# 2018 Air Quality and Health Effects Research Plan

**Background**:

The major goals of NYSERDA's Environmental Research Program are to increase understanding and awareness of the environmental impacts of current and emerging energy options, provide a scientific and technical foundation for formulating effective, equitable, energy-related environmental policies and resource management practices, and build scientific capabilities within New York State (NYS).

There have been many changes in the past few years with respect to energy and environmental policy and energy markets. While there is uncertainty in some areas such as federal policies, states such as New York have developed policies that are buoyed by market trends in renewable energy, natural gas use, and emerging technologies.

Energy policies in NYS and elsewhere are expected to change how and where electricity is generated, how buildings are heated and cooled, and how people and goods are transported. Many of these transformations will result in changes in the emissions profiles of energy sources and their proximity to where people live and work. Some technologies, such as zero-emissions technologies (energy efficiency, solar, wind, hydroelectric power, and electric vehicles) will result in significant emissions reductions. However, given the intermittency of solar and wind energy, they may require some level of backup by other generation sources or energy storage. Similarly, electric vehicles, while non-emitting during operation, do require charging from the grid. Where and when charging takes place will also alter emissions profiles. Combustion technologies are similarly complex. Fuel switching, such as re-powering to natural gas that displaces coal- or #6 fuel oil combustion can result in significantly lower sulfur dioxide ($SO_2$), nitrogen oxide (NOx), and particulate matter (PM) emissions. In contrast, biomass fuels used for heating, combined heat and power, or electricity generation will result in large increases of PM emissions (100- to 2000-fold) and may require emissions control technology to mitigate local air quality and public health impacts. Finally, energy storage technologies will allow for more strategic dispatch of both renewable and conventional energy.

New York is embarking on a comprehensive energy strategy that includes initiatives presented in the State Energy Plan, Reforming the Energy Vision (REV), Clean Energy Fund (CEF), and Clean Energy Standard (CES).

REV and additional initiatives in the State Energy Plan have the following goals to be accomplished by the year 2030:

- 40% reduction in greenhouse gas (GHG) emissions from 1990 levels
- 50% of energy generation from renewable energy sources
- 23% decrease in energy consumption in buildings

Collectively, these objectives will influence energy-related emissions with respect to their spatial and temporal patterns and will also affect ambient concentrations of ozone ($O_3$), PM, their precursors, co-pollutants and air toxics (which include hazardous air pollutants) as well as GHGs. Human exposure to these energy-related pollutants and associated public health effects will change as well. Overall public health and environmental benefits are anticipated by reducing fossil fuel use. However, local and site-specific impacts are more challenging to estimate.

REV, for example, is expected to transform the way in which NYS values, generates, distributes, and manages electricity. Its implementation is expected to result in the increased penetration of distributed energy generation and storage technologies and installation of micro grids. These technologies will include solar, wind, fuel cells, hydroelectric, energy storage, and various combustion technologies, along with an increased use of energy efficiency technologies and demand-side management measures to address peak load demand on New York's electric system. The REV effort contains more than 40 initiatives to build a clean, resilient, and more affordable energy system, including:

- The NY-Sun Incentive Program aims to add more than 3 gigawatts (GW) of installed solar capacity in the State by 2023.
- New York has an Offshore Wind Master Plan for 2.4 GW to be developed by 2030.
- Charge NY is an initiative to encourage installation of 10,000 electric vehicle charging stations and encourage electric vehicle adoption.
- New York Truck – Voucher Incentive Program provides incentives for clean vehicle technologies to provide for the purchase of alternative fuel vehicles and verified diesel emission control technologies. https://truck-vip.ny.gov/
- New York Prize is a first-in-the nation competition to help communities create micro-grids – standalone energy systems that can operate independently in the event of a power outage. This helps communities reduce costs, promote clean energy, and build reliability and resiliency into the electric grid and will also help modernize NYS's electric grid system. Micro-grid projects selected include the use of solar and natural gas-fired combined heat and power systems with selective catalytic reduction [for NOx reduction]. Some facilities with existing diesel generation will be adding diesel particulate filters.
- NYS anticipates deploying 1,500 MW of energy storage by 2025.

Large changes to the electric transmission and distributed grid will be needed for implementing REV. The Department of Public Service has a proceeding underway to enable an increase in overall Distributed Energy Resources (DER) penetration and more accurately compensating for the benefits that DER installations provide to the system. One of the factors is environmental benefits. The Environmental Research Program can help inform policy-makers of the environmental and public health benefits of DER spatially and temporally. For example, a solar installation may have higher economic value in a congested area of the grid due to the locational based marginal price (LBMP), but it may also have greater environmental benefits as well, especially on high electric demand days if it can prevent higher emitting resources from being required. More information may be found at: http://www3.dps.ny.gov/W/PSCWeb.nsf/All/8A5F3592472A270C8525808800517BDD.

A wide range of distributed generation and emission control technologies exist, and in some cases, distributed generation will displace a larger emissions source and decrease both local air pollution and human exposure. However, distributed generation may contribute to adverse local air quality and public health impacts depending upon fuel choice and the specific siting location. Understanding the operational cycles and exhaust gas temperature in detail as well as the site-specific landscape and meteorology are important for project design. For example, placement of a new source within an urban canyon where emissions cannot easily disperse could adversely impact people at street level, through operable windows or air intake units and this must be avoided.

Along with the initiatives stated above, the New York State Department of Environmental Conservation (NYSDEC) is developing a rule for distributed generation sources. This will assist NYS in planning to meet the National Ambient Air Quality Standards (NAAQS) for ozone ($O_3$) and continuing to meet the NAAQS for fine particulate matter (PM2.5). More information may be found at: http://www.dec.ny.gov/regulations/104487.html.

In 2015, the NAAQS for $O_3$ was strengthened from 75 to 70 parts per billion (ppb) and will soon be under review again. The NAAQS for PM2.5 is currently under review. Decisions at the federal level to no longer pursue the Clean Power Plan and potentially delay implementation of the NAAQS may also have an impact on emissions sources and air quality within, upwind and downwind of NYS. Despite the uncertainty of federal policy, the energy markets have continued to make solar and wind power development competitive with natural gas and coal.

Governor Cuomo's 2017 State of the State Address called for "Health Across All Policies," and directs NYS agencies to consider public health and human health considerations into all decision and policy making. Use of zero and low emissions technologies promotes a healthy and safe environment and may reduce chronic disease in burdened communities in NYS by improving outdoor air quality and reducing exposures to PM2.5, $O_3$, and air toxics. Considerations for distributed generation projects under REV will be critical to avoid unintended consequences in short-term human exposure at the community or neighborhood level, especially in such high population densities as New York City (NYC), and to prevent backsliding on the gains in air quality and associated human health benefits over the past two decades. More information may be found at: https://www.health.ny.gov/prevention/prevention_agenda/health_across_all_policies/

A new generation of monitoring technologies offers opportunities for improved spatial, temporal, and vertical observation of air quality and meteorology, and can improve exposure assessment. These include measurements by satellites, remote sensing (e.g. from rooftops, aircraft, or vessels), multiple low-cost monitors, and New York's state-wide MESO-scale NETwork (MESONET) capable of providing high-quality weather and climate data.

Together, these policy objectives, technical innovations in energy technology and management, market changes, and emerging scientific capabilities will present opportunities and potential challenges for air quality and public health in NYS. This Environmental Research Program area will support research to improve the scientific and technical foundation for the key policy-relevant questions in the Environmental Research Plan as described below.

