A Strategic Plan for Monitoring and Mitigating Air Pollutants

North Suffolk Communities of Revere, Chelsea, and Winthrop

Prepared by the Air Partners Group at
Franklin W. Olin College of Engineering
PI Dr. Scott Hersey
scott.hersey@olin.edu

North Suffolk
Public Health Collaborative
an initiative of the communities of Revere, Chelsea and Winthrop

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Executive Summary

Air Quality Monitoring and Mitigation has become an important priority in the North Suffolk region; specifically in the communities of Chelsea, Revere and Winthrop. As such, the communities were awarded a State Action for Public Health Excellence (SAPHE) grant to develop a data- and community-driven strategic plan for how to most effectively understand and reduce exposure to air pollutants for residents in the area.

This plan represents the culmination of a 10 month research and planning process centered on stakeholder interviews with residents, advocacy groups, and municipal employees, analysis of existing data related to pollutant sources in the region, and pilot work aimed at validating the methods recommended below. These findings informed a 3 year proposed path for municipalities to follow to achieve maximum impact in monitoring and mitigating exposure to air pollutants in the North Suffolk communities.

It focuses on 3 major areas

Area 1: Developing a community owned sensor network to provide a comprehensive characterization of the pollutants in the area and to identify the areas that are most impacted by said pollutants

Area 2: Installing HEPA purifiers as a means of air pollution mitigation and exposure reduction for those most vulnerable to the effects of poor air quality

Area 3: Engaging with community members and experts through sustained awareness campaigns focusing on the sources and health impacts of air pollutants, as well as ways to engage with air monitoring data and HEPA-based pollutant mitigation strategies to reduce pollutant exposure while supporting continuous, equitable, and inclusive community control over decision making related to reducing community-level exposure to pollutants.

This plan articulates a clear set of goals and measurement techniques for monitoring air quality and mitigating residents' pollutant exposure providing a crucial blueprint for communities to effectively seek implementation funding and successfully complete implementation projects once funded.

Background

Scientific Background

Poor ambient (outdoor) air quality is responsible for 4.2 million deaths worldwide each year[1], in addition to a wide range of adverse health impacts, including cardiovascular disease, neurological disorders, some cancers, preterm birth and low birth weight, and even reduced IQ and school performance for children. Communities closest to major pollutant sources experience disproportionate pollutant exposure and health impacts. With a myriad of known pollutant sources including Logan International Airport, automobile and diesel truck traffic, industrial facilities, and shipping activities, the North Suffolk communities have an imperative to understand the dynamics of air pollutant exposure in order to identify the most heavily impacted areas and prioritize those areas for pollutant mitigation.

Criteria pollutants, namely particulate matter (PM) pollutants, carbon monoxide (CO), nitrogen oxides (NO_x) and ozone (O_3), drive health-impacting outcomes. Among these sources, PM pollution has been identified by epidemiologists as the most dangerous. Within PM, the smallest particles are increasingly associated with the most adverse health outcomes, with ultrafine particles or UFPs (smaller than 100 nm in diameter) emerging as the greatest threat. Due to their small size, UFPs can penetrate deep into the lungs, enter the bloodstream and can even cross the blood/brain barrier. And because they are so small, they contribute little to total particle mass and are therefore effectively unregulated by mass-based PM standards.

1 https://www.who.int/teams/environment-climate-change-and-health/air-quality-and-health/ambient-air-pollution

Criteria pollutants and UFPs are prevalent in the North Suffolk communities, owing to the density of sources described above. Here, we propose a strategic plan for paired monitoring and mitigation of air pollutants that begins with establishing an exposure-relevant air monitoring network to identify the highest priority areas for mitigation on the basis of high pollutant exposure and community demographics. Pilot work associated with the SAPHE planning grant suggested that lower-cost sensors deployed with high spatial density can provide unambiguous evidence about where in space and time the most significant sources of pollutants are located. Knowledge about where sources are and how they contribute to overall exposure for people in the community can also inform future regulations, zoning, strategic planning and legislation. Furthermore, access to real time data about air quality in their neighborhood empowers community members to make decisions about their outdoor exposure. Beyond these important summary data about source location and dynamics, there are well known connections between digital tools increasing the likelihood of positive health outcomes[2] and it is expected that access to real-time air quality data will lead to similar benefits via exposure reduction.

Importantly, the strategic plan proposed here leverages ambient pollutant data to inform the highest priority areas for mitigation via HEPA air purifiers. Pilot work associated with the SAPHE planning grant found that across municipal buildings and classrooms resulted in a 55-92% reduction in indoor PM exposure across the size range including UFPs, $PM_{2.5}$, and PM_{10}. Epidemiological literature suggests that these exposure reductions are associated with improvements in blood pressure[3], and are expected to result in other positive health benefits as well. We therefore recommend that they be a cornerstone of reducing residents' exposures to air pollutants in priority areas.

Finally, we recommend that an awareness-building campaign be combined with these monitoring and mitigation efforts in order to maximize community engagement with both air quality data (summary and real-time) and HEPA air pollutant mitigation. While the pilot work associated with this planning grant demonstrated strong potential for impact via the implementation of these technologies in the North Suffolk communities, there are significant human factors that may lead to inconsistency in accessing and acting on data, as well as using HEPA air purifiers according to best practices. An ongoing awareness campaign leveraging campaign strategies from the domain of public health is expected to overcome these challenges and maximize the impact of technology deployments.

2 https://academic.oup.com/tbm/article/11/5/1037/5934751

3 https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7878425/

Community Background

While the communities of North Suffolk have existing knowledge of the sources and impacts of air quality in their communities, this knowledge lacks specificity and is paired with significant concern about the current lack of monitoring and mitigation efforts. Sources like Logan Airport, Route 1, petrochemical storage facilities, and the Wheelabrator Incinerator in Saugus are troubling to community members, local advocates and air quality experts alike, but it is unclear whether the actual pollutant exposure associated with these sources is as significant as perceived and the impact of these sources in space and time is entirely unknown. As evidenced by the WIN2030 plan in Winthrop and the purchase of HEPA purifiers with CARES act funding in Revere to the work of university groups in Chelsea, the North Suffolk communities are devoting resources to mitigating air quality. This strategic plan acknowledges the unique combination of motivation to understand and reduce pollutant exposure with a lack of concrete information about source contributions and the spatiotemporal dynamics of pollutant exposure in the North Suffolk communities, and is designed to both provide this concrete information while also using that concrete information to inform strategic mitigation efforts.

This approach conforms to insights from dozens of stakeholder interviews with residents, municipal officials, elected officials, and advocacy groups in the North Suffolk areas about the strengths, weaknesses, opportunities, and threats (SWOT) surrounding air quality. Strengths identified by stakeholders include a strong culture and history of community-based environmental advocacy in the area, with several established and active groups advocating for environmental justice across Chelsea, Revere, Winthrop, and East Boston. Another strength identified by many was the degree to which decision-makers in municipal government and elected office were aware of air pollution concerns in the community and expressed interest in finding pragmatic and effective ways to work for better air health.

The most common weakness identified by stakeholders was a lack of data about the spatial and temporal dynamics of air pollutants across the North Suffolk communities, including a lack of quantitative knowledge about the importance of known and suspected pollutant sources and a lack of exposure-relevant information about the impact of these sources on residents. A related weakness vocalized by stakeholders was a sense of disempowered fear related to air pollution, owing to the aforementioned lack of concrete information combined with a lack of access to strategies that can be confidently employed to reduce pollutant exposure.

Three opportunities were identified by stakeholders relating to air quality in the North Suffolk communities.

First, drawing on successes by advocacy groups in East Boston at establishing community-owned air monitoring networks to provide concrete data to support real-time pollutant awareness and data-driven advocacy, stakeholders saw a significant opportunity to replicate that approach in the North Suffolk communities to make gains in air health. **Second,** stakeholders saw success stories of leveraging federal, state, and municipal funds to purchase HEPA air purifiers combined with evidence that HEPA air purifiers can result in substantial indoor PM exposure reduction as an opportunity to replicate these exposure-reducing strategies in their communities. **Finally,** related to the strength articulated by an awareness and shared concern about air pollutants among municipal and elected officials, stakeholders saw a significant opportunity to engage in collaborative governance processes with decision makers who were similarly motivated to reduce air pollutant exposure in their communities.

The single most consistent threat identified by stakeholders to progress on air health in the North Suffolk communities is the power dynamic that exists between known polluters (in particular Massport, who operate Logan Airport and the Wheelabrator incinerator) and the communities that their pollutants impact. This power dynamic further contributes to the sense of disempowered fear described above, and is perceived to result in pre-ordained "dead ends" to air pollution advocacy based on a history of resistance and opposition by these polluters to community voices advocating for air health, as well as the perceived disproportionate influence that these polluters have on local and state politics.

This strategic plan aims to capitalize on the strengths identified by community stakeholders in a way that addresses opportunities and weaknesses while maintaining some protection from threats. For example, leveraging local knowledge and support from resident and advocacy group stakeholders while establishing community-owned air monitoring networks across the North Suffolk communities draws on advocacy strengths while addressing the weakness of insufficient air pollutant information. Combining access to HEPA purifier mitigation strategies with concrete information about air pollution impacts from ambient monitoring draws on the strength of related work in East Boston and an evidence-based approach to mitigation strategy while addressing the weakness of a lack of access to air pollutant mitigation approaches. Finally, an awareness campaign related to air pollutant data and HEPA usage not only serves the purpose of maximizing engagement and impact with those components of the strategic plan, but also support the identified strength of collaborative governance by mobilizing a broader community base in the process of pragmatically working via regulatory and legislative processes to reduce pollutant exposure. Notably, none of these approaches requires cooperation from powerful known polluters such as Wheelabrator or Massport, though it is hoped that future collaboration with these polluters may result in mitigation funding to support more widespread investment in both air monitoring and HEPA purifier mitigation - and eventually operational changes as collaborative approaches begin to include these polluters.

Process

In early 2021, the North Suffolk Public Health Collaborative (NSPHC) was awarded a State Action for Public Health Excellence (SAPHE) Grant to be directed by the Metropolitan Area Planning Council (MAPC) to develop a Air Quality Monitoring and Mitigation program in the North Suffolk communities of Revere, Chelsea and Winthrop. The Air Partners team from Olin College, under the direction of Professor Scott Hersey, was charged with supporting the grant and providing technical services and assistance to develop a strategic plan for air pollution monitoring and mitigation. The Air Partners team employed a number of methods in the creation of the strategic plan, including stakeholder interviews, research, and pilot work. Each is described briefly below.

Stakeholder Interviews

To gather essential community context and ensure that this plan was both contextually appropriate and actionable, the Olin team leveraged previous stakeholder interviews with community members and advocacy groups and conducted a number of interviews with stakeholders in municipal offices in each community. In Revere, the team spoke with Elle Baker, an Open Space and Environmental Planner. In Chelsea, the team spoke with Alex Train, Chelsea Director of Housing and Community Development; Ben Cares, Senior Planner and Project Manager; Ibrahim López-Hernández, Sustainability Manager; and Darya Mattes, Resilience Manager. Lastly, in Winthrop, the team had conversations with Rachel Kelley, the Planning and Community Development Director. Each of these conversations shed light on sources that may have been overlooked by other research methods but were of significant concern to community members, and also informed the specific recommendations made by the strategic plan.

Research

After gathering context through stakeholder interviews, the Air Partners team analyzed an array of sources with information about the sources of pollutants in the North Suffolk region in order to understand the context of pollution emissions and inform priority areas for monitoring and mitigation.

Meteorology was considered as a driver of exposure to air pollutants from area sources, with wind tending to transport pollutant emissions in the direction of prevailing winds. Wind speed and direction data were obtained from the KBOS meteorology station in East Boston for the period 2015-2020 and visualized via a windrose plot, indicating the dominant wind speed and wind direction by season. This analysis indicates that the prevailing wind directions throughout the year are from the W, NW, and SW directions, with Spring and Summer experiencing occasional easterly winds. This suggests that, in general, areas to the E, NE, and SE of pollutant sources will typically experience the greatest pollution impact from those sources.

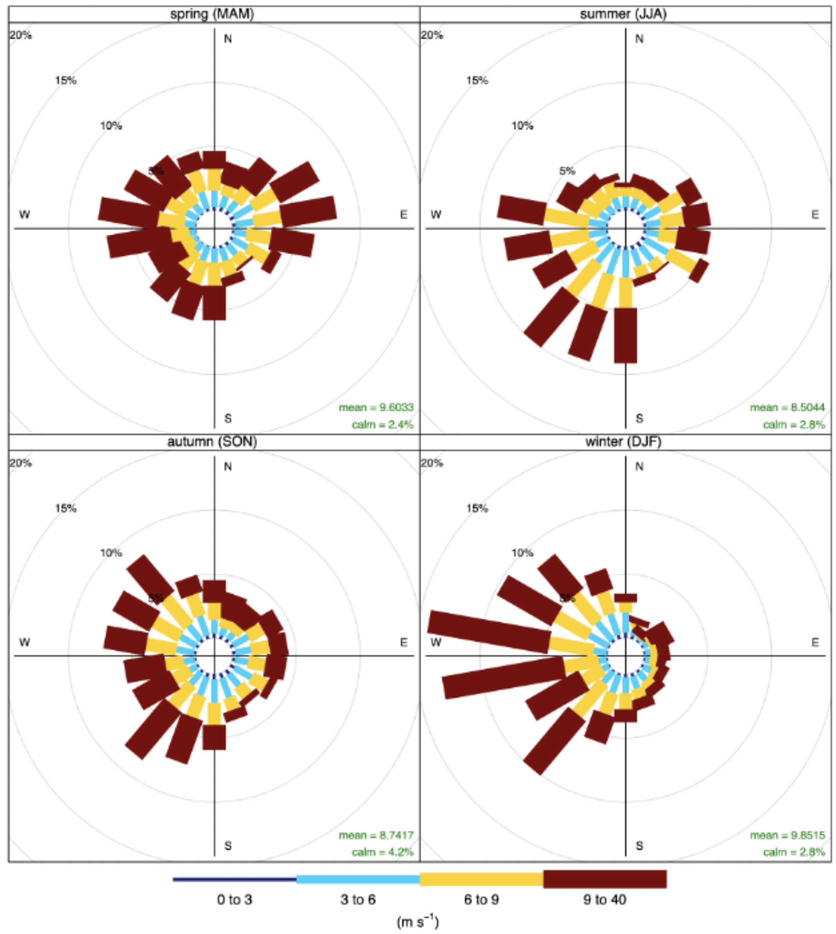

Figure 1: Windrose plot for the period 2015-2020, showing prevailing wind direction and wind speed by season.

Next, the team created a database of individual pollutant sources in the region to assemble into an interactive tool for assessing potential community pollutant exposures. General Edward Lawrence Logan International Airport was considered as a significant source of pollutants across the North Suffolk Communities - both due to ground-based operations of aircraft and vehicles and flights of aircraft over the communities. The area of Logan Airport can be considered an area source for air pollutants, with wind transporting pollutants in the downwind direction. According to the meteorological analysis described above, these pollutants are expected to most heavily impact Winthrop and Revere (to the E, NE, and SE of Logan).

The team also included the airspace of Logan Airport as a pollutant "source," as indicated by the 65 DNL map for airport operations. While this map explicitly defines noise contours associated with aircraft, the jet engine activity that produces noise significant enough to impact the ground at 65 dB or higher is also correlated with pollutants - notably NO_x, CO, UFPs, and Black Carbon - mixing to the ground via vortices. This 65 DNL map, therefore, represents the potential for pollutant impact via flight paths of aircraft arriving to and departing from Logan Airport.

The team also identified significant pollution point sources registered with the EPA's National Emissions Inventory (NEI)[4], which provides a comprehensive and detailed estimate of air emissions of criteria pollutants, criteria precursors, and hazardous air pollutants from air emissions sources Including point source data was a crucial way to understand and characterize the locations and effects of the most heavily polluting point sources in the area, and the most significant impact from these point sources is expected in the dominant downwind direction (typically E, NE, and SE). The point source data came from zip codes in the North Suffolk region, namely 02151, 02150, and 02152.

Traffic on major roadways was another pollutant source analyzed in Chelsea and Revere, but was limited for Winthrop because the Massachusetts Department of Transportation does not install or maintain sensors in that community. Any road with more than 20,000 vehicles was included in this initial research, and Route 1, Route 1A, Boulevard St, and Revere Parkway were all identified as significant potential line sources of air pollutants in the North Suffolk Communities.

Having tabulated and mapped the most significant pollutant sources in the area, the Air Partners team incorporated data on the location of vulnerable populations as a means of beginning to prioritize areas for air monitoring and mitigation as the overlap between prevalence of pollutant sources and the location of at-risk individuals. Children experience a disproportionate impact from degraded air quality due to their increased respiration rate and rapid physiological development, so school sites were identified in their relationship to pollutant sources. Additionally, Environmental Justice (EJ) communities were located in their relationship to known and suspected pollutant sources and were prioritized on the basis of their EJ designation. According to the Massachusetts Department of Environmental Protection, an EJ community has any one of the following: a block group whose annual median household income is equal to or less than 65 percent of the statewide median ($62,072 in 2010); or 25% or more of the residents identify as a race other than white; or 25% or more of households have no one over the age of 14 who speaks English only or very well - English Isolation[5].

Figure 2 displays a screenshot of the interactive map that was created as an artifact summarizing this research phase. The map may be accessed and explored via the footnoted link provided.[6]

4 https://www.epa.gov/air-emissions-inventories/national-emissions-inventory-nei

5 https://www.mass.gov/info-details/environmental-justice-populations-in-massachusetts

6 https://www.google.com/maps/d/u/0/edit?mid=1lBgJs8-jMSamkv2qwq9FA82RiQypP1GL&usp=sharing

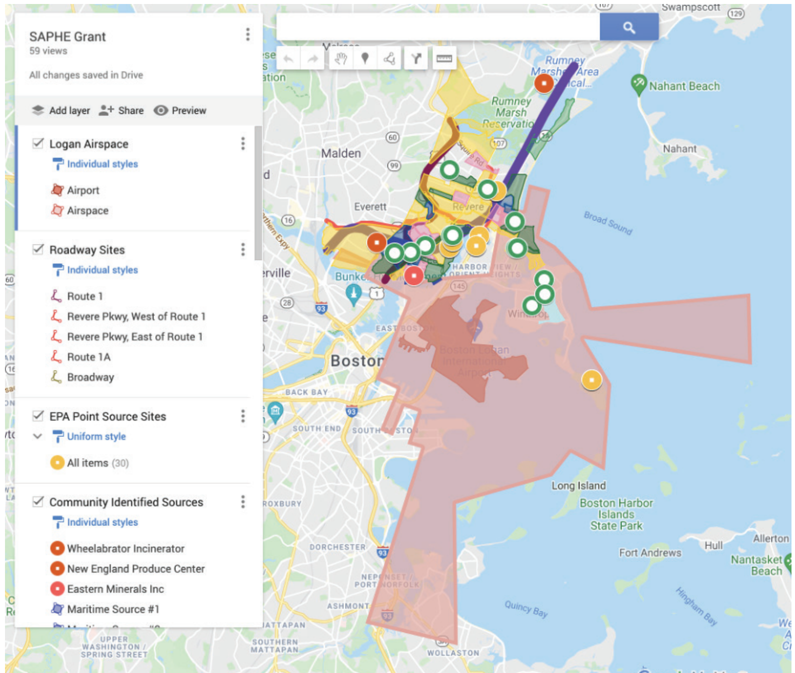

Figure 2: Screen shot of the interactive pollutant source visualization tool generated by the Air Partners team.

Pilot Work

In order to validate the combined approach of community-owned air pollution monitoring and deployment of HEPA air pollutant mitigation strategies, we piloted both approaches to determine their potential to achieve the intended outputs and outcomes. Here we briefly describe the pilot work undertaken as part of the SAPHE planning grant process, as well as the important results and insights from the pilot work.

Air Monitoring

To validate the potential for lower-cost air pollutant sensors to characterize the spatial and temporal dynamics of air pollutants in the North Suffolk region, the Air Partners team installed 9 air quality sensors across the communities. Figure 3 displays the sensors themselves and a map of sensor locations. The sensors were manufactured by local air quality data company QuantAQ, who is a global leader in lower-cost air monitoring sensors. Sensors included both Modulair-PM instruments, which measure PM (PM_1, $PM_{2.5}$, PM_{10}, size-resolved PM for sizes between 350 nm and 40 μm); and Modulair instruments, which offer the same PM measurements in addition to gas-phase pollutant measurements of CO, CO_2, NO, NO_2, and O_3.

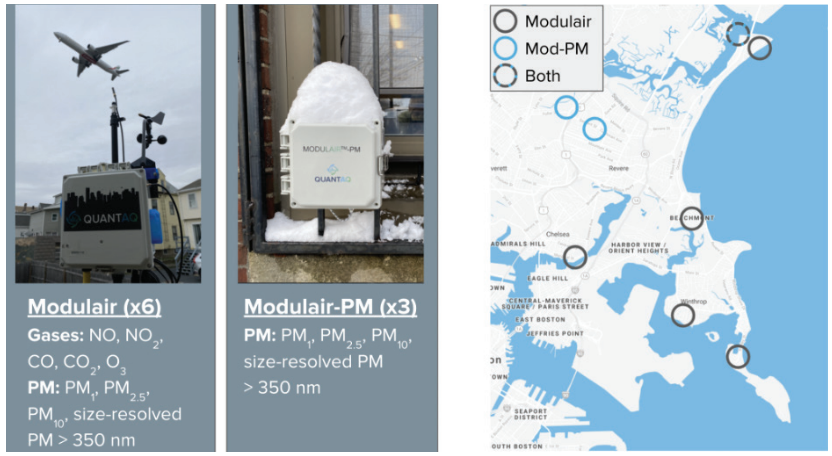

Figure 3: Sensors and sensor locations for pilot air pollutant monitoring.

These instruments were installed in January, 2020, and an initial data analysis was performed in April 2020. Here, a case study is presented for Modulair and Modulair-PM data from Gibson Park in Revere, which is situated just East of the Wheelabrator incinerator. Data visualizations from other sensors in the pilot network can be viewed here.[7]

The first capability that the Air Partners team sought to validate with pilot sensors is the ability to distinguish temporal trends in air pollutants characteristic of a site. To do this, data from 3 months of sensor operation were summarized in diurnal plots, representing pollutant concentrations by hour of day for a “typical” (average) day during that period, as well as the average for each “typical” day of the week (Figure 4).

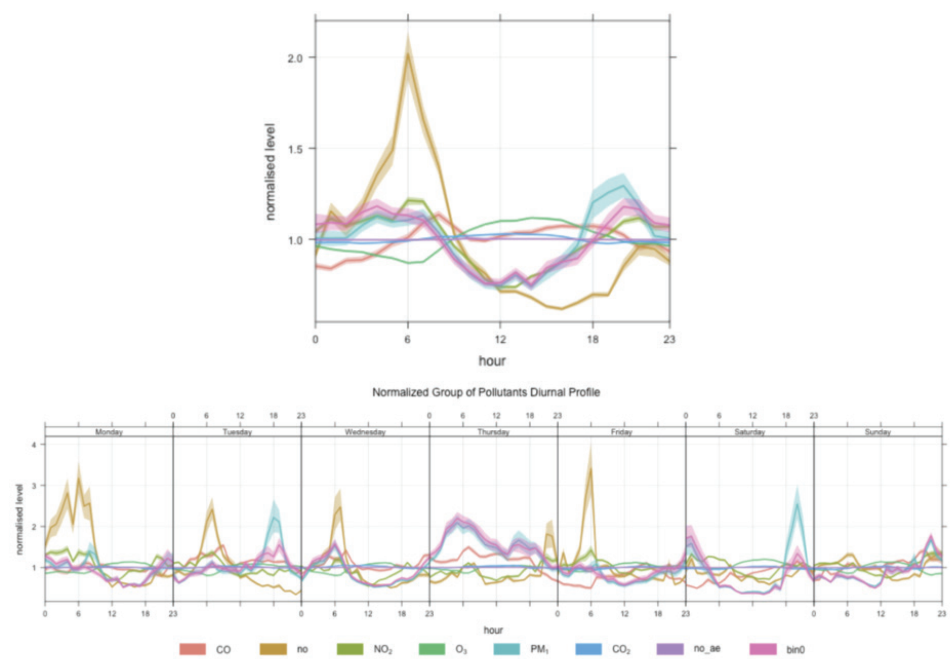

Figure 4: Diurnal profiles for pollutant concentrations for Jan. 22 to Apr. 10, 2021 at Gibson Park in Revere. Pollutant concentrations are normalized by the average pollutant concentration across the entire sampling period.

7 https://docs.google.com/presentation/d/1wxgPlcp8ZJx5uuwBb9JOqqgoHH232DdPbVFaNGvUqss/edit?usp=sharing

Data are displayed for CO, NO, NO_2, O_3, PM_1, CO_2, and bin0, which represents the particle concentration for the smallest size bin of particles (350-500 nm). NO_ae is a diagnostic for sensor performance. Data suggest that at Gibson Park, the concentration of all pollutants is at its highest in the morning hours between 5:00 and 7:00 am local time, with a secondary maximum in the evening between 6:00 and 9:00 pm. Notably, NO is disproportionately elevated in the morning and PM1 is disproportionately elevated in the evening. These results indicate that with even a short time series of data, the lower-cost instruments employed in this pilot work are able to distinguish the temporal variability in pollutant exposure at a particular site. Longer time series and analysis on the basis of seasonal variability in diurnal profiles is expected to provide even more robust characterizations of these temporal trends.

Next, the relationship between meteorology and pollutant concentrations were investigated as a means of validating that the pilot sensors are capable of identifying the directionality of pollutant sources. Figure 5 displays a polar plot of CO superimposed on a map, which superimposes pollutant concentration data on a compass to correlate wind speed (concentric circles of the polar plot, with outer circles representing higher wind speeds) and wind direction with pollutant concentration (blue to red, with red representing higher concentrations).

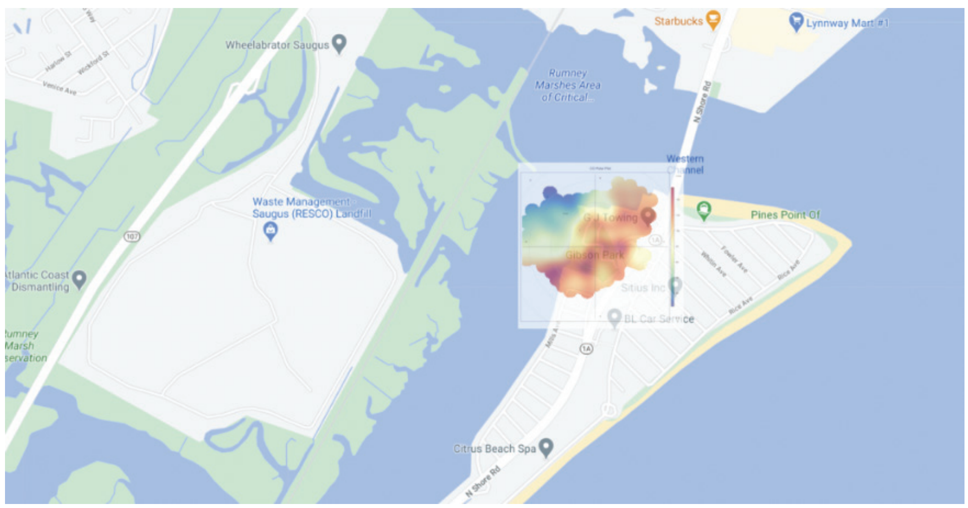

Figure 5: Polar plot for CO at Gibson Park in Revere.

Figure 5 clearly indicates that the highest concentration of CO is associated with wind direction from the S, SE, E, and NE of the sensor, which corresponds to the direction of Route 1A. Because CO is associated with automobile emissions, this result indicates that at Gibson Park, the adjacent roadway is the most significant contributor of CO exposure, and that this exposure is highest when wind is coming from the direction of the roadway.

Figure 6 displays a polar plot for NO at the same site, and indicates that in addition to a roadway-associated source from automobiles, there is a significant source of NO to the NW of the site - immediately in the direction of the Wheelabrator incinerator.

Figure 6: Polar plot for NO at Gibson Park in Revere.

Polar plot analysis indicates that in addition to the ability of these sensors to characterize the temporal variability in pollutant exposure, they are able to distinguish the directionality of source impacts at a particular site. This information is crucial for strategically prioritizing mitigation strategies in downwind, source-impacted areas, as well as in developing regulatory frameworks for reducing exposure from these sources.

HEPA Pollutant Mitigation

As part of the pilot work associated with this grant, 302 HEPA air purifiers were installed in municipal buildings, schools, and daycare facilities across the North Suffolk region. Before and after PM monitoring was performed in a subset of ~10% of these settings with sensors including both reference-grade measurements of UFPs and lower-cost measurements of PM from Modulair-PM instruments (PM_1, $PM_{2.5}$, PM_{10}, size-resolved PM for sizes between 350 nm and 40 µm). An example of these data for a classroom is displayed in a box plot in Figure 7, which shows median (thick black line) first to third quartiles of data (boxes) and min/max particle concentrations before and after HEPA installation. Particle concentrations are represented as the ratio between indoor and outdoor pollutant concentrations, such that a value of 1 indicates that PM concentrations are the same indoors and outdoors, less than 1 indicates lower concentration indoors than outdoors, and higher than 1 indicates higher concentration indoors than outdoors. Data were cleaned before analysis to remove spurious indoor sources related to activities such as COVID-19 sterilization and cleaning.

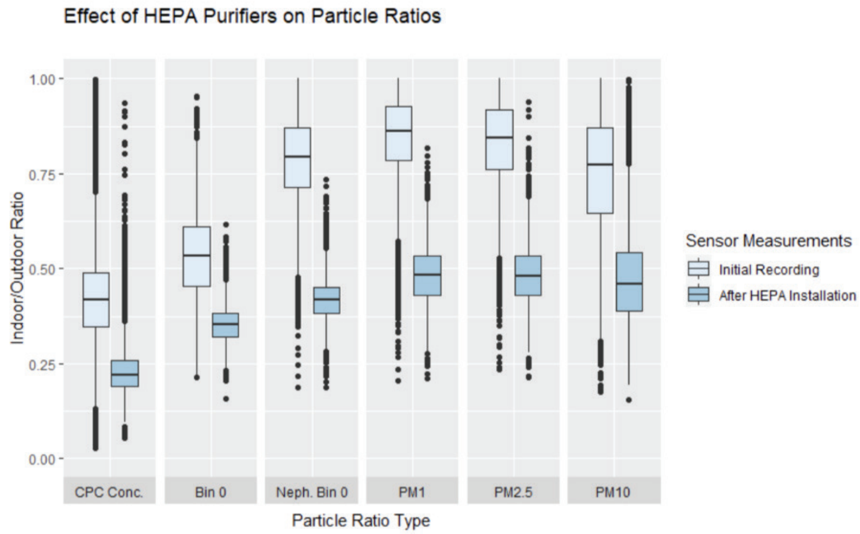

Figure 7: Example of pre- and post- HEPA purifier installation PM data for UFPs measured by a reference grade instrument (CPC conc.), fine particles measured by the Modulair-PM (350-500 nm; Bin 0 and Neph. Bin 0), and PM_1, $PM_{2.5}$, and PM_{10} measured by the Modulair-PM.

These data indicate that significant indoor exposure reduction is possible with best-practices HEPA purifier usage, and indeed a summary of all data from the HEPA deployment pilot indicates a 40-79% reduction in PM exposure in real-world contexts (Figure 8). It is noteworthy that some of the rooms evaluated under the pilot intervention had existing, low-quality HEPA filtration in place before installing higher-quality HEPA purifiers (Austin Air Healthmate) in the pilot (indicated by “filtration pre-pilot” bars). These rooms experienced the least benefit from the intervention, owing to an existing lowered baseline from existing filtration. Under ideal room conditions (no open windows or doors; no filtration pre-pilot), exposure reduction averaged 70% for consistent HEPA usage and 42% for periodic usage (room occupants turned the air purifier on and off throughout the day, and left it off for some entire days). For rooms open to outdoor air via cracked or frequently-opened doors and windows, exposure reduction averaged 79%.

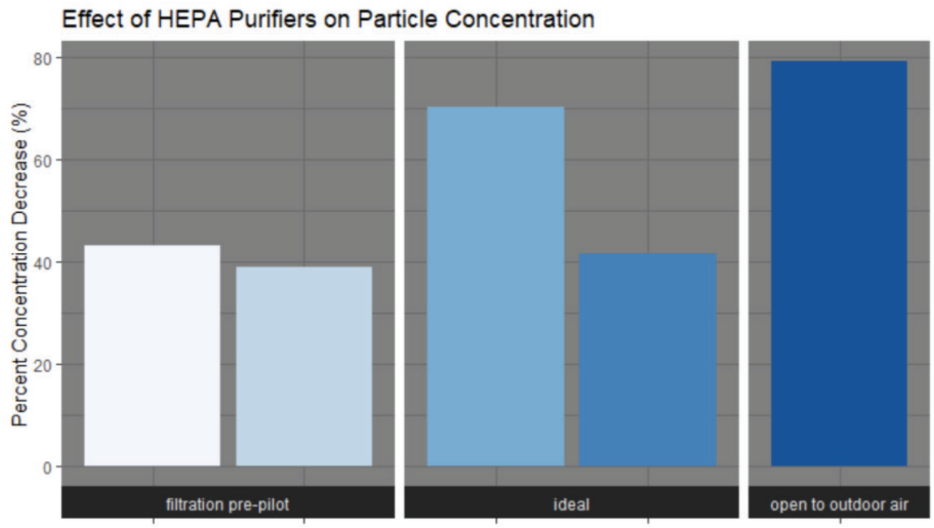

Figure 8: Summary data for exposure reduction during HEPA pilot deployments. Filtration pre-pilot indicates rooms where there was existing, low-quality HEPA purification before installing a higher-quality purifier, for rooms open to outdoor air (white, left) and rooms closed to the outdoors (gray, right). Ideal conditions indicate rooms with no pre-existing filtration devices and not open to outdoor air, for rooms with consistent usage (100% of occupied time; light blue on left) and rooms with periodic usage (30-60% of occupied time; blue on right). Rooms open to outdoor air (dark blue to the far right) had windows consistently cracked and/or doors that frequently opened to the outside.

It is noteworthy that there is significant variability in HEPA benefit according to room characteristics and human-driven HEPA purifier usage, but that exposure reduction was nonetheless significant (>40%) in all cases. This variability - particular in human-driven factors - suggests that community engagement strategies should be employed simultaneously with HEPA device installation to ensure consistent, best-practices usage, and that devices such as automatic outlet timers might be employed to moderate HEPA purifier operation during building occupation hours or time periods characterized by high pollutant concentrations identified by ambient monitors.

Strategic Plan

Objectives and Key Performance Indicators

Based on the research and pilot phases of work described above, the Air Partners team assembled a strategic plan for monitoring and mitigating air pollutants in the North Suffolk communities.

This plan centers on: 1. Establishing community-owned air monitoring networks, 2. Installing HEPA air purifiers in priority areas defined by proximity to sources, pollutant exposures revealed by ambient monitoring, and the location of at-risk populations, and 3. Ongoing community engagement designed to engage stakeholders with ambient data and best practices HEPA purifier usage. The strategic plan is organized into a set of objectives and subobjectives, each with recommendations for how to measure success with key performance indicators.

Ambient Pollutant Monitoring

Establish community owned air monitoring networks that provide data that is exposure relevant as defined by data that has high spatial and temporal resolution. This network is intended to develop a comprehensive picture of air quality in the North Suffolk region. The data from the network can inform future mitigation interventions (like HEPA purifiers) and provide evidence for policy and advocacy.

1.1. Identify and confirm locations of priority areas and priority pollutant sources. These areas are most important to characterize because they are the most vulnerable and impacted by the effects of poor air quality.

Metrics/KPIs: Identify census blocks that are environmental justice communities as defined by:

- Block group whose annual median household income is equal to or less than 65 percent of the statewide median ($62,072 in 2010); or
- 25% or more of the residents identify as a race other than white; or
- 25% or more of households have no one over the age of 14 who speaks English only or very well - English Isolation

Or communities around known or suspected sources as defined by:

- Regions within 350 meters (.22 miles) of roadways that have more than 10,000 vehicles per day
- Regions within 350 meters (.22 miles) of an EPA point source[7]
- Near airport regions that are within the 65DML sound band
- Regions of high density or high frequency observed combustion by the community as indicated in brief focus groups with individuals from local advocacy organizations and community members (six sensors to be allocated for this community input)

7 https://oceanservice.noaa.gov/education/tutorial_pollution/03pointsource.html

When determining where to place sensors, the environmental justice communities (top list) should be prioritized over the known or suspected source locations (bottom list). Essentially, one should place all sensors according to the first list, then move to the second list to place the rest of the sensors. By placing sensors in this way, communities can ensure that they are collecting data to understand both the most important sources and the most impacted communities.

1.2. Purchase and install sensors in the network to provide high spatial and temporal resolution that feed real time data to the app. The real time air quality app will allow residents to use the data collected by sensors to inform their decisions and potentially shift their behavior if conditions are poor.

Metrics/KPIs: Install sensors that measure CO, CO_2, NO, NO_2, O_3, PM_1, $PM_{2.5}$, PM_{10}, and size-resolved PM at at least 1 min time resolution in 75% of priority areas identified in 1.1 at distances of 100 meters (328.1 feet) and 300 meters (.19 miles miles) surrounding known and suspected sources, as defined in 1.1, and 1 kilometer (.62 miles) by 1 kilometer (.62 miles) in all other areas (with at least one sensor on every census block) to achieve optimal resolution.

A grid of this density will support a highly accurate depiction of the communities while being the most cost effective option.

1.3. Monitor and evaluate the effectiveness of the sensor network to ensure that it is working as intended and is of use to residents.

Metrics/KPIs: Sensors send data to the app at least 90% of time, at least 90% of sensors in the field running and reporting data, the app has at least 5% of the community's population representing unique users per month.

With the sensor network continuously reporting data to the app, and the community utilizing the app, these air quality monitoring strategies are expected to result in an outcome of engagement with and increased awareness about air quality sources and impacts, as well as the opportunity to make informed decisions about outdoor exposure.

8 https://www.mass.gov/info-details/environmental-justice-populations-in-massachusetts

HEPA Air Pollutant Mitigation

Install HEPA air purifiers in priority areas. HEPA purifiers are pleated mechanical air filters that have been proven to mitigate the worst impacts of air quality. Equipping people with HEPA purifiers is a crucial step toward equity and better health outcomes for everyone (and especially those most vulnerable).

2.1. Identify and confirm locations for HEPA purifiers. These purifiers are to be placed with those who are most at risk of feeling the worst effects of poor air quality.

Metrics/KPIs: Identify residences, educational facilities and places of work in the priority order as follows:

By population:

- Environmental Justice Communities[8]
- School-Age children, 0-18 years old, (priority ordered from youngest to oldest) and adults older than 65 (priority ordered from oldest to youngest, with priority also given to densely populated communities i.e. nursing homes or day care facilities)

By location:

- Within 100 meters (328.1 feet) in the East, Northeast and Southeast (due to the prevailing wind direction) of known or suspected pollutant sources (see 1.1 for definition) or in areas that experience pollutant concentrations over 50% of the baseline for at least 2 hours a day as revealed by the community owned sensor network
- Within 100 meters (328.1 feet) in all other directions of known or suspected pollutant sources (see 1.1 for definition) or in areas that experience pollutant concentrations over 50% of the baseline for at least 2 hours a day as revealed by the community owned sensor network

These lists should be treated with equal weight, but spaces that meet multiple high priority items on either or both lists should be given priority. In addition, because individuals with existing cardiovascular conditions, such as Asthma or COPD, are at higher risk for adverse health impacts from pollutant exposure, efforts should be made to prioritize HEPA purifier distributions to these populations. We recommend a HEPA purifier deployment strategy that partners with the Department of Public Health and community health centers to target these populations. By distributing purifiers with this method, those who are affected most by air pollution will be the first to get the help they need.

2.2. Purchase and install HEPA air purifiers in the locations detailed in 2.1.

Metrics/KPIs: HEPA purifiers are procured with the following characteristics:

- Greater than 25 square feet of HEPA filter medium surface area
- Greater than 5 meters (16.4 feet) per second exit velocity of air from device
- Greater than 2 year span between filter medium replacements

These purifiers provide exceptional performance, while lasting a long enough time between filter medium replacements to be useful and feasible in residences without a need for constant maintenance.

2.3. Monitor and evaluate the effectiveness of HEPA purifiers on community health outcomes and their usage rates in the community.

Metrics/KPIs: Measure the PM exposure reduction and collect before and after usage data for at least 5% of HEPA purifiers, usage data loggers in 5% of HEPA purifiers, survey to everyone with purifiers with a goal response rate of 25% to ensure that purifiers are being used at least 50% of the buildings occupied hours and reducing at least 40% of pollutants.

By conducting comprehensive testing and analysis, municipalities can ensure that HEPA purifiers are working and being used as expected to contribute to desired positive health effects.

Community Engagement

Ensure that interventions have high levels of community engagement, and the community has agency over decisions. In order to make this plan sustainable, equitable, and useful, it is essential that this action plan is driven by what the community actually wants and needs and that constituents have complete control.

3.1. Equip community members with ambient data. This data will likely be in the form of the real time air quality app, and later a tool for exploring air quality trends.

Metrics/KPIs: Ensure 95% of community members have access to app and tool, it feels inclusive and accessible to 85% of people as measured on brief community surveys with at least a 15% response rate, and at least 5% of community users are active on these platforms across the entire demographic of a community.

By creating inclusive and accessible access to data, municipalities can empower all citizens to make healthier, more informed decisions in the midst of suboptimal air quality.

3.2. Engage with and educate the community around the importance of air quality monitoring and mitigation efforts and inform community members of how to get involved.

Metrics/KPIs: Communications about air quality monitoring and mitigation at least 2 times per year using at least 2 different channels (email, town halls, social media, flyers and posters etc). At least 10% of people interact with communications and 5% of the community acts on those communications in some way (follows up with communicator or otherwise engages with the call to action).

Involving the community in communications around air quality monitoring and mitigation allows residents to better protect and advocate for themselves and their neighbors.

3.3. Continue community engagement to ensure that HEPA purifiers are being used and used properly.

Metrics/KPIs: At least 75% of HEPA purifier owners utilize HEPA purifiers as indicated on brief community surveys of HEPA purifiers with at least a 15% response rate. Communicate about HEPA purifier proper usage at least 4 times yearly using at least 3 different channels (email, text message, mailings etc) that include information about maintenance and use in at least 11 languages.

HEPA purifiers are completely ineffective if they are not turned on. Continually engaging with the community around the importance and efficacy of HEPA purifiers supports members in observing best practices, thus decreasing the impacts of poor air quality on their health.

3.4. Build or utilize existing Air Quality Coalition composed of community advocacy organizations, municipal leadership, community public health groups, air quality experts, and service to monitor progress around air quality monitoring and mitigation in their communities.

Metrics/KPIs: Multi-organization team that meets once a month which includes at least 4 representatives from community advocacy organizations, municipal leadership, community public health groups, air quality experts, and service providers respectively to mutually support one another in doing work around air quality monitoring and mitigation.

It is crucial to regularly convene community experts from each municipality to share lessons learned, resources, and encouragement throughout the process of enacting the actions detailed in this plan.

Implementation plan

There are many potential pathways to accomplishing these objectives. While it may be beneficial to assemble a plan based on an array of circumstances, there is also an example timeline of one way to enact this plan in three years. This plan assumes a 3-year timeline with full funding for implementation available.

	Year 1 End	Year 2 End	Year 3 End
	Phase 1: Ambient monitoring and mitigation prioritization **Objectives: 1.1, 1.2, 2.1, 3.1, 3.4**	**Phase 2:** Site identification, HEPA mitigation, compliance **Objectives: 1.3, 2.2, 3.2, 3.3**	**Phase 3:** Monitoring, evaluation, and compliance **Objectives: 2.3**
GOALS	1. Establish a community-owned air monitoring network. 2. Identity (or confirm) primary pollutant sources. 3. Identify (or confirm) priority areas for mitigation.	1. Identify HEPA mitigation sites 2. AQ and HEPA awareness campaign 3. Install HEPA purifiers 4. Indoor/outdoor air monitoring for M+E 5. Compliance follow-up	1. Continued HEPA installation 2. Continued M+E 3. Compliance follow-up
ACTIVITIES	1. Purchase and install ambient sensors 2. Analyze and interpret data 3. Generate ranked source list 4. Community engagement to publicize real-time data	1. Community engagement for siting and awareness 2. Purchase and install HEPA air purifiers 3. Purchase and install indoor air monitors for M+E 4. Compliance support	1. Purchase and install air purifiers 2. Indoor/outdoor air monitoring for M+E 3. Community engagement to elevate awareness and HEPA use compliance

Figure 9: Example 3-year timeline for strategic plan implementation. M+E refers to monitoring and evaluation.

The goals and activities outlined in Figure 9 map to the objectives described above. While the exact timeline of implementation is flexible, the ordinality of objectives is important. While some priority areas for HEPA mitigation can be identified immediately on the basis of downwind proximity to sources and the location of at-risk populations, the ambient monitoring established in Phase 1 will provide important insight about additional areas that should be prioritized for mitigation investments. So while some HEPA air pollutant mitigation investments may be made for obvious priority areas during Phase 1, it is recommended that broader roll-out follow data analysis that identifies the most heavily pollution-impacted areas of vulnerable residents.

Also noteworthy is that significant community engagement activities are recommended in each phase, such that no part of this plan should be implemented without building community-level awareness about both ambient air quality data and the HEPA pollutant mitigation resources available. These community engagement activities will be essential to achieving tangible benefit via pathways of residents engaging with air quality data and residents gaining access to HEPA purifiers and using them consistently according to best practices.

Cost

The costs of the purifiers and sensors are a key component of the strategic plan, especially when considering feasibility. As such, the sensor costs are broken down in Table 1 below

Item	Cost
Modulair PM Sensors (PM Only)	$1295 per sensor
Modulair Sensors (Gas and PM)	$3995 per sensor
Solar Kits (for either Modulair PM or Modulair)	$495 per sensor
Data Subscription	$25 per month per sensor

Table 1: Cost details for sensors in the community owned sensor network. Modulair is one sensor brand that meets all of the criteria outlined in Objective 1.

The Modulair sensors which measure gaseous pollutants are more expensive, but provide a crucial understanding of UFP concentrations in given areas. The solar kits allow the sensors to be installed in areas where an electrical outlet is not easily accessible, and the data management fees ensure that members of the community have access to sensor data in real time.

HEPA purifiers also come with a variety of associated costs, including the cost of the purifier itself, the replacement filter medium, and an electricity cost. Those costs are detailed in Table 2 below.

Item	Cost
HEPA Purifier (Wholesale)	$357
HEPA Purifier (Retail)	$595
Replacement Filter (Wholesale)	$144
Replacement Filter (Retail)	$240
Electricity Cost	$55-80 (per year)

Table 2: Cost details for HEPA purifiers that meet the criteria outlined in Objective 2.

Table 2 breaks down many of the costs of HEPA purifiers, but notably excludes a one-time shipping fee, as well as any HEPA purifier related awareness programming. The wholesale 5 year cost per purifier is $838.50, while they retail at $1172.50.

Maintenance

The purifiers and community owned sensor network also necessitate a comprehensive plan for maintenance and longer term management (and a need for additional related personnel). While the development of that specific plan is outside the scope of this specific effort, in creating this strategic plan, a number of recommendations became apparent.

Some maintenance to the community owned sensor network is crucial to ensuring the longevity of the ambient data monitoring plan. An individual will likely need to spend 2-4 hours per week per municipality ensuring that all sensors in the network are collecting data and transmitting it to the app. Since the app is still in the development phase, there is no existing model for its maintenance, but that maintenance is not included in the 2-4 hour role described above.

If communities hope to attain all of the benefits of HEPA purifiers, maintenance is also essential. Since purifiers will be placed in residences, municipal buildings and other congregate care settings, the maintenance methods differ significantly. In municipal buildings and other congregate settings (schools, daycare facilities, nursing homes etc), those already on building maintenance or facilities staff should also be responsible for the installation and upkeep of HEPA filters; replacing filtration mediums and troubleshooting any issues that arise.

In residences, or other settings where no building maintenance or facilities staff (or equivalent) exists, the installation and maintenance should be done by members of the Department of Public Health for each community. This work will have a substantial implementation period, then require an individual to work approximately 2-5 hours a week until the more taxing period when filters need to be replaced, in which the workload will again increase. While the Department of Public Health is the ideal location for this effort, in the event that staff do not have the bandwidth to do this work, it could also be done in collaboration with a university or community group.

Next Steps

Immediately, these objectives can inform the yearly action plan of the MAPC CHIP working group, and the group (and others interested in this work) can continue the community engagement they already partake in, perhaps aligning it further with the goals outlined in Objective 3. In addition, as more funding becomes available, it will be key to start preparing resources and personnel for sensor network and purifier deployments.

The contents of this plan should be revisited at regular cadences to guarantee progress toward stated objectives. We recommend evaluating different components of this strategy at different times; a shorter cadence to understand data, a slightly longer one to discuss and adapt strategies and an even longer cadence to evaluate longer term health impacts. While these cycles will undoubtedly depend on a variety of external factors (i.e. funding or resources), one example timeline could have the data meetings occurring quarterly, the strategy reflections biannually, and the health outcome improvement discussions every 5 years. These conversations should be among the individuals in the coalition described in objective 3.4, with at least one meeting a year having explicit public invitation.

Conclusion

Guided by this strategic plan, the communities of Chelsea, Revere, and Winthrop will be equipped to make tangible steps toward better air health. This plan represents the culmination of months of research and conversations with air quality experts, municipal officials, and community stakeholders, and provides tangible goals and evaluation metrics. Further, this strategic plan may serve as the blueprint for applications for funding to support its implementation.

Full plan implementation is expected to achieve substantial benefits in the North Suffolk communities. Adverse health outcomes associated with air pollutant exposure represent degraded quality of life, a force driving racial and socioeconomic inequity, and trillions of dollars per year in lost work days, medical costs, and other expenses. By working to strategically reduce residents' exposure to air pollutants through implementation of the plans outlined here, leaders in the North Suffolk communities will make tangible steps toward more just and thriving communities.

Complete implementation of the plan across the North Suffolk communities will likely take years. By leveraging the interactive mapping tool linked above, however, the highest the most important areas can be identified and prioritized for air monitoring and HEPA mitigation investments. Air Partners remains available to support the processes of finding funding and implementing this plan.