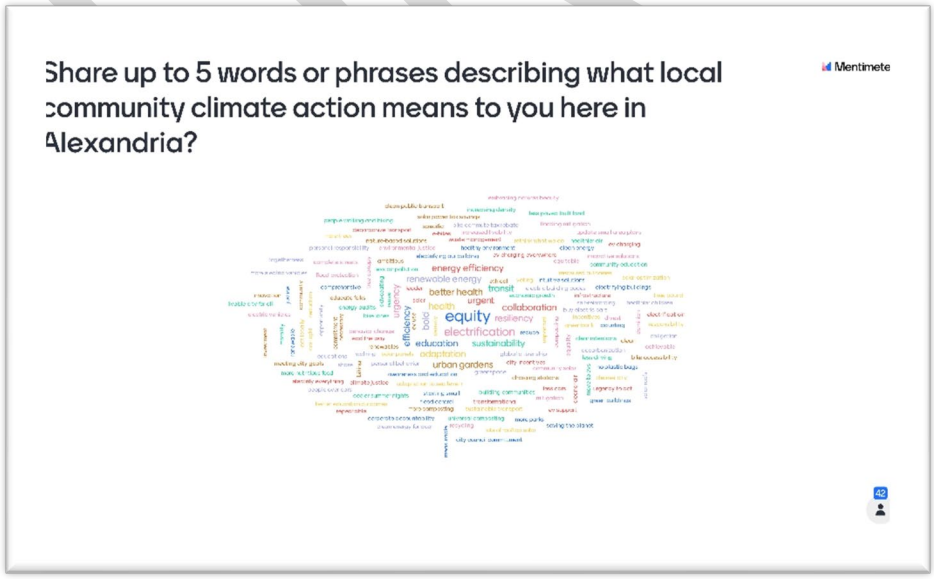
- Javier Bastos, Alexandria's business community and institutional organization interests
- Leah Devendorf, Alexandria youth interests with specific priority of Alexandria high school students
- Mary Harris, Co-Chair, Clean energy and climate policy or technology
- Fiona Herbold, Alexandria youth interests with specific priority of Alexandria high school students
- Praveen Kathpal, At-large member of the Alexandria community
- Alyssa Morin, At-large member of the Alexandria community
- Raquel Nicora, Diversity, racial and social equity, and inclusivity issues of diverse Alexandria populations, including those of Alexandria's aging population
- Marian Pegram, Co-Chair, Diversity, racial and social equity, and inclusivity issues of diverse Alexandria populations, including those of Alexandria's aging population
- Josh Sawislak, Alexandria's business community or institutional organization interests
- Marta Schantz, EPC Member
- Rose Stephens-Booker, Member reflecting climate change solutions to support the City's economic development goals
- Stephen Walz, Member reflecting environmental, clean energy, or climate change action advocacy organization or interest
- Sangina Wright, At-large member of the Alexandria community

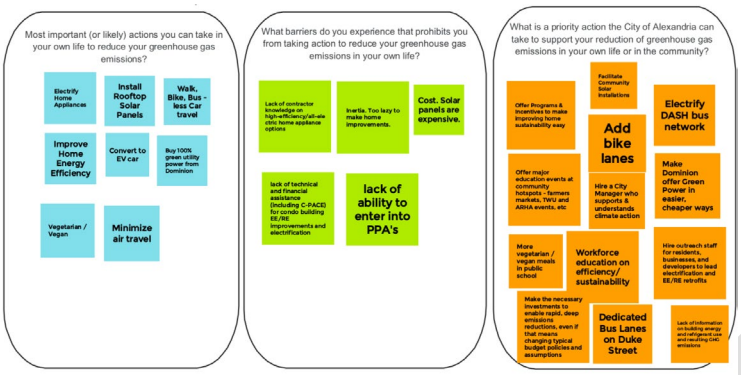
The Task Force will apply a lens of diversity, racial and social equity, and inclusion following the ALL Alexandria vision, goals, and actions in making recommendations about energy and climate change action planning, and will leverage climate change action solutions to support Alexandria's COVID-19 pandemic economic recovery efforts and economic development goals.

Meeting 1 – May 4, 2021 – Introduction
Meeting 2 – July 27, 2021 – Mitigation
Meeting 3 – October 5, 2021 – Mitigation
Meeting 4 – December 7, 2021 – Vulnerability and Adaptation
Meeting 5 – February 2, 2022 – Adaptation
Meeting 6 – July 17, 2022 – Action Overview
Meeting 7 – October 12, 2022 – Preliminary review
Meeting 8 – November 14, 2022 – Final review and recommendation

Community Engagement Workshops

Community Engagement Workshop 1 – November 16. 2021 - Climate Mitigation
The Alexandria community learned about energy and climate change issues affecting Alexandrians, specifically focused on climate change mitigation (i.e., greenhouse gas inventory, emissions, mitigation actions, and equity considerations). Participants shared ideas and perspectives on how Alexandria can help mitigate climate-change causing greenhouse gas emissions from commercial and residential buildings and transportation systems. Jason Samenow of the Washington Post's Capital Weather Gang provided reflections on how changing climate is impacting our local Metropolitan D.C. communities and the importance of collective community climate action to mitigate greenhouse gas emissions. In addition, Andrea Denny of the U.S. Environmental Protection Agency's State and Local Climate and Energy Program Energy and Climate, and Josh Radoff of ICLEI Local Governments for Sustainability shared share important actions local communities can take for collective climate action. The workshop included facilitated roundtable discussions focused on reducing energy use and greenhouse gas emission in buildings and transportation share benefits of community equity, health outcomes, and economic prosperity. Due to the COVID 19 pandemic, the community workshop was held via Zoom.



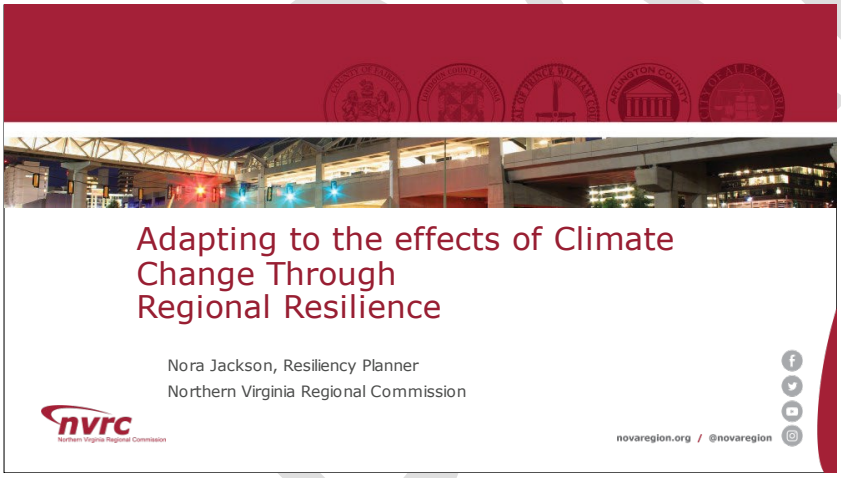

Most important (or likely) actions you can take in your own life to reduce your greenhouse gas emissions?
Electrify Home Appliances
Install Rooftop Solar Panels
Walk, Bike, Bus - less Car travel
Improve Home Energy Efficiency
Convert to EV car
Buy 100% green utility power from Dominion
Vegetarian / Vegan
Minimize air travel
What barriers do you experience that prohibits you from taking action to reduce your greenhouse gas emissions in your own life?
Lack of contractor knowledge on high-efficiency/all-electric home appliance options
Inertia. Too lazy to make home improvements.
Cost. Solar panels are expensive.
lack of technical and financial assistance (including C-PACE) for condo building EE/RE improvements and electrification
lack of ability to enter into PPA's
What is a priority action the City of Alexandria can take to support your reduction of greenhouse gas emissions in your own life or in the community?
Facilitate Community Solar Installations
Offer Programs & incentives to make improving home sustainability easy
Add bike lanes
Electrify DASH bus network
Offer major education events at community hotspots - farmers markets, TWU and ARHA events, etc
Hire a City Manager who supports & understands climate action
Make Dominion offer Green Power in easier, cheaper ways
More vegetarian / vegan meals in public school
Workforce education on efficiency/ sustainability
Hire outreach staff for residents, businesses, and developers to lead electrification and EE/RE retrofits
Make the necessary investments to enable rapid, deep emissions reductions, even if that means changing typical budget policies and assumptions
Dedicated Bus Lanes on Duke Street
Lack of information on building energy and refrigerant use and resulting GHG emissions

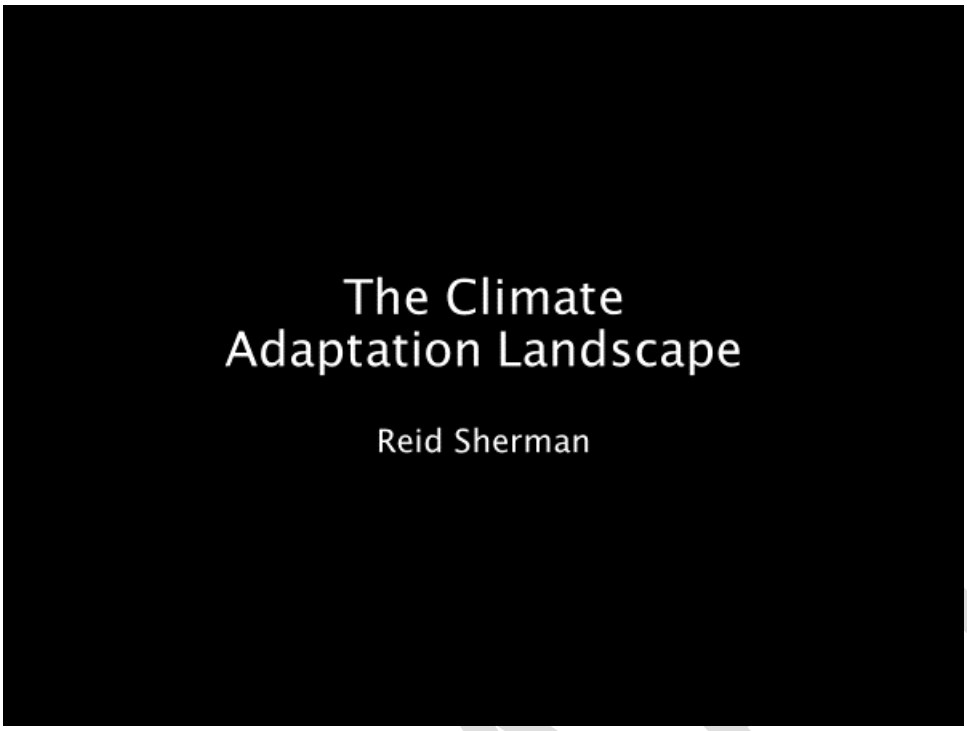

Washington D.C. weather and climate:
Trends and projections
Salwan Georges
Jason Samenow
November 16, 2021
The Washington Post

Community Engagement Workshop 2 – March 1, 2022 – Climate Vulnerability and Adaptation

The Alexandria community learned about energy and climate change issues related to climate change vulnerabilities and adaptation. Specifically, the presentation topics included impacts of increased temperatures, increased precipitation, and sea level rise. During the Community Workshop, participants shared ideas and perspectives on how Alexandria can help better adapt to the impacts of climate change.

Dr. Reid Sherman, climate adaptation consultant for federal agencies and former Environmental Policy Commissioner (EPC), provided an overview of what constitutes climate adaptation and why it is important with a focus on governance, policy, and implementation. Ms. Nora Jackson, a resilience planner with the NVRC discussed adaptation at the regional level by highlighting mitigation and planning efforts that address extreme heat and severe storms. Dr. Dan Medina, PE, with the City of Alexandria's Department of Project Implementation will highlight Flood Action Alexandria initiative, which focuses on becoming a more flood resilient City. The workshop included opportunities for participation via facilitated roundtable discussions focused on climate change vulnerability and adaptation to help create a more resilient Alexandria. Due to the COVID-19 pandemic, the workshop was held via Zoom.

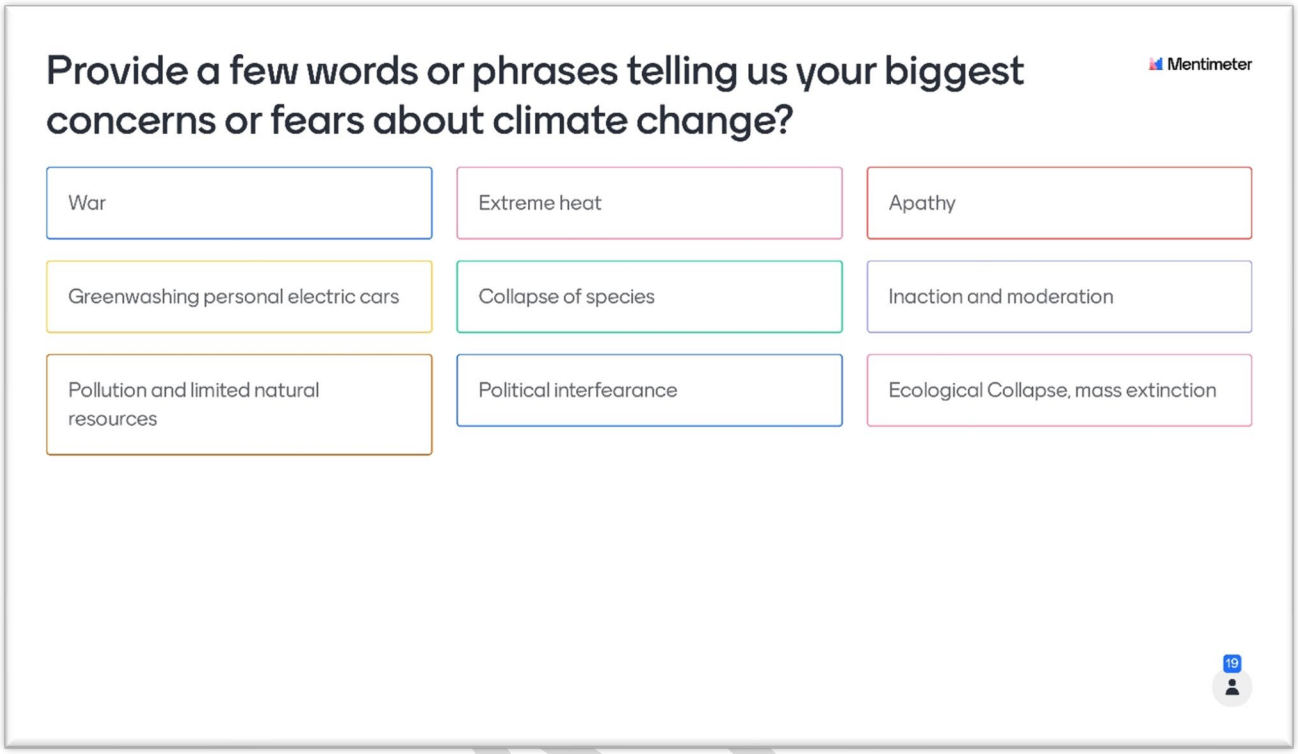


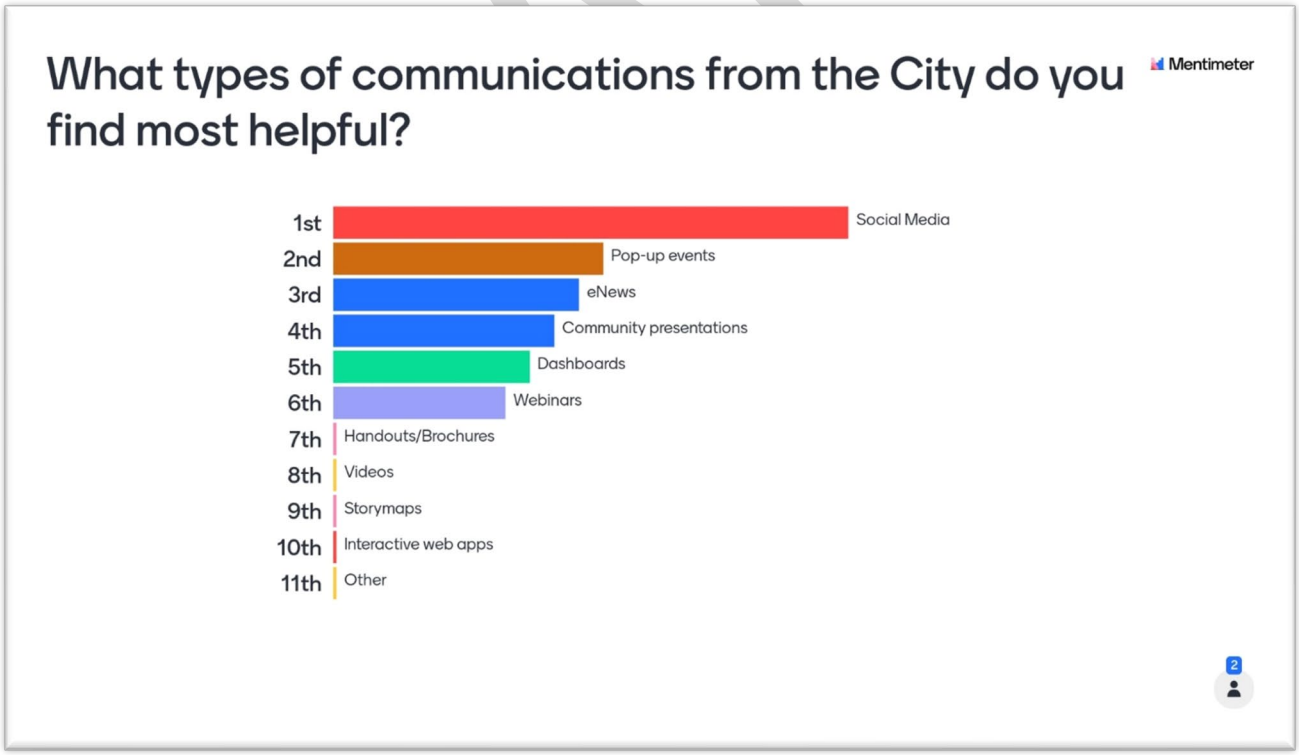

The Climate
Adaptation Landscape
Reid Sherman


A Holistic Approach to Flood Mitigation
Daniel Medina, PhD, PE
Stormwater Program Manager
FLOODACTION
Energy and Climate Change Action Plan, Workshop #2
March 1, 2022

Community Engagement Workshop 3 – August 27, 2022

[Summary]


Provide a few words or phrases telling us your biggest concerns or fears about climate change?
Mentimeter
War
Extreme heat
Apathy
Greenwashing personal electric cars
Collapse of species
Inaction and moderation
Pollution and limited natural resources
Political interfearance
Ecological Collapse, mass extinction
19


What types of communications from the City do you find most helpful?
Mentimeter
1st Social Media
2nd Pop-up events
3rd eNews
4th Community presentations
5th Dashboards
6th Webinars
7th Handouts/Brochures
8th Videos
9th Storymaps
10th Interactive web apps
11th Other
2

Direct Outreach
[Summary of Direct Outreach to UNITE Here!, Casa Chiralagua, Tenants and Workers Union]

City Commissions
[Summary of City Commission Meetings - Environmental Policy Commission, Planning Commission, Transportation Commission]

Public Comment
[Summary of Public Comment Period]

Appendix E: GHG Emissions Technical Methods and Approach

BAU Modeling

The Alexandria BAU model estimates future annual emissions assuming that no new policies or actions are taken to mitigate emissions. It incorporates factors such as projected population growth, economic growth, and electricity grid emission factors. Even anticipated state level policies such as the VA Clean Economy Act are not factored into the BAU model. The outcome of this model is intended to be a reasonable worst-case scenario for emissions from Alexandria through 2050. The outputs of the BAU scenario focus on sectors that are likely to be targeted by mitigation efforts in order to gauge the efficacy of potential mitigation measures. The sectors modeled in the Alexandria BAU scenario include:

- Building Energy Use – Energy consumption from electricity, natural gas, fuel oil, and propane from existing and new construction in residential and commercial subsectors.
- Transportation – On and off-road vehicle, rail, and aviation travel emissions.
- Waste – Emissions from landfills or waste to energy plants for solid waste emissions, emissions from wastewater treatment for wastewater emissions.
- Agriculture – emissions from agricultural activities
- HFCs – HFCs usage in sectors such as refrigeration and air conditioning.
- Fugitive Emissions – Emissions from leaked gases, mainly natural gas.

Building Energy Use

Building energy use includes building emission projections based on energy consumption from electricity, natural gas, fuel oil, and propane in existing buildings and new construction in residential and commercial buildings. The base year for energy consumption in existing building is 2020 and was taken from a preliminary 2020 Alexandria GHG inventory as provided by MWCOG for the City.

Forward looking projections through 2050 (excluding 2019-2021) for existing buildings determine energy use as the sum of the prior year's energy consumption from existing buildings and the energy use added from the new construction. The additional energy consumption from new construction is based on energy use intensity (EUI) represented by the energy consumption per household/commercial square foot multiplied by the number of new households or commercial square feet each year. This EUI is derived from the preliminary *2020 Alexandria GHG Inventory* provided by MWCOG in terms of number of households or commercial square feet and the energy use for the residential and commercial subsectors respectively. This derived EUI was then multiplied by the projected

number of new households or commercial square feet. This household/commercial square foot growth was derived from the City's projections for commercial building growth based on 1,000 square feet per household and 250 square feet per job. New growth of households was assumed to be housed in 95% multifamily households.

For 2021 specifically, energy consumption was calculated by applying a weighted average of energy consumption in newly constructed households/commercial square feet. These new constructions employ a stricter energy code and electricity consumption than in existing buildings. Additionally, an 80 to 90% compliance rate is applied to newly constructed houses to account for discrepancies in code compliance. Similar methodology was used to calculate energy use in 2022. Past 2022, building EUI for new construction were then held constant to 2020 levels in the BAU scenario.

For fuel oil and propane uses, which are significantly lower than electricity and natural gas, a constant value was used and held, resulting in constant emissions from these two fuels throughout the time series of the BAU scenario.

The 2019 Green building policy is being represented within the mitigation strategies and is therefore not accounted for in the BAU scenario.

Transportation

On Road Vehicles

Transportation emissions consist of the emission from on-road vehicles, off-road vehicles, rail, and aviation travel emissions. On-road emissions projections are estimated using vehicle miles traveled (VMT) and emissions projections developed by MWCOG as part of the Transportation Planning Board's Long-Range Transportation Plan. GHG and VMT estimates are provided for 2018, 2030, and 2045. These are used to calculate an implied emission factor for these years. VMT, emission factors, and then total emissions for intervening years are interpolated, and 2046-2050 are extrapolated using a linear trend. Due to the estimates' built-in assumptions regarding increases in vehicle efficiency and increase in electrification that reduces tailpipe emissions, the vehicle emissions factor decreases from 2020 to 2050. Specifically, the CO_2 emission factor decreased by 27% from 2018 to 2045 and 8% from 2030 to 2045, while N_2O and CH_4 follow a similar pattern. This decrease in emission factors also causes overall emissions to decrease, thus why BAU emissions are decreasing over time.

Off-road emissions are projected through 2050 by growing the emissions in the base year of 2018 in line with the growth rate of the population of Alexandria from population forecasts. The base year emissions in 2018 were estimated from MWCOG's Long-Range Transportation Plan.

Rail emissions were held constant through 2050 and were based on 2018 emissions estimated in the 2018 MWCOG Inventory, which calculates emissions based on diesel

consumption data from transit authorities provided by the Federal Transit Authority. Similarly, to off-road emissions, aviation travel was projected and grown through 2050 based on population forecasts with a base year of 2018 from data found in the MWCOG's Inventory. These emissions assume no major changes to rail or aviation infrastructure and does not project and changes in transportation habits of Alexandria.

Waste

Solid Waste

Solid waste emissions projection assume that all was in Alexandria is treated at the Covanta waste-to-energy (WTE) plant and that no waste is treated by landfill. This is based on the results of the 2018 Alexandria Inventory ICLEI Local GHG Contribution Analysis Tool. The BAU scenario assumes that this treatment method will not change, and that the Covanta WTE will resume activities through 2050 with no changes to the percentage of solid waste from Alexandria being sent to the facility. The emissions generated from that facility are estimated based on ICLEI – U.S. Community Protocol for Accounting and Reporting of GHG Emissions with the most recent calculation values (which were last updated in 2013). The amount of solid waste generated from Alexandria through 2050 was projected using population forecasts using 2018 as the base year for waste combustion emissions, which was taken from the 2018 Alexandria Inventory ICLEI Local GHG Contribution Analysis Tool.

Wastewater

Wastewater emissions projections assumes that the population is entirely serviced by sewer systems and that there is no significant population that is served by septic systems, as is reported in the 2018 Alexandria Inventory ICLEI Local GHG Contribution Analysis Tool. The emission from wastewater treatment is grown using the same growth rate as population for Alexandria, using 2018 as the base year for wastewater emission in sewer and sewer N2O effluent in alignment with the 2018 Alexandria Inventory ICLEI Local GHG Contribution Analysis Tool. Emission factors from the treatment of wastewater and wastewater effluent N2O emissions are derived from the emissions per capita from the data in the 2018 Alexandria Inventory ICLEI Local GHG Contribution Analysis Tool.

Agriculture

Agriculture emissions projections are based on the 2018 Alexandria Inventory ICLEI Local GHG Contribution Analysis Tool. Emission projections are extrapolated to 2050 based on the inferred annual growth rate of -5.4% between 2005 and 2018 from emissions from agricultural activities, mainly soil fluxes from urban fertilizer applications.

HFCs

HFC emissions are projected through 2050 using population forecasts of Alexandria using 2018 as the base year for HFC emissions. HFC emissions in 2018 are derived as a proportion

of total HFC usage found in EPA's greenhouse gas emissions inventory and Alexandria's population in relation to the total U.S. population.

Fugitive Emissions

Fugitive emissions are based on applying a natural gas leakage rate to the natural gas consumption of residential and commercial buildings from the *2018 Alexandria Inventory ICLEI Local GHG Contribution Analysis Tool,* which is derived from the *Metropolitan Washington Energy Utility Data Survey Analysis*. The natural gas leakage rate is derived using reported 2018 natural gas fugitive emissions from the *2018 Alexandria Inventory ICLEI Local GHG Contribution Analysis Tool* Alexandria's inventory divided by natural gas consumption.

Mitigation Modeling

The Alexandria Mitigation model lays out decarbonization strategies to decrease greenhouse gas emissions in each sector. The strategies modeled in the mitigation model includes:

- Clean Energy – VA Clean Economy Act
- Transportation Mitigation Package
- New Buildings – Energy Efficiency and Electrification
- Existing Buildings – Energy Efficiency and Electrification
- Aviation – Clean Fuels
- Renewable Natural Gas
- Off-Road Emissions Mitigation
- HFC Phasedown – American Innovation & Manufacturing (AIM) Act
- Controlling Fugitive Natural Gas Emissions
- Solid Waste Emissions Mitigation
- Future Technology and Acceleration Mitigation

Clean Energy

Electricity Grid

To reduce overall emissions from electricity generation, modeling showed the City of Alexandria is adopting a cleaner electricity grid through the implementation of Virginia's Clean Economy Act (VCEA). The VCEA outlines a path for Virginia's power supply to get to zero carbon emissions by 2050. Thus, all mitigation strategies will assume that the VCEA emission factor will be utilized. The emissions factor used in inclusive of imports to Virginia from other states which do not presently have a mandate toward zero carbon electricity, as such the emissions factor used is slight above zero for 2045-2050 in the modeling.

Renewable Natural Gas

To reduce emissions from natural gas use, modeling showed the City of Alexandria employing the use of renewable natural gas (RNG). The methodology involves using the results of the 2020 study on the use of biofuels in the Greater Washington D.C. metropolitan region[51] (Study on the Use of Biofuels (Renewable Natural Gas) in Greater Washington, D.C. Metropolitan Area- Washington Gas Company, 2020) which provides the estimate conservative low, achievable, and aggressive high levels of adoption of RNG within the D.C. region by 2040. These estimates were scaled to the City's level by determining Alexandria's gas consumption level as a percentage of the D.C. region, which estimates the City's RNG adoption rate in 2040. The City's RNG adoption rate will grow linearly until the estimated amount in 2040 and held constant through 2050.

Transportation

The City of Alexandria is mitigating transportation emissions through three major pathways: 1) vehicle technology and fuels (VT), 2) mode shift and travel behaviors (MS), and 3) TSMO.

The vehicle technology and fuels pathway involve transitioning traditional ICE light, medium, and heavy-duty vehicle sales into EV sales by 2050. In addition, promoting the adoption of electric city buses, achieving a 50% adoption rate by 2030 and 100% by 2050. The increased use of biodiesel and renewable diesel fuels is also adopted.

The mode shift and travel behaviors pathway focus on providing alternatives to vehicle travel and thereby reducing overall greenhouse gas emissions. This pathway includes enhancing bike, pedestrian, and micromobility environments to encourage walking and biking, reducing transit fares to encourage the use of public transportation, and promoting telework options to reduce the need to commute into work.

The TSMO pathway are targeted at improving overall transportation efficiency, decreasing overall vehicle idling time and increasing traffic flow. This includes ramp metering, improved incident management, active signal control, and active transportation demand management. Ecodriving emission improvements are also included.

The modeling process used here was also employed by the TPB Climate Change Mitigation Study of 2021.[52] Alexandria-specific baseline VMT, emissions, and grid assumptions were used to adapt the model.

[51] https://www.washingtongas.com/-/media/3a5633e2c3c64ed08fe1ef96c65d8207.pdf.

[52] https://www.mwcog.org/tpb-climate-change-mitigation-study-of-2021/.

Aviation

To reduce emissions from the aviation sector, the City is assuming the implementation of the Clean Aviation Fuel Act. This Act is assumed to decrease emissions from aviation by 2% in 2025, 25% in 2035, and achieve aviation fuel carbon neutrality by 2050.

Off-Road Emissions

Emissions from off-road vehicles are reduced through better fuel efficiency (from technology upgrades, and hybrid equipment), the use of cleaner fuels (including hydrogen, biofuels), and some electrification of equipment. This strategy was modeled in alignment with medium- and heavy-duty vehicle decarbonization of 2% by 2025, 50% by 2035, and 80% by 2050.

Buildings

New Buildings

It was assumed that 70% of new buildings will be multifamily residential while only 30% will be commercial, which also includes mixed use developments. It is assumed that new buildings will be more efficient when compared to existing buildings due to increased stringency from improved buildings codes through 2050. In addition, new construction is assumed to be 95% electric starting in 2022. Efficiency over code was assumed to be 15% over code for new buildings built between 2022 and 2030, 10% over code for new buildings built between 2030 and 2040, and 5% over code for new buildings built between 2040 and 2050.

Existing Buildings

To reduce emissions from existing buildings, it was assumed that Alexandria's buildings have similar electricity and natural gas usage profiles as those within the South Atlantic region of Commercial Building Energy Survey (CBECS) and Residential Energy Consumptions Survey (RECS). The South Atlantic regional energy use was calibrated to use Alexandria's BAU based on total commercial, multifamily residential, and single family residential's energy use. It was assumed that 50% of existing commercial energy use is multifamily residential based on Alexandria's building data.

A total of 57 commercial energy efficiency, electrification, and retrofit measure were identified for commercial buildings, and 24 were identified for residential buildings. These measures were then applied individually to each building, based on the baseline condition as determined by CBECS/RECS data, and a representative building for each building stock was developed.

Assumptions for existing buildings aligned with an end-of-life electrification strategy whereby individual components will switch to comparable electric versions. These assumptions are in alignment with the National Renewable Energy Lab (NREL) Electrification

Futures Study, which provides adoption curves for residential and commercial space and water heating, and cooking. Generally, the high electrification scenario was applied to building profiles as a replacement as existing equipment reaches the end of its useful life.

Utilizing the energy consumption from that building and savings percentage associated with each mitigation measure, the estimated savings for each measure for all buildings associated with that representative building was calculated. The average savings for that specific building type in that climate zone and census division was finally calculated by dividing the total savings for all those associated buildings by the number of associated buildings.

In addition to modeling for electricity and natural gas, modeling was completed to reduce other fuels such as fuel oil and propane gas in the City's commercial and residential buildings. Conversions to gas were anticipated for both fuels on a schedule of 2% by 2025, 50% by 2035, and 90% by 2050.

HFC Phasedown

The American Infrastructure and Manufacturing Act (AIM Act) of 2020 directed the EPA to drawdown the use of hydrofluorocarbons (HFCs) in use as a refrigerant, blowing agent, and other applications. Taking a stepwise approach, an eventual drawdown to 15% of 2020 levels by 2036 is expected. This methodology assumes that 5% of HFC using equipment turns over annually, with new equipment lowering emissions along the set schedule. This provides for an 82.5% reduction in total emissions from HFCs by 2050 given an assumed 20-year lifetime of the equipment.

Fugitive Emissions

Fugitive emissions are attributable to leaks in the natural gas distribution systems serving the City of Alexandria. Through the implementation of leak reduction programs and better servicing, fugitive emissions can be reduced to zero. For this mitigation strategy, the amount of fugitive emissions was calculated after current and new building electrification was implemented. This accounted for between 1.2% and 1.4% of total gas consumption. This total emissions amount was then fully mitigated.

Solid Waste

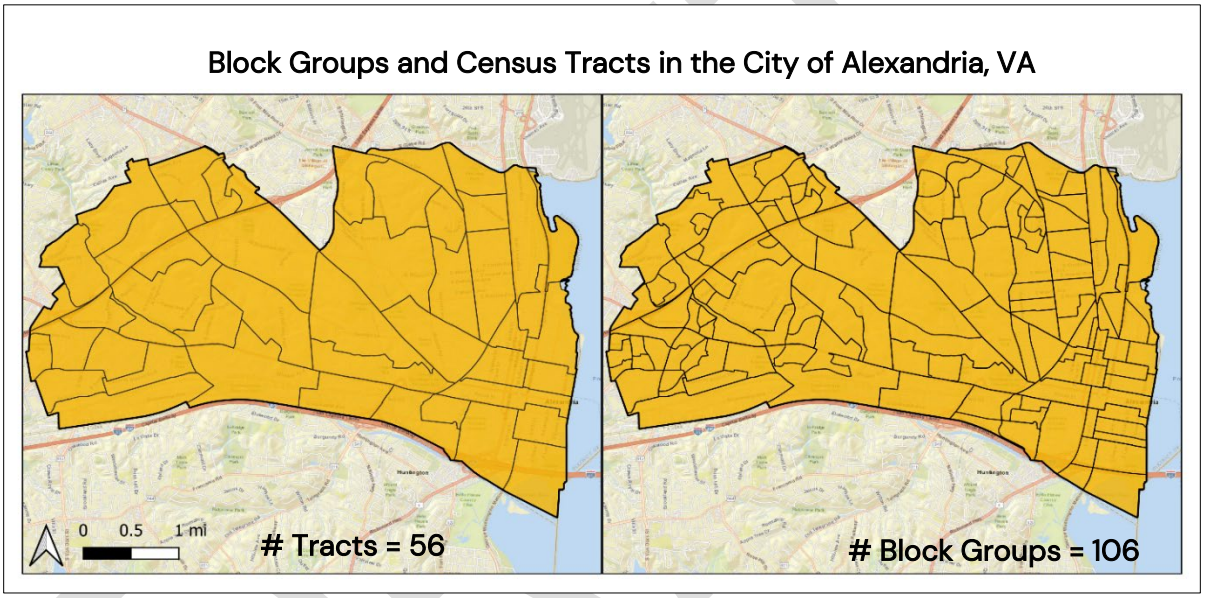
The methodology to estimate GHG reductions from waste reduction and diversion assumes a 50% reduction in waste generation by 2035 and a 90% reduction by 2050 (compared to the BAU). The modeling also assumes that waste will continue to be processed through combustion at the Covanta Waste-to-Energy. These modeling assumptions were set based on the reductions necessary to meet the long-term carbon neutrality goal by 2050, as well as the following national-level goals and guidance.

Appendix F. Heat Vulnerability Assessment Methodology

The City of Alexandria conducted a heat vulnerability assessment to identify areas with greatest vulnerabilities and opportunities for adaptation. A Heat Vulnerability Index (HVI) was calculated for each Census block group in the City.

The vulnerability assessment was conducted at the block group level, as opposed to larger census tracts to analyze heat vulnerability at a smaller geographic granularity (see Figure 26). The higher resolution will enable the city to make more targeted adaptations based on identified vulnerabilities.

Figure 26. Census Tracts and Block Groups in Alexandria



The HVI included variables representing the three components of vulnerability, based on the following formula:

$$Heat\ Vulnerability\ Index\ (HVI) = Exposure\ (E) + Sensitivity\ (S) + Adaptive\ Capacity\ (AC)$$ [53]

Where:

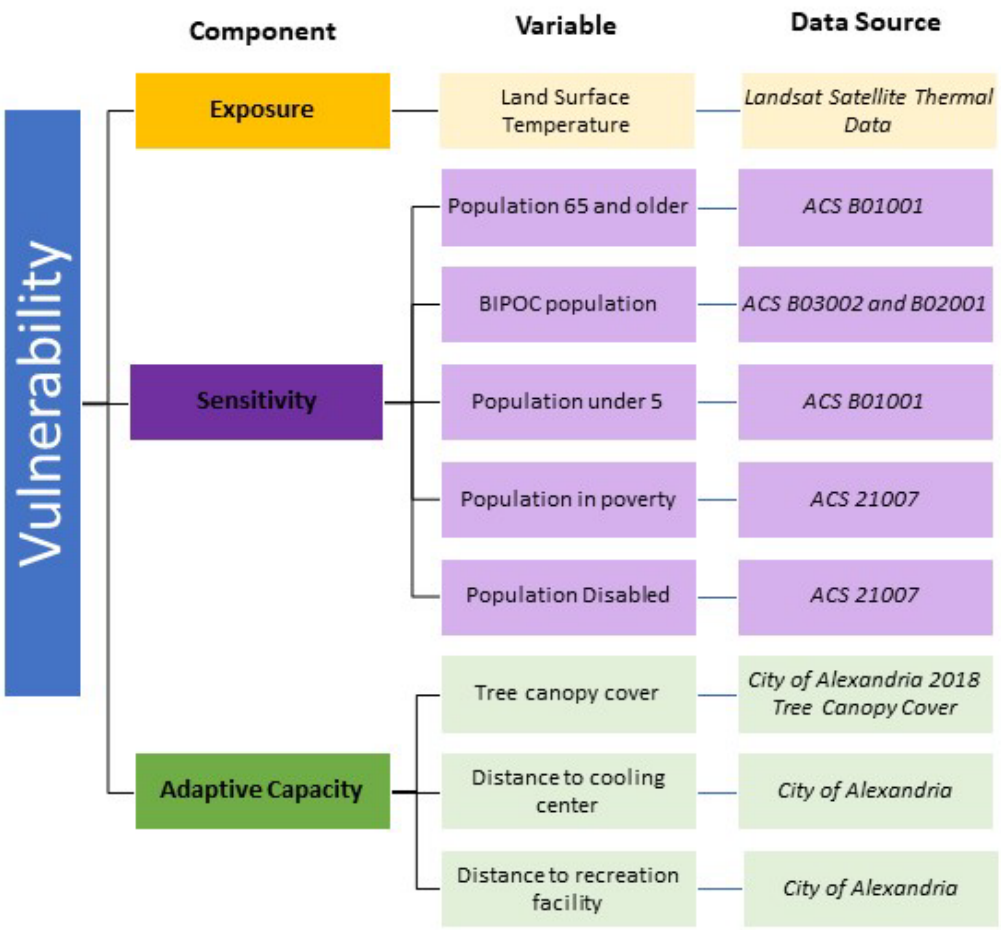
- **Heat Vulnerability Index** for each block group was scored on a scale of 0 (least vulnerable) to 3 (most vulnerable), which effectively ranked HVI's among block groups within the City of Alexandria
- **Exposure** was determined by the block group's relative land surface temperature, compared to regional maximum and minimum temperatures, from two extreme heat events.

[53] HHVA Methodology 4.5.2021.pdf (harriscountytx.gov).

- **Sensitivity** included an aggregated average of characteristics that can contribute to greater adverse impacts from heat (Adults Aged 65 and Older, Minority Status, Poverty, Disability Status, and Children Aged 5 and Younger)
- **Adaptive Capacity** included an aggregated average of physical characteristics of block groups which increase adaptive capacity and decrease overall vulnerability. In this assessment, we will assess tree canopy cover, proximity of block groups to cooling centers, and proximity of block groups to recreation amenities and green space.

The overall methodology is summarized in Figure 27. Each component type and its associated variables are described in greater detail below. Each component was scored on a scale of 0 to 1, where 0 represents lowest vulnerability and 1 is highest vulnerability. This resulted in a possible HVI range of 0 to 3.

Figure 27. Vulnerability Assessment Methodology?



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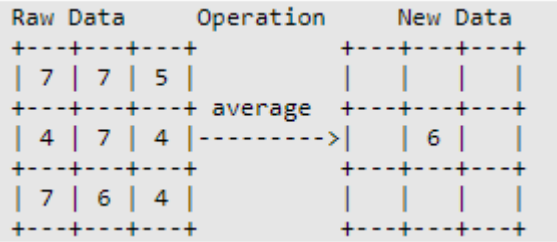
Exposure

Exposure was calculated using the average relative land surface temperature in each block group for two summer days.[54] This produced a value between 0 and 1 for each block group's temperature and was assessed within percentile ranges above minimum temperature and up to the maximum temperature during a given extreme heat event.

The City extracted land surface temperature from two Landsat images using Google Earth Engine. A methodology developed by Ermida et al. was utilized to transform top of atmosphere values into land surface temperature values.[55] Two Landsat 8 images from summer months (May through September) from 2020 to 2021 were selected using optimization techniques that selected the images with the least amount of cloud cover over the city of Alexandria. Minimal cloud cover is desired because clouds prevent the satellite sensor from taking measurements, leaving a blank area without data. Landsat does not capture temperature directly, but rather the top of atmosphere (TOA) brightness temperature. The TOA temperature was converted into land surface temperature by combining TOA measurements with the Normalized Vegetation Index, atmospheric data, and surface emissivity. After land surface temperature was calculated, the two images were uploaded to QGIS and clipped to the city's boundary. From there, the average pixel value was calculated on a cell-by-cell basis following NVRC Urban Heat Islands methodology.[56] The r.neighbors[57] tool was used to calculate the mean statistics for each cell in the surrounding [area] (see Figure 28).

Figure 28. Sample of the r.neighbors Tool in QGIS. This method was used to smooth the average land surface temperature layer.



[54] Land surface temperatures are generated utilizing LANDSAT 8 Thermal Infrared Sensor (TIRS) taken on July 29, 2020, and September 2, 2021. These images were selected as the least cloudy Landsat images from summer months (June through September) 2020 to 2022.

[55] Ermida, S.L., Soares, P., Mantas, V.M., Göttsche, F., & Trigo, I.F. (2020). Google Earth Engine Open-Source Code for Land Surface Temperature Estimation from the Landsat Series. Remote. Sens., 12, 1471.

[56] Northern Virginia Regional Council. "Urban Heat Islands." Accessed April 2022. https://www.novaregion.org/1509/Urban-Heat-Islands.

[57] This makes each cell category value a function of the category values assigned to the cells around it, and stores new cell values in an output raster map layer.

The land surface temperature was normalized on a scale of 0 to 1 using the equation for exposure. The minimum temperature was subtracted from the average land surface temperature value from the r.neighbors output for each cell and divided by the difference between the maximum and minimum temperature. This resulted in a scaled value ranging from 0 to 1 for each 30m-by-30m cell. Zonal statistics were calculated to find the average scaled value variation for each block group.

$$Exposure^{58} = \frac{Block\ Group\ Average\ Temperature - Minimum\ Temperature}{Maximum\ Temperature - Minimum\ Temperature}$$

Sensitivity

Sensitivity captures which populations may be most likely to experience health or financial burdens because of extreme heat. Five socio-economic variables were identified from existing literature discussing vulnerable demographics and indicators that contribute to heat vulnerability.

Previous studies (Reid et al., 2009[59]; Conlon et al. 2020[60]; Nayak et al. 2018[61]) used principal component analysis to distill various vulnerability factors to determine a HVI. The City drew on these analyses to identify variables for use in the heat vulnerability assessment, limiting the number of variables to five in order to focus the assessment and its outcomes. The variables and justification for including them are described below.

- **Percentage of Population 65 and Older;**
    - People who are 65 years and older are more prone to heat-related health problems, according to the CDC[62]
    - Data source: Census Bureau ACS 2020 5-Year Estimates Table B01001
        - Added population estimates for males and females 65 years and older
- **Percentage of Population 5 and Younger;**

[58] The input for this equation is the smoothed average of the two Landsat images.

[59] Reid CE, O'Neill MS, Gronlung CJ, Brines SJ, Brown DG, Diez-Roux AV, et al. (2009). Mapping community determinants of heat vulnerability. *Environmental Health Perspectives,* 117(11):1730-1736, PMID: 20049125, 10.1289/ehp.0900683.

[60] Conlon KC, Mallen E, Gronlund CJ, Berrocal VJ, Larsen L, and O'Neill MS. (2020). Mapping Human Vulnerability to Extreme Heat: A Critical Assessment of Heat Vulnerability Indices Created Using Principal Components Analysis. *Environmental Health Perspectives,* Vol. 128, No. 9.

[61] Nayak SG, Shrestha S, Kinney PL, Ross Z, Sheridan SC, Pantea CI, Hsu WH, Muscateillo N, Hwang SA. (2018). Development of a heat vulnerability index for New York State, Public Health, Volume 161, Pages 127-137, ISSN 0033-3506, https://doi.org/10.1016/j.puhe.2017.09.006.

[62] Heat Stress in Older Adults | Natural Disasters and Severe Weather | CDC.

  - Young children are more susceptible to heat illness than adults, due to greater surface area to body mass ratio, lower rates of sweating, and slower rates of acclimatization[63]
  - Data source: Census Bureau ACS 2020 5-Year Estimates Table B01001
    - Added population estimates for males and females 5 years and younger
- **Percentage of Population Designated as Black, Indigenous, or Persons of Color (BIPOC)**
  - Minority groups are more likely to experience heat risk due to comorbidities associated with higher rates of asthma in youth and COPD in adults.[64]
  - Data source: Census Bureau ACS 2020 5-Year Estimates, Table B03002 and Table B02001
    - This variable is the percentage of the population that identifies as non-white.
- **Percentage of Population with Poverty Status**
  - Individuals in poverty are less likely to be able to afford air conditioning, leaving them susceptible during extreme heat events.
  - Data source: Census Bureau ACS 2020 5-Year Estimates, Table C21007, "Age by Veteran Status by Poverty Status by Disability Status for the Civilian Population 18 Years and older"
    - Estimates for the number of nonveteran and veterans below the poverty line were added together for populations under 64 and 65 and older to get total estimates for the population below the poverty line for residents 18 years and older
- **Percentage of Population with Disability Status;**[65]
  - Individuals with disabilities are more likely to be unemployed and earn less income compared to those without disabilities. Additionally, disabilities create mobility issues which reduces access to cooling centers and other resources.[66]
  - Data source: Census Bureau ACS 2020 5-Year Estimates, Table C21007
    - Estimates for the number of nonveteran and veterans with disabilities were added together for populations under 64 and 65 and older to get

[63] Heat illness in children – PubMed (nih.gov).

[64] https://planning-org-uploaded-media.s3.amazonaws.com/publication/download_pdf/PAS-Report-600-r1.pdf.

[65] Based on the census block group dataset "Poverty Status in the Past 12 Months by Disability Status"

[66] Climate Change and the Health of People with Disabilities (epa.gov).

total estimates for the population disabled and population below the poverty line for residents 18 years and older

- *Additional Variables for Consideration that were not included in the sensitivity score: Income by Household, Immigration Status, Housing Density, Adults with Asthma and/or COPD, Adults with Diabetes, Percentage of Population without Health Insurance, Percentage of Population Working Outdoors, Educational Attainment*

The overall sensitivity score for each block group were quantified as an aggregated percentage of total block group populations vulnerable to heat, out of the overall total population of each block group.

$$Sensitivity\ Per\ Variable\ = \frac{\text{Vulnerable Population}}{\text{Total Population}}$$

$$Sensitivity = \frac{Sensitivity\ Per\ Variable\ (S1 \dots S5)}{5\ Social\ Variables}$$

Adaptive Capacity

Adaptive capacity captures physical characteristics of surface conditions and cooling resources at the block group level. Adaptive capacity is primarily achieved through higher degrees of tree canopy cover and the presence of cooling centers within reasonable walking or commuting distance.[67]

The methodology accounted for the following physical attributes of each block group:

- **Percentage of tree canopy cover**
  - This variable was scored on the inverse of the percentage of the block group with tree canopy cover, whereby a score of 1 represents no tree canopy (and higher vulnerability), and 0 represents lower vulnerability.
  - Data source: City of Alexandria Tree Canopy Cover
- **Distance from locations of cooling centers**
  - Block groups were scored based on the distance to the closest cooling center from the block group centroid, as shown in the table below.

Table 6. Scoring rubric used for the cooling center component value of the adaptive capacity score.

Distance to closest cooling center	Score (1 = higher vulnerability)
≤ 0.5 miles	0
0.5 – 1 mile	0.5

[67] 8. HHVA Methodology 4.5.2021.pdf (harriscountytx.gov).

> 1 mile	1

- Cooling center locations:[68]
  - Charles Houston Recreation Center (901 Wythe St.)
  - Leonard "Chick" Armstrong Recreation Center (25 West Reed Ave.)
  - Lee Center (1108 Jefferson St.)
  - Mount Vernon Recreation Center (2701 Commonwealth Ave.)
  - Nannie J. Lee Recreation Center (1108 Jefferson St.)
  - Patrick Henry Recreation Center (4653 Taney Ave.)
  - William Ramsay Recreation Center (5650 Sanger Ave.)
  - Libraries (Branch hours vary, check the links below for hours)
  - Charles E. Beatley, Jr. Central Library (5005 Duke St.)
  - Kate Waller Barrett Branch Library (717 Queen Street)
  - Ellen Coolidge Burke Branch Library (4701 Seminary Road)
  - James M. Duncan Branch Library (2501 Commonwealth Ave.)

- **Distance from recreation amenities (sports fields/courts, swimming pools, public gardens, playgrounds, picnic shelters, and dog parks)**
  - Block groups were scored based on the distance to the closest open or green space from the block group centroid, as shown in the table below.

Table 7. Scoring rubric used to determine the recreation amenity component value of the adaptive capacity score.

Distance to recreation amenities	Score (1 = higher vulnerability)
≤ 0.5 miles	0
0.5 – 1 mile	0.5
> 1 mile	1

  - Data source for recreation amenities: City of Alexandria

The overall adaptive capacity score for each block group was quantified as a portion or number of resources over a given block group. For example, for tree canopy over, adaptive capacity will be calculated as follows:

$$Tree\ Canopy\ Cover\ variable = 1 - \ Proportion\ Tree\ Canopy\ Cover\ of\ Block\ Group$$

$$\text{Adaptive Capacity} = \frac{Cooling\ Center\ Score + Adaptive\ Capacity\ Score + Proportion\ nontree\ canopy\ cover}{3}$$

The overall adaptive capacity score is an average of each of the three variable scores. A higher score corresponds to lower adaptive capacity. This is the opposite of the exposure and sensitivity variables where higher scores correspond to higher exposure or sensitivity.

[68] Summer Cooling Options for Alexandria Residents and Seniors | City of Alexandria, VA (alexandriava.gov).

Scores for all three variables were arranged so that higher scores correspond to higher vulnerability.

Vulnerability Output

An aggregated HVI across block groups for the entirety of Alexandria was developed by adding the exposure, sensitivity, and adaptive capacity scores together. Additionally, the Heat Vulnerability Indices were broken down by each of the five social variables into separate, viewable, layers. The separate sensitivity HVIs were created by adding the sensitivity variable (as proportion of the population from each block group) with the exposure and adaptive capacity scores.

The HVI scores by block group will help the City identify and assess priority areas for targeted adaptation interventions.

Areas of Future Research

This heat vulnerability assessment provided a foundational understanding of increasing heat's impact on the Alexandria community, to identify preliminary opportunities to address challenges related to extreme heat. Further analysis could provide additional insights for adaptation planning, such as in the following areas.

Consideration of ambient air temperatures. This study used daytime land surface temperature to measure heat exposure. Land surface temperature is how hot the ground is to the touch, while ambient air temperature is the temperature of the air from just above the ground to roof height. Ambient air temperatures are generally less extreme than land surface temperatures since they are subject to winds and other atmospheric forces. The human physiology primarily experiences the stress of heat through both land surface temperature and ambient air temperature, so additional research into ambient air temperatures can aid in developing heat indices that reinforce the impacts on public health due to extreme heat.

Consideration of nighttime air temperatures. Concrete, brick, and asphalt absorb and store heat throughout the day and slowly release it back into the air at night. During heat waves, heat stress can continue to build overnight and the lack of respite from hot temperatures can prevent those susceptible to heat stress from recovering. [69] The sensitivity and adaptive capacity maps provided in this heat vulnerability assessment could be paired with an analysis of nighttime hot spots to identify populations vulnerable to nighttime heat.

[69] Belles, Johnathan. Why Nighttime Temperatures Are Also Dangerous During Heat Waves. (2019, August). *The Weather Channel,* https://weather.com/safety/heat/news/2019-07-19-nighttime-heat-wave-deadly-dangerous.

Overlay heat vulnerabilities with housing density and building material. Housing density and building material also play a significant role in how extreme heat will impact a community. The IPCC Sixth Assessment Report found that tall buildings that are closely constructed next to one another absorb and store heat, while also reducing natural ventilation. Therefore, it is apparent that increased housing density over a given footprint has a positive correlation with extreme heat impacts on residents. For areas around Alexandria where such developments and urban geometries exist, further studies can be carried out to assess retrofits to building materials and surfaces to prevent radiative head from being absorbed, retained, and elevating internal building temperatures to unsafe levels.

Summarize heat vulnerabilities by zoning type. Additional analysis of the heat vulnerability assessment results compared to local zoning typologies may also offer useful insights for adaptation planning. For example, it would be valuable to compare HVI in residential and commercial areas, as well as identify the number of people impacted in certain zones.

Incorporation of additional sensitivity indicators or demographic groups. The HVI currently focuses on five demographic characteristics that contribute to heat vulnerability. Additional characteristics could be included in future analyses as needed.

Refine recreation facilities data. Proximity to recreation facilities is currently included in the adaptive capacity component of the HVI, as recreation facilities often have green space or shade, drinking fountains, and other cooling amenities. However, some recreation facilities may have stronger cooling amenities than others, which could be accounted for in future interactions of the assessment as needed.