# B. AIR QUALITY AND HEALTH EFFECTS POLICY-RELEVANT QUESTIONS

The Air Quality and Health Effects area of the Environmental Research Program will support research to improve the scientific and technical foundation for the following key policy-relevant questions:

- What are the links between energy sources, emissions, ambient concentrations, and exposures for energy related emissions (e.g. criteria, precursors, air toxics) in New York environments?
- What are current energy-related greenhouse gas emissions source locations and strengths, and how might they change due to changes in conventional and renewable energy?

- What are the weaknesses in the energy-related emissions estimates for New York, which, if addressed, would improve the assessment of emissions, air quality, and exposure reduction strategies?
- What are the local and regional emission-reduction measures for PM, $O_3$, their precursors, and air toxics, which will represent a cost-effective means of reducing human exposure?
- Are there mitigation options that can help reduce the specific components of the combustion-related fine particle/oxidant complex that are causing adverse air quality impacts and health effects? What are the impacts of these alternative mitigation options on emissions of climate-forcing agents?
- Given that the recent initiatives in NYS energy policy such as REV, CEF and VDER are expected to result in the increased penetration of distributed energy technology (e.g. microgrids), what are the specific changes that are expected to occur in the power, building heating and cooling, and transportations sectors? What are the anticipated changes (increases and decreases) in emissions, ambient concentrations, and exposure estimates at the local (site-specific) level with annual, daily, and hourly time resolution?
- What are the local and regional implications to NAAQS in the next decade due to changes in conventional and renewable energy markets (i.e. natural gas, solar, wind, biomass, distributed generation, micro grids, etc.)? How might sub-daily patterns or human exposure change?
- Are energy regulations and policies having the intended outcome for reduced emissions, ambient concentrations, and exposure reductions of air pollutants at a regional, local, and site-specific level? How might these benefits be valued?
- Are there changes in the roles of certain atmospheric chemical reaction mechanisms that have resulted due to changes in emissions, including spatial and temporal patterns, or physical processes?

## B.1. AIR QUALITY MONITORING TRENDS ANALYSIS, AND MODELING

In order to address the questions above, it is necessary to continue to characterize ambient air pollutants such as $O_3$, particulate matter, air toxics, their precursors, and greenhouse gases (GHGs). Changes in energy sources and patterns necessitate improved characterization of air quality at the local level. There is great interest in organic species due to their large contribution to PM2.5 mass and a need for greater understanding of semi-volatile species and the atmospheric processes controlling them. Due to the importance of organic species, Topic B.1.a focuses entirely on improving the monitoring, characterization, and understanding of atmospheric processing of organic PM2.5 and precursor species. However, there is still a need to characterize other non-organic trace species resulting from combustion or atmospheric processes (Topic B.1.b). Characterization of methane and other greenhouse gases and air toxics is also needed.

A new generation of monitoring technologies offer opportunities for improved spatial, temporal, and vertical observation of air quality and meteorology and can improve exposure assessment. These include measurements by satellites, remote sensing (e.g. from rooftops, aircrafts or vessels), and New York’s state-wide MESO-scale NETwork (MESONET) are capable of providing high-quality weather and climate data. Several MESONET sites are or will be located within NYC, and many of these are enhanced with vertical profilers to measure vertical wind profiles up to 3 km, vertical temperature and moisture profiles, and sky conditions.

The NOAA/NASA GOES-R geostationary satellite was launched successfully in November 2016 and will begin to produce operational aerosol optical depth (AOD) data in fall of 2017 with much higher precision than previous GOES series: see http://www.goes-r.gov/education/docs/fs_aerosols.pdf .

The ESA/SRON TROPOMI instrument will be launched in October 2017 and will have global daily coverage for NO2, formaldehyde, and methane at 7 km resolution. The operational data stream will begin in early 2018. See http://www.tropomi.eu/.

The NASA TEMPO geostationary instrument will be launched in the 2019-2020 time frame and will provide hourly data over North America with ~2.1 (N/S) x 4.4 km spatial resolution for ozone (including sensitivity to ozone in the lowermost troposphere), NO¬2, and formaldehyde; see http://tempo.si.edu/overview.html .

The data from these satellites will improve upon the horizontal temporal (and vertical for ozone) resolution of existing space-based air quality products. These advances will improve the capacity for satellite products to improve understanding of ozone transport and formation mechanisms that cannot be captured by ambient monitoring networks.

Improved modeling tools for trends analysis as well as for accountability studies (Topic B.1.c) will be necessary to predict or validate whether emission-control measures and energy policies are having a beneficial impact on air quality. This section of the research plan will also focus on opportunities in integrating air quality observation systems with chemical transport models for improved air quality forecasting (Topic B.1.d) and for multipollutant air quality management strategies (Topic B.1.e).

## Topic B.1.a: Combustion Products—Improve Monitoring, Characterization, Trends, and Understanding of Processes Involving Organic Species

Problem Statement

Energy production and use involves multiple fuels that, when combusted, emit gaseous and particulate carbon compounds (organic carbon [OC] and elemental carbon [EC]). These carbonaceous species affect the formation of secondary aerosol particles and ozone. The chemistry and nature of these compounds are the least well-characterized of all air pollutants, yet organic carbon compounds comprise more than 40 percent of the PM2.5 mass in New York City on an annual basis. Understanding the sources and processes by which organic carbon compounds form PM2.5 is critical for developing effective control strategies. Advancing our knowledge of the organic carbon compounds including air toxics in air pollution depends on combined measurements of speciated volatile organic compounds (VOCs), semi-volatile organic compounds (SVOCs), and secondary organic aerosols (SOAs). Only with combined measurements can a complete description of the organic fraction in air be determined.

Research Focus

PM: Improved spatial and temporal measurements of speciated organic aerosols are needed to assist in identifying the sources and concentration gradients of organic aerosols in New York State. Source apportionment using additional tracers to identify major source types, regions, or pollution events may be useful. In addition, highly time-resolved data of organic PM species may assist in identifying diurnal patterns of secondary aerosol production and the processes involved. The interpretation of this ambient data will need to be supplemented with ambient VOC measurements and emissions inventory data (Topic B.2).

Technologies for vehicles are changing and more electric and hybrid-electric vehicles are entering the fleet. Vehicle ownership is trending downward and more complete street planning allows for alternative transportation. These changes in emissions, localized and regional ambient air quality and exposure also need to be characterized.

Measurements of PM2.5 and OC in rural regions show that biomass combustion for heat and power is the major contributor to wintertime rural PM. Wood smoke is also a significant contributor in urban locations. In Rochester, NY PM from wood combustion has been observed to contribute 30% of PM2.5 mass during winter. Topography and meteorology greatly impact ambient wood smoke concentrations and exposure. There is a need to characterize emissions and ambient concentrations due to wood combustion and trends over time on a local level as new technologies are phased in and older inefficient ones are retired.

VOCs: Improved information is needed with respect to VOC sources, role in aerosol formation, role in ozone formation, control technology options, and data gaps. There is a need to better quantify VOCs, air toxics, and other species not previously measured that may indicate changing roles in emission source sectors relevant to $O_3$ and PM2.5 formation as a result of historical VOC control measures. A number of biogenic and consumer product VOCs along with their oxygenated products and related species in the atmosphere have previously been difficult to measure, but analytical instrumentation techniques have improved over time. Better quantification of these species and derived atmospheric products would help inform the need to revise chemistry mechanisms in air quality models that have not previously incorporated these more reactive species because of the historical dominance of mobile source VOCs. Activities under this recommendation would seek to apply more recent analytical techniques to measuring atmospheric species in answering the following questions:

- What are the atmospheric species to measure in order to determine the relative abundance of combustion-related vs. non-combustion-related VOCs? Possible candidate species may include more oxygenated larger VOCs and siloxanes (these are more specific to consumer products).
- What is the relative importance of oxidized biogenic VOC products in the atmospheric chemistry of ozone and PM2.5?

In addition, highly time-resolved measurements of speciated ambient VOCs are needed for both anthropogenic and biogenic species, to estimate the significance of their impact on photochemical oxidant cycles leading to $O_3$ and secondary organic aerosol, regionally and locally. This may also require measuring other oxidant species.

Data interpretation needs to consider not only the spatial and temporal distributions of VOCs and secondary organic aerosols, but also the potential for end-product formation during atmospheric processing (e.g., formaldehyde, acetaldehyde, acrolein, organic nitrates). In addition, air toxics also need to be characterized locally and regionally.

## Topic B.1.b: Atmospheric Species—Improve Monitoring, Characterization, Trends, and Understanding of Processes

<u>Problem Statement</u>

The production, transport, storage, and use of energy results in emissions of many gaseous and particulate chemical species. These emissions may be involved in numerous complicated atmospheric processes, including $O_3$ production and aerosol formation. Information is needed to characterize atmospheric species, including trace gas concentrations, particle size distributions, and chemical composition of aerosols. The species of interest in the atmosphere include not only those species that are directly emitted or that are formed through atmospheric chemistry, but also intermediate species that can provide insights into the chemistry. Beyond ground-based measurements, the vertical profile and spatial distributions of aerosols and gases are needed for improved understanding of atmospheric processing and air quality management.

<u>Research Focus</u>

- Perform highly time-resolved measurements of NOy, NOx, $HNO_3$, HONO, PAN, $H_2O_2$, CO, $CO_2$, $O_3$, $NH_3$ organic peroxides, OC, and VOCs in urban and regional atmospheres in New York State to improve the quantitative understanding of atmospheric oxidation cycle and ozone production.
- Measure ground-level methane to characterize and estimate methane gradients adequately, identify sources of direct or fugitive emissions and inform the methane inventory.
- More fully assess existing monitored air pollutant data sets from the Photochemical Assessment Monitoring Stations (PAMS) network[1] as well as other data (e.g. supersite locations such as Pinnacle and Whiteface; IMPROVE sites; satellite measurements) for New York to construct a history of NMOC speciated data for comparative regional and urban trend analysis. A more comprehensive assessment of the PAMS data can inform planning needs, such as:
    - Has the volatile organic compound (VOC) reactivity changed over time due to pollution control programs, changes in technologies, fuels, activities, or other changes? What fraction of VOC on a reactivity-weighted basis is emitted by vegetation? Has this changed over time?
    - Are there changes in VOC speciation trends over time that have implications for enhanced or diminished formation of organic carbon PM species at the local and regional scales?

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[1] The 1990 Clean Air Act Amendments required enhanced research-oriented monitoring in areas classified as serious non-attainment for the then existing 1-hour ozone standard. The PAMS network was required to provide data to: evaluate control strategies; pollutant and metrological data for photochemical grid models; evaluate source emission impacts; detect trends; support attainment designations and maintenance plans; and evaluate exposure to air toxics. New York State has collected PAMS data from a Queens site that it now plans to move to an existing Bronx site. NYS DEC also plans to establish a new PAMS site on the north shore of Long Island near Stony Brook. Historical PAMS data have also been collected at PAMS sites in NJ and CT.

  - If a VOC reactivity change has occurred, does it have implications for the sensitivity of ground-level ozone formation?
  - Do current air quality models used for simulating ozone and PM2.5 formation adequately represent the key VOC species observed in the PAMS data set?
  - Are there detectable VOC species trends in the NYC area due to low sulfur fuel oil requirements and energy technology conversions from fuel oil to natural gas? For example, have air toxics changed significantly over the years in the NYC area, and if so, can they be attributed to changes in fuel types and characteristics?
  - Have consumer product VOC emissions become significant in the NYC region? If so, what are the implications of this for PM2.5, ozone, and air toxic reduction strategies?
- Review and interpret existing oxidant measurements in selected urban and rural sites and combine with photochemical modeling to look for improved measurement overage and indicators of anomalies that could influence $O_3$ chemistry.
- Expand VOC and PM-OC speciation measurements to include quantitative tracers of biogenic or natural components, primary OC and secondary OC vs. anthropogenic components.
- Measure ambient ammonia concentrations to identify its spatial and temporal distribution, source types, and its role in secondary particle formation.
- Characterize particle-size distributions in New York State on a highly time-resolved basis to identify source types and dynamics in particle production and growth. These measurements should be performed alongside detailed measurements of gaseous compounds and speciated aerosols in the ultrafine, accumulation mode, and coarse thoracic size ranges.
- Expand the use of remote sensing. Research is needed into multisensory-data analysis from different instruments, which can potentially improve vertical, spatial and temporal resolution of air pollutants such as $O_3$, PM, and quality of aerosol optical data, for estimating coarse/fine-mode fractions, separating absorbing and non-absorbing aerosols, or observing plumes from aloft or from peaking electricity plants, and particle formation events. Remote-sensing data, such as that measured by satellite or roof-top mounted remote sensing instruments or aircraft, can help to provide spatial and vertical pollutant distributions, identify sources, improve emission inventories and evaluate modeled distributions of trace gases and aerosols where monitors are lacking. Intensive satellite observations with very high resolutions zoomed in on one area such as the NYC region could be considered. Validation measurements such as those at long-term monitoring sites should also be performed.
- Perform updated analysis comparing trends in monitoring vertical distribution of pollutants over the NYC area, and compare to surface measurements. Beyond ground-based measurements in PAMS, there are also historical data sets from the International Consortium for Atmospheric Research on Transport and Transformation (ICARTT) in 2004 that provide vertical profile and large-scale spatial distributions of aerosols and gases downwind of NYC. More recent aircraft flights by the University of Maryland (UMD) (flights are funded by several NESCAUM states) are underway in the 2017 and 2018 ozone seasons to collect VOC, NOx, and aerosol-related measurements over Long Island Sound. The ICARTT data sets and more recent UMD flights provide a basis for investigating historical trends over Long Island Sound and at higher altitudes not completely captured by on-shore surface measurements. They also provide planners with an indication of how well surface monitors along shorelines like Long Island Sound reflect

pollutant species and chemistry occurring over water and at higher altitudes (important for downwind transport assessments). Questions that may be investigated include:

  - Given changes in precursor emissions, how has the surface level OH and $HO_2$ radical budget changed in the last decade, and what are the implications for $O_3$ and secondary PM2.5 formation and regulatory control strategies?
  - Has the vertical atmospheric chemistry (i.e., pollutant profiles with height) in and downwind of NYC changed since the ICARTT measurements? If so, can these be attributed to regulatory programs and energy transitions?
  - Do precursor pollutant ratios in the vertical profiles provide useful information on trends in $O_3$ sensitivity to past and current VOC and NOx control programs?
  - Do the ICARTT measurements and more recent studies provide an adequate baseline for assessing future changes in air quality resulting from energy transitions? Are there anticipated indicator species not in the present data sets that could be added to current monitoring programs or field campaigns?
  - Can near-shore surface pollutant measurements along Long Island Sound provide the same information as over-water measurements?
  - Evaluate the additional need for focused measurement campaigns in NYC.
- Develop methodologies for interpreting satellite or remote sensing data in terms of air quality parameters of interest for air planning and public health (surface quantities). For example, aerosol optical depth has been used as a proxy for surface PM2.5, but the correlation between these two measurements is complex and needs to be better understood.
- Measure PM2.5 species, particle size, and gases using a high temporal resolution for better source identification and apportionment, process studies, identification of contributions by major events, support of exposure assessments, health studies, and trend analysis. Samples for analysis may include archived samples from previous studies, or from multiple monitors in a small geographic (e.g. neighborhood or site specific) area to maximize research value.
- Better characterize trace metal speciation present in PM and develop spatial-scale microenvironment measurements.

## Topic B.1.c: Trends Analysis, Tool Development, Model Evaluation, and Accountability Studies

<u>Problem Statement</u>

Recent trends analyses have demonstrated that $SO_2$, NOx, PM2.5 and aerosol sulfate have been decreasing significantly over the past decade across NYS due to state and federal air quality and energy policies and changes in energy markets. In contrast, annual ozone has not shown a significant decrease, however there are fewer extreme-high levels in summer and an elongated ozone season starting in spring. At the local level, NYC has experienced very large decreases in $SO_2$ emissions due to phasing out of #6 oil. Continued studies are needed to assess how air quality regulatory programs, energy policies, and electricity, heating, and transportation market trends impact air quality and public health, especially locally. This will require improved modeling for energy systems, improved air quality modeling, and observations with high spatial and temporal resolution. This is especially important as distributed generation, renewable energy, energy storage, and electric vehicle markets increase. For example, the

MESONET provides improved meteorological information including mixing height that might be used to improve spatial (vertical and horizontal) and temporal resolution of photochemical and dispersion modeling results for air planning and permitting or distributed generation design.

Research Focus

- Develop improved air quality modeling techniques to support high spatial (horizontal and vertical) and temporal resolution to evaluate local and regional air quality and possibly exposure estimates and health impact analysis. This may be site-specific, neighborhood, or regional scale.
- Develop approaches for evaluation of atmospheric models for improved spatial and temporal resolution to determine:
  - How well do models simulate changes in air quality induced by changes in weather versus changes in emissions;
  - How well do models simulate the dynamics of the energy markets and changes in emissions;
  - The ability of air quality models to estimate accurately the emissions reductions needed to comply with standards or local air quality goals; and
  - Zero-state emissions scenarios in the Northeast for ozone and PM2.5.
- Analyze changes in PM2.5, PM components, NOx, NOy, NHx, VOCs, ozone, CO, $CO_2$, formaldehyde, and other trace gases to determine trends resulting from regulatory programs, energy policies, and changes in energy markets. Approaches may include trends analysis of data from ground-based measurements and remote-sensing techniques, including satellite measurements. Analysis should have sufficient temporal and spatial scope to capture the possible impacts of the regulatory or policy implementation, or market change, on ambient concentrations and exposure levels for New York State residents. A large database of measurements exists for Whiteface Mountain, Rochester, Pinnacle State Park, and Queens College, which is available for trends analysis.
  - Investigate $O_3$ trends and the smaller than anticipated reduction in response to downward trends in emissions.
  - Conduct trends analysis of major gas and particle pollutants using National Emissions Inventory and Canadian inventories.
  - Evaluate whether, and to what extent, global air quality impacts $O_3$ trends in NYS.
  - Investigate why long-term measurements indicate a decrease in PM2.5, sulfate, and nitrate, but an increase in OC. What are likely sources or atmospheric processes that have resulted in this observation?
- Perform accountability analyses to evaluate how changes in regulations, policies, technology or energy use patterns change emissions, and effect local or regional air quality, exposure, and public health. One consideration is to follow a population during a period of this change. This topic relates to Topic B.3. Exposure and Health Effects.

## Topic B.1.d: Integrated Air Quality Observations for Improved Air Quality Forecasting

Problem Statement

There is a need for an integrated air quality observation system that coherently brings together meteorological and air monitoring measurements including satellite and other remote sensing data and

3-D chemical transport models for better air quality forecasts. The ultimate system will be able to make air quality predictions with multiple observations from different platforms. Times of high electricity usage coinciding with stagnation events are of particular energy-relevance.

Research Focus

Research is needed on the development of a regional, integrated air-quality monitoring system in and around NYS to meet NYS air quality and energy policy needs. This would require the creation of partnerships to pull together ongoing research and development in surface sampling and remote sensing of aerosol (AOD), trace gases, and chemical transport modeling. This research topic also relates to Topic B.2.c and Topic B.2.d, which focus on improved emissions estimates. Remote sensing can provide improved spatial and temporal resolution of air quality measurements, filling gaps in existing monitoring networks. As a result, there is a need to understand, assess, and exploit new ground-based measurement strategies to validate satellite products and improve understanding of the connections between new satellite data sources (e.g., GOES-R, TEMPO, TROPOMI)[2] to ground-based remote sensing (e.g. LIDAR, PANDORA) and measurements collected at the long-term monitoring sites. Further, there is a need to continue developing frameworks to assimilate satellite data (i.e. data from vertical profile, meteorological data, and chemical data) into air quality models, and to address model gaps such as the understanding of how pollutants move within the boundary layer. Improved temporal and spatial resolution is needed to better characterize the boundary layer over land and water. Additionally, there is a need to understand and characterize limitations in satellite datasets. For example, many satellite instruments cannot retrieve on cloudy days, and have low frequency of images per day.

- One potential application is in understanding the high levels of ozone observed in air masses transported across Long Island Sound. Because there is a dearth of meteorological measurements, there is a need to develop a better understanding of meteorological conditions, their influence on the evolution and transport of pollution plumes, and the adequacy of near-shore meteorological measurements to represent conditions over Long Island Sound. Are on-shore profile measurements adjacent to Long Island Sound consistent with vertical structure over Long Island Sound?
- As seen by the meteorological measurements, do air quality models contain sufficient vertical resolution to adequately predict chemical evolution and transport of pollution plumes over water?
- Is there a strong sea breeze effect influencing shoreline pollutant levels transported over water in Long Island Sound, and if so, are air quality planning and forecasting models capable of capturing these on high pollution days?

## Topic B.1.e: Improved Energy-sector Modeling for Energy and Environmental Policy Evaluation

Problem Statement

Enhancement of New York's electricity-sector modeling capability is necessary to more fully evaluate the impacts of existing and proposed energy and environmental regulations and policies on the electricity-

[2] For more explanation of new generation satellites, see Background section.

generation sector. Critical issues include emissions, electric system operation, markets, wholesale prices for energy and capacity, allowance prices, fuel use and diversity, imports and exports, new capacity needs, new technologies, plant retirements, integration of micro-grids, distributed generation, energy storage, electric vehicles, building energy systems, and electric system reliability. It is important to further develop and refine the capability and tools to analyze both generation and transmission systems with high temporal and spatial resolution. This capability will enable the comprehensive analysis of New York policies as well as policies developed at the regional and national levels, informing decision-makers in developing sound energy and environmental policies.

Research Focus

The following are needed improvements to specific modeling capabilities:

- Improve the capacity to model operation of oil/gas steam-generation units and the associated air emissions, which largely occur in the Downstate non-attainment areas. Improve the model representation of overall operation of units, including fuel-switching between oil and gas, that is due to factors other than economic dispatch. Factors to consider and quantify include reliability rules, local operation requirements due to load pockets, fuel availability/supply disruptions, fuel storage capability, start-up and ramp-up times, short-term environmental limitations, short-term price and supply expectations, extreme weather, forced outages, transmission constraints, unplanned transmission outages, and monthly, weekly, daily, and hourly load shapes.
- Improve the capacity to model operation of oil/gas-turbine peaking units and the associated air emissions that impact air quality at critical times.
- Improve the capacity to model imports and exports of electricity to and from the region. Imports are largely dependent on appropriate representation of the transmission system.
- Improve the representation of new generation and transmission technologies, renewable sources and markets, end-use energy-efficiency technologies, energy storage, microgrids, combined heat and power, and emission control technologies.
- Improve the capacity to incorporate as model inputs the changes in power flows that may occur as a result of system changes.
- Improve the capacity to develop links between various models, whereby output from one model becomes critical input for another model with a different function. For example, yearly new generation requirements estimated by the multi-year Eastern Regional Technical Advisory Committee (ERTAC) can be used as input data for the detailed, single-year Multi-Area Production Simulation (MAPS) model. Another critical link is the capability to use hourly point-source emission output data from MAPS as input to the multi-dimensional episodic air quality model used by the NYSDEC.

The following are examples of specific modeling analyses that are needed:

- Model high-electricity-demand days by evaluating the hourly emissions impacts on a single design peak day, to estimate impacts of controls on specific generation units, demand-response programs that temporarily reduce electricity load, and permanent demand reductions due to energy-efficiency programs.
- Model the impacts of achieving proposed energy-efficiency and renewable targets and proposed appliance and equipment standards.

- Model emissions scenarios for REV development especially regarding timing and spatial distributions across NYS and related to the multistate region.
- Develop a foundational study on a prediction methodology for future emissions in response to REV to 2030 and beyond.
- Model the impacts of energy and environmental policy proposals on local energy use and resulting emissions, air quality, and health effects with high spatial and temporal resolution.
- Model improvements in the transmission system, including new lines and new technologies (e.g. microgrids).
- Model energy and emissions scenarios for wide-scale adoption of new vehicle technologies (electric, hybrid, idle reduction) and in fleets with limited geography such as at airports.
- Improve and apply energy models to better characterize the air-quality impacts of distributed generation and microgrids including when operating in islanded mode or with energy storage at the neighborhood scale. This is challenging due to the low stack height and influence of surrounding buildings and terrain.

### Topic B.1.f: Multi-Pollutant Air Quality Management Strategies

Problem Statement

Air quality management appears to be more effective and efficient if plans are designed on a multipollutant basis, including criteria pollutants, hazardous air pollutants (HAPs), and climate-forcing agents (Topic B.2.d). This approach would apply to development of emission controls for energy production and use, including emerging technologies and mobile sources. The technical basis of such an approach needs to be evaluated in a New York State context.

Research Focus

- Examine potential opportunities for optimizing emission controls for interrelated pollutants ($O_3$, PM and their precursors, mercury, greenhouse gases, etc.) in New York State and the region while minimizing potential adverse side effects.
- Explore reactivity-based control strategies and potential effects on regional ozone and secondary PM formation. This should include strategies for optimizing control measures for specific source types (with consideration of new energy technologies and fuel changes) on NOx, NOy, VOCs, $O_3$, $SO_2$, and other photochemically active trace gases.
- Model multi-pollutant strategies to evaluate the degree to which various programs interact with each other in achieving environmental goals.

## B.2. SOURCE CHARACTERIZATION, POLLUTION CONTROL TECHNOLOGIES, AND EMISSIONS ESTIMATES

There is a need to improve the quality of emissions inventories that are widely used for multiple applications, including state implementation planning (SIPs) (through air quality modeling), air quality forecasting, emissions and air quality trends analyses, source attribution studies, human exposure studies, and accountability-type studies. For example, many electric generating units are well characterized due to continuous emission monitoring, but older peaking units used on high-electric demand days do not have continuous emissions monitors. Efforts here should emphasize those source types related to energy production, transport, storage and use that are currently not adequately characterized, including but not limited to: peaking electric generating units, back-up generators, and distributed generation technology; use of number 4 oil, number 6 oil, or biofuels for heating or power production; mobile sources on-road, off-road, and in ports and airports; trains and pipelines used for fuel transport, fuel depots or other storage (including trains), and residential wood combustion. Emissions estimates need to be made on finer spatial and shorter temporal scales, and to establish chemical speciation of emissions (with focus on speciation of emissions for both primary fine PM and VOCs). More complete emissions profiles are desired including measurements during start-up, steady state, and shut-down phases of operation, and emissions including PM, PM components (e.g.. BC), NOx, VOCs, $SO_2$, particle number, air toxics and GHGs.

## Topic B.2.a: Emissions Estimates—Better Characterization of Poorly Characterized Sources and Pollutants

Problem Statement

Much of the current emissions inventory is based on emission factors that in some cases are more than 20 years old. Due to changes in technology, activity patterns, and emissions of interest, there is a need to evaluate the current inventory to identify those source categories that are poorly characterized and to improve the inventory by improving emissions factors and activity data. Recently, there have been important changes in energy technologies, fuels used or their activity patterns, and domestic fuel extraction (current and legacy). Due to regional variations in air quality and source types, and the cost of measuring emission factors, efforts to improve the emissions inventory should consider having a regional focus and involve adjacent states and U.S. EPA.

*Mobile Source Emissions*: With respect to mobile source emissions, there have been significant improvements in technologies including hybrid and electric vehicles and increases in efficiency and reductions in emissions. Along with technology advances, other factors are influencing transportation emissions over time, such as changing durability of the control technologies and different vehicle operating conditions, which can include the influence of driver behavior and operational (including illegal) bypasses of emissions control equipment during on-road driving.

The dramatic changes in vehicle emissions over time may not be adequately captured in current mobile source emission inventory estimates, such as EPA's Motor Vehicle Emission Simulator (MOVES). An assessment specific to the NYC region is needed to determine the adequacy of the current mobile source NOx emissions inventory. This is a significant issue since air quality modeling suggests that ground-level ozone is highly sensitive to transportation NOx emissions.

In addition to NOx, the rapid decreases in transportation VOC emissions are shifting the urban VOC budget away from energy (e.g., gasoline, diesel) to non-energy related sources (e.g., coatings, adhesives, consumer products, vegetation). If the VOC species mix in and around NYC is changing, it has implications for the reactivity of the evolving VOC composition in the formation of ground-level ozone and organic carbon PM2.5.

*Methane:* In 2018, the National Academy of Sciences (NAS) Committee has developed a report on anthropogenic methane emissions in the U.S. (funded by EPA, DOE, NOAA, and NASA) and their focus is to improve measurement, monitoring, reporting, and development of methane inventories. There remains a need to combine strategies for improving air quality and reducing greenhouse gases by improving the methane inventory in NY. This need may be addressed by understanding methane emissions as well as identifying the sources of methane emissions and the technology to find and measure these emissions.

*Ammonia:* While NOx and $SO_2$ emissions are decreasing, ammonia emissions are increasing. Major sources in NYS include agricultural and animal operations, fertilizer applications, and urban and regional transportation sources. An EPA Clean Air Science Advisory Committee (CASAC) panel is currently reviewing the secondary NAAQS for SOx and NOx to protect "environmental health" and NOx would include both oxidized N (NOy) and reduced N (ammonia and ammonium).

*Oil and Gas:* Oil and gas use and emissions patterns are changing. Mobile sources were described above but there are residential, commercial, and industrial applications using oil and gas fuels that need more complete emissions estimates. There is also domestic oil and gas extraction currently taking place in upwind areas as well as NYS. Fugitive emissions result from fuel storage, transport systems (e.g. trains and pipelines), extraction operations, and abandoned wells within NYS. Improved estimates of all of these emissions are needed.

Research Focus

Research should focus on those emissions inventories with greatest uncertainties. Examples of energy related sources in need of improved inventories are: stationary diesel engines; mobile sources, including passenger vehicles, diesel buses and trucks, and non-road equipment; marine vessels; locomotives; stationary commercial and residential boilers and furnaces; electrical generating units (including peaking units); distributed generation units; pipelines; trains; compressor stations; and storage depots. Emissions of primary particle by size, speciated PM emissions, PM precursors, $O_3$ precursors, VOCs, non-methane organic compounds (NMOCs), air toxics, hazardous air pollutants, methane, and ammonia are high priorities for improvement. This characterization includes understanding emissions outside the average operation such as upsets, start-ups, and shut-downs. In addition, emissions from back-up generators need better characterization because of their use on high electricity-demand days. Satellites and other remote-sensing techniques may provide improved measurements of temporal variability in emissions and top-down estimates for comparison with bottom-up emission inventory estimates. Intensive satellite observations with very high resolutions zoomed in on one area, such as the NYC region, could be considered.

*Mobile Sources:* Investigate the adequacy of mobile source emission inventories currently used by air quality planners to appropriately estimate NOx, VOC, and other emissions (e.g. elemental carbon, air toxics) from the transportation sector. Also refine estimation of major sources like seaports and airports in NYC or NYS. Potential questions to address include:

- Do field measurements and/or fuel-based estimates of NOx emissions in the NYC region reasonably agree with estimates from MOVES or other models used in air quality modeling?
- If transportation VOC emissions have significantly declined, are the other non-energy VOC sources adequately quantified in emission inventories used for air quality planning?
- Can current mobile source inventory models such as MOVES adequately capture prospective pollution changes from transitioning the mobile source fleet in the NYC region to electric and alternative-fueled vehicles?

*Methane:* Develop a refined gridded bottom-up methane inventory for NYC, NYS and the region by source categories (natural gas and petroleum systems, waste water treatment facilities, enteric fermentation and manure management, other agriculture processes, soils, forest sinks and wetlands, waste landfills, other land management techniques; offset credits, etc.). Top-down studies (e.g., aircraft, satellites) could be used to reconcile top-down and bottom-up approaches. In addition, identify reasonably available methane detection technology and develop a list of oil and gas sector equipment and which technology may be used to identify leaks from that equipment. Furthermore, differentiate between leak detection technology used to identify leaks vs. technology used to measure leaks.

*Ammonia:* Develop a robust state and regional level $NH_3$ inventory. Top-down studies (e.g., aircraft, satellites) could be used to reconcile top-down and bottom-up approaches.

*Oil and Gas:* Develop an updated inventory for emissions from oil and gas extraction, storage and transport systems including pipelines, trains, compressor stations, and distribution systems. Beginning with the sources covered in the EPA oil and gas tool, ensure that inputs and assumptions are correct, and refine data such as components per well (i.e. separators). Categorize activities with the appropriate source classification codes (SCC) and assign emissions (methane, VOC, toxics) to each SCC. Furthermore, it is important to distinguish emissions on a county and basin level.

- Useful inventory types
    - Pollution emissions inventory – which pollutants and at what rate out of each process, characterization of leaks.
    - Equipment inventory – for example, how many pneumatic devices? Driven by gas or air? Low bleed vs. high bleed?
- An assessment of “small” facilities vs. “large” facilities. Several studies show a phenomenon called a “fat tail” meaning most emissions come from a small amount of facilities which are typically smaller operations.
- Determine the extent of emissions after the city gate (i.e. going to the homes & businesses) vs. before the city gate.

## Topic B.2.b: Emissions Inventory—Micro-Inventory

Problem Statement

Emissions inventories tend to represent broad geographical areas and relatively long-time intervals. As a result, the data are of more limited value to air quality modeling and exposure studies on shorter time intervals. There are localized geographical areas of high emissions density where concentrations cannot be predicted by the inventory. These hotspots often are located in densely populated areas. Human exposure is a result of many individual sources, such as commercial buildings burning fuel for domestic hot water and space heating, highly congested roadways, construction equipment, and industrial facilities. Increased distributed energy generation, changing energy-use patterns, emerging technologies such as combined heat and power, condensing boilers, ground-source and air-source heat pumps, and increased use of natural gas, low-sulfur fuels, liquid bio-fuels or biomass fuels will change building source profiles. Improvement in the inventory of emissions sources, fuel types, and activity patterns is essential for improved pollution-mitigation planning, air quality forecasting, and exposure assessments.

Research Focus

Develop “micro-inventories” through pilot-scale studies (including method development) with the goal of improving or ground-truthing the current inventory (e.g., boiler size, commercial activities, back-up generators) and supporting concurrent or subsequent exposure studies at the community-level scale.

These studies must resolve and/or estimate the emissions at much finer spatial (a few hundred meters) and temporal (an hour or less) scales than traditional inventories, which are generally at the county level and are based on annual or seasonal averages. Their development should also be tied to specific human exposure studies.

There is a need for gridded inventories for NYC and the region to improve spatial resolution and photochemical model results.

### Topic B.2.c: Emissions Inventory—Improved Estimation of Seasonal Emissions

Problem Statement

Energy-related emissions vary seasonally depending on fuel use, fuel availability (e.g. wind and solar), home heating needs, transportation patterns, electrical demand, natural sources and meteorological conditions. Improved emissions inventories are needed to adequately describe these changes and improve emissions estimates. One special case is high-electricity-demand days (HEDD) in summer. These days occur when conditions are very hot, air conditioning use increases, and the demand for electricity is very high. This leads to emissions of PM and ozone precursors at levels higher than modeled by air quality planners, due to increased generation at some plants and the start-up of “peaking” plants (often combustion turbines or diesel engines) to meet the increased load. Additionally, back-up generators in highly populated areas with emissions rates much greater than central station plants are used to support load on the electrical grid. New micro grids will emerge as well, and will need to be characterized for actual operational duty cycles. When meteorological conditions are stagnant, emissions are prevented from dispersing quickly. This results in high ozone and PM in the ozone transport region, often close to or exceeding the NAAQS. Improved emission estimates are needed for these days in order to develop emissions-reduction strategies, including increased energy efficiency, renewable energy, energy management strategies, and improved air quality forecasting. Estimates also need to take into consideration the effect of climate change on biogenic emissions and seasonal variability.

Research Focus

Substantial improvements in systematic estimation of emissions by season using innovative methods are needed, with high spatial and temporal resolution.

Where practical, efforts should be coordinated with the micro-inventory effort. Research is also needed to identify the meteorological and other conditions that result in the operation of sources, as well as emissions from start-up and shut-down operations. Understanding these conditions can provide the basis for more accurately predicting emissions from these units.

A foundational study on prediction methodology for future emissions in response to REV is needed, perhaps for 2030.

## Topic B.2.d: Source Characterization—Improved Emission Profiles, Emissions Factors and Activity Patterns

Problem Statement

Current emissions inventories are lacking detailed source-emissions profiles (including chemical speciation of emissions, primary particle size distributions, VOCs, and HAPs) and activity patterns with adequate time resolution.

Even when current emission inventories may reasonably quantify the magnitude of air pollutant emissions in the NYC region, the temporal profile of those emissions, if not also appropriately captured, can have implications for air quality and energy policy. Inadequate temporal profiles of NOx emissions in regulatory air quality models, for example, can affect the perceived effectiveness of NOx versus VOC controls at reducing ground-level ozone.

Furthermore, as energy transitions occur in the NYC area, such as shifts to more local-scale microgrids, energy storage, and increased time-of-day demand periods for electric vehicle (EV) recharging, a baseline needs to be established to evaluate how these future energy-related shifts may affect future air quality. These changes can have profound benefits in the region by shifting generation away from relatively dirtier fossil fuels, but may also have potential adverse effects as more disbursed sources and changes in the timing of emission peaks to serve shifting demand can increase pollutant exposures in local populations, even if the new sources are cleaner relative to a displaced pollution source that may have been much farther away.

There is a need to consider what is happening at the edge of the fuels market. Activity in biogas, biodiesel, other liquid fuels (e.g. pyrolysis oils), and biomass need emissions measurements and methodologies that capture start-up, burn-out, steady-, and transient- states of operation.

Research Focus

First, studies are needed to improve the quality of emissions profiles, emission factors and activity data for those point, area, and mobile (on-road and off-road) sources for which current data are missing or inadequate and to examine emerging technologies. More-sophisticated emissions profiles need to be developed with other stakeholders using dilution sampling for both VOCs and fine PM. Examples of energy-related sources include back-up generators, distributed generation technologies, industrial boilers, construction equipment, residential fuel use (including wood), and commercial/institutional sources of combustion.

Where possible, real-time in-use emissions for all phases of the burn/operational cycle should be measured to compare with tabulated emission factors (e.g., AP-42 values). This will improve the emissions profiles, emissions factors, the inventory, and air quality management. In-use mobile-source emissions characterization studies are examples of the types of studies that are essential because they provide data about rapidly transforming emissions (particle formation and chemical reactions) in air pollution hot-spots. Such hot-spots are not well characterized by regional monitors and are of limited use in identifying the need for pollution mitigation strategies (such as diesel-emission reduction technologies) and exposure studies. This type of study will also support accountability assessments.

Second, studies are needed to examine the temporal distribution of emissions during sporadic or episodic events. The transition to distributed generation will also affect emissions depending on the pace, location, and types of technologies.

Third, there is a need to better quantify the temporal profile and quantity of NOx emissions in the NYC region, especially on high-electric demand days during the summer, that also establishes a baseline for evaluating impacts of future changes in electric generation in New York State and adjacent areas.

Areas to investigate include:

- Do time-resolved remote-sensing measurements of NOx and aerosol profiles in the NYC region during periods of high electric demand (e.g., hot summer days with high a/c load) agree with air quality model predictions? This will also inform air quality and energy planners on whether distributed diesel generation, a potentially high polluting source sector operating only over short periods to meet peak electric demand, is a significant public health concern in the NYC region.
- Can measurements of temporal pollutant profiles in the NYC region provide a baseline to inform assessments of the potential health benefits and costs in shifting to a more distributed generation system that fosters cleaner generation technologies but in closer proximity to population centers?
- Can measurements of temporal pollutant profiles in the NYC region provide a baseline to inform assessments of potential health benefits and costs of increased EV recharging in the NYC region in the event the region's electric demand profile changes over time to support EV recharging patterns?

## Topic B.2.e: Source Characterization—Improved Emission Measurement Method Development

Problem Statement

Improved sampling instrumentation and chemical measurement technologies are needed to better quantify primary PM and gaseous emissions (GHG, PM and $O_3$ precursors) from stationary stacks (including residential, commercial, and industrial technologies), mobile tailpipes, and area sources. In addition, improved chemical speciation is needed. For example, characterization of individual hydrocarbon emissions rather than total VOCs is needed for more source types. Instrumentation for speciated organic PM would also be an improvement over OC measurements and would serve to advance air quality planning.

Beyond improved instrumentation, measurements are needed for sources under varying operational conditions such as start-up and variable loads. Measurements should also be developed under different (seasonal) ambient conditions.

Additional technologies are evolving that could help measure emissions from area sources under actual conditions. Improvements in remote-sensing technologies, whether ground-based, air-based, or satellite based, may provide verification of existing inventories, improved measurement of area or fugitive source emissions under actual ambient conditions, and identification of previously unidentified point sources.

Research Focus

Innovative methods are needed to characterize PM emissions with respect to composition and size and gaseous emissions (GHG, PM and $O_3$ precursors). Source emissions should be characterized under varying operating conditions (start-up, steady-state, shut-down, idle, cruise, partial loads, full load, etc.). Examples of these source types would include but not be limited to residential and commercial boilers and furnaces, distributed generation and combined heat and power. Sampling with a dilution technology direct from a stack for real-time measurements is highly desired.

Measurements should include:

- PM2.5, PM components, NOx, NOy, NHx, VOCs, CO, $CO_2$, $CH_4$, other GHGs, formaldehyde, and other trace gases emissions from petroleum sources and bio-fuels blended with petroleum products in applications including back-up electricity generators; distributed generation technologies; on-road, non-road, and marine diesel engines; and residential, commercial, and utility oil combustion;
- PM2.5, PM components, NOx, NOy, NHx, VOCs, CO, $CO_2$, $CH_4$, other GHGs, formaldehyde, and other trace gases emissions from residential or small commercial operations;
- Speciated organic SVOC emissions from commercial food operations; and
- Biogenic sources of gases and particles, especially wildfires and VOCs.
- New methods are also needed to measure mercury (Topic A.1) and air toxics.

Demonstrations of remote-sensing and data-analysis tools are needed to assess their usefulness in:

- Quantifying primary PM, precursors of secondary PM and ozone, and their subsequent transformation in short time intervals in complex urban environments;
- Quantifying non-urban emissions such as biogenic emissions from area sources;
- Quantifying anthropogenic (sulfate, nitrate, and VOCs) and biogenic (forest fire) emissions transported into New York State; and
- Developing datasets appropriate for use with air quality models for planning and forecasting.
- Characterizing spatial and temporal GHGs emissions (urban, rural, NYS, regional).

Additionally, there is a need for harmonization regarding how to measure ultrafine particles (e.g. particle size vs. mass vs. composition).

# B.3. EXPOSURE AND HEALTH EFFECTS

Critical gaps in the current understanding of the relationships of exposure to energy-related air pollution in New York persist. Recent changes in energy policy, emerging technologies, regulations, and markets in NY and elsewhere will result in changes in emissions to the atmosphere, and will depend on the specific changes in technologies, fuel sources, and activity patterns. An increase in distributed energy generation will change the geographic patterns of exposure to combustion by-products. Given these potential changes, there is a need to better understand how the emissions changes will affect human exposure to energy-related pollution, and ultimately, health outcomes.

## Topic B.3.a: Improved PM Component Exposure Characterization

<u>Problem Statement</u>

While it is now well established that exposure to PM2.5 causes adverse health effects, what remains unclear is whether specific components of PM2.5 and associated co-pollutants are responsible for the observed effects. Atmospheric PM is a complex mixture of chemical compounds resulting from the mixed composition of numerous sources. Studies are needed to improve understanding of the relationships between local exposure and health effects and specific components of PM and co-pollutants. Health effects considered may be acute or chronic health effects (i.e. acute cardiovascular, reproductive, developmental, neurological, chronic pulmonary, etc.).

Research Focus

- Support efforts to augment the available ambient PM speciation data in New York for use in health exposure studies. There is a need to characterize organic species and trace metals in detail to determine if there are health endpoints associated with them. The focus should be on size and chemical components of PM2.5 and associated gas-phase organic precursors. Personal monitors and crowdsourcing may be a valuable tool.
- Review and interpret the progress in PMx exposure and health studies including exposure and health trends since the last federal state of the science report. From this evaluation, indicate the strengths and weaknesses of current state of knowledge and its application to New York conditions.
- Recommend key studies to address weaknesses in the state of the science. Projects of interest might include, but are not limited to, expansion of analytical capabilities of ongoing studies, analyses of archived samples using multi-element/chemical analysis techniques, or intensive but short-duration monitoring campaigns focused around hot-spots of particular concern.
- Projects might address relationships between personal and ambient exposure, augment and strengthen ongoing epidemiologic studies, or support source-apportionment analyses, particularly where epidemiological studies are being considered. To the extent possible, projects should use state-of-the-art analytical methods and capabilities (e.g. assessing exposures in congested microenvironments).
- Better characterize at the local level and over shorter time frames changes in exposure to ultrafine particles and trace species as a result of changing energy sources and distributed energy (e.g., increased use of solar or wind generation with energy storage).
- Projects might evaluate and use remote sensing, multiple low-cost monitors, or personal monitors to measure PM components and co-pollutants over short-time intervals using miniature, light-weight monitors.

## Topic B.3.b: Localized Ambient PM and Co-Pollutant Exposure Characterization

Problem Statement

While general air quality has improved over the past 40 years because of regulatory control programs and more recently due to changes in fuels for power production, geographic areas exist where high-emitting or highly concentrated sources may cause consistently higher concentrations of air pollution than other areas. As distributed energy generation increases, examining pollutant concentrations and exposures in localized geographic areas is increasingly important. Detailed spatial and temporal characterization of concentrations of PM components and co-pollutants is needed to aid exposure studies in areas of major sources such as power plants, back-up generators, distributed generation technologies, microgrids, major express highways, areas of high levels of traffic, warehouse staging areas with high numbers of diesel vehicles, residential communities impacted by wood smoke, or other locations heavily impacted by energy-related sources such as marine ports, airports, and railyards. Spatially-intensive air monitoring is needed to assess concentration gradients, contributions from important source types, exposure assessments, and potential health effects. Activities in these areas could be coordinated with or extend research conducted as part of a micro-inventory (Topic B.2.2).

Research Focus

- Assess the potential health relevance of pollution exposure hot-spots in New York State. There should be a defined residential or occupational population nearby that is potentially impacted by the hot-spot. These might include, but would not be limited to, areas in and around the port of New York, particular neighborhoods impacted by high-volume road traffic, areas affected by a high density of diesel generators or distributed energy sources, or neighbors impacted by high concentrations of wood smoke.
- Characterize the spatial and temporal patterns of concentrations in the vicinity of the hot-spot, e.g., through receptor modeling efforts, by spatially intensive air monitoring, remote sensing, multiple low-cost monitors, or personal monitoring to characterize personal exposures and to assess human health risks.
- Review and interpret current status of studies investigating the combined exposure to PMx and $O_3$ (possibly including PM speciation and other oxidants) applicable to New York urban and non-urban conditions.
- Better characterize spatial exposure of ultrafine particles, trace metals, and air toxics, especially formaldehyde, due to a change in energy sources and distributed generation. Additionally, better understand resultant changes in health outcomes.
- Better assess actual exposure, e.g., exposures in homes and in vehicles. Exposure to pollutants in vehicles can vary considerably depending on the type and age of the car as well as the road debris in the specific area. Health endpoints such as heart rate variability and lung function and asthma should be assessed.
- Obtain additional emissions data for distributed energy sources (fossil units and diesel back-up generators) as new units have significantly different emissions than older units.

## Topic B.3.c: Accountability Studies and Health Impact Assessments

Problem Statement

Studies are needed to perform an analysis of whether emerging energy technologies and environmental policies to reduce emissions yield measurable improvements in air pollution concentrations, exposure, and by extension, human health. Regulatory programs are focused on reducing source emissions. However, there are also emerging sources such as distributed generation technologies that may decrease or increase PM, CO, NOx, $SO_2$, or air toxics exposure. Accountability studies will assess policies to changes in emissions, ambient concentrations, personal exposures, and health effects. Health impact assessments may be performed to determine the effectiveness of a site-specific change in energy technology, or broader energy or environmental policy or regulatory actions on a local or regional level.

Research Focus

- Perform exposure assessments or health impact assessments of locations or demonstration projects with potentially significant changes in emissions such as distributed generation with a microgrid (e.g. NY Prize), distributed generation such as large-scale renewable (solar, wind), energy efficiency, pedestrian/green vehicles zones, or where older technology has been or may be displaced (for example coal fired power plants or "peakers").

- Undertake studies to analyze and/or model exposure and develop risk assessment methods that will help quantify the health benefits of different pathways for achieving carbon goals (e.g., fuel switching, reduction of sulfur in gasoline, or increased use of wood heating). For example, which carbon reduction method would result in the largest health benefits? Examine additional health outcomes (e.g. neurological, pulmonary, and cardiac). Proposals should clearly define the energy or environmental policy of interest or changing energy market and have a plan with sufficient temporal and spatial scope to capture the possible impacts of these regulatory or market changes on ambient concentrations, human exposures, and health risks for New York State residents.
- Explore approaches in applying low-cost techniques to improve measurements in spatial variation of air quality at the local scale. There are demographic and geographic variations in populations susceptible to air pollution effects, but the regulatory monitoring network is not designed to capture spatial variation in air quality at sub-regional scales. Furthermore, current models of emissions have few parts that respond to day-to-day variations in human behavior or weather. On a neighborhood scale, inexpensive sensing can change how we think about emissions and air quality. For example, early results using personal air monitors worn by New York City bicycle commuters suggest it is possible to improve estimates of inhaled air pollutant doses (e.g., black carbon) across highly variable pollution levels encountered during an urban commute ride. In addition, installing higher numbers of low-cost but less precise stationary monitors relative to fewer but more precise regulatory monitors can improve flux estimates of air pollutants for comparison to emission inventories. This has important application to local scale exposures as the spatial extent of urban plumes has significantly decreased over the years, thus increasing pollution gradients within urban cores. The goal of this recommendation is to develop an understanding of how to interpret data collected by a dense network of many individual instruments in a manner that informs planning needs. It would entail learning to think about daily variability in ways that inform planners in developing more effective approaches to reducing local exposures.
- Develop a better understanding of the historical trend in atmospheric formaldehyde and other air toxic concentrations. New York City and State monitoring indicates that while many pollutants of concern have been decreasing over time as a result of pollution control programs and shifts in energy use, one important air toxic, formaldehyde, appears to be increasing. The reasons for this trend are not fully understood. One possible explanation related to energy trends is a postulated increase in secondary formation of formaldehyde as a by-product of increased natural gas and biofuel combustion. An alternative explanation (or in addition to) is that secondary formaldehyde formation in the atmosphere has become more rapid in recent years as a result of NOx reduction programs. Formaldehyde can also be a useful indicator species in conjunction with NOx for assessing the relative effectiveness of NOx versus VOC control measures, and in evaluating changes in atmospheric chemistry over time as a result of pollution control programs. Research questions to address include:
    - Why have formaldehyde concentrations increased in the New York City region while many other air pollutants are decreasing?

    - Do measured trends in formaldehyde concentrations relative to NOx levels provide information to air quality planners on the effectiveness of past pollution control programs, and give an indication of their future effectiveness?
    - Will increased natural gas combustion in distributed generation systems (e.g., microgrids) in the NYC region have implications for public exposure to formaldehyde?
- Develop an approach to track and assess the efficacy of pollution reduction projects funded by Volkswagen (VW) settlement funds through direct atmospheric measurements, and support monitoring studies consistent with the approach. As a result of enforcement litigation over VW's illegal tampering with the NOx emission controls of its cars, New York State has received funding through a trust created as a result of litigation settlements with VW. The funds are to support NOx mitigation projects to offset the excess NOx emissions created by VW's illegal tampering. NYSDEC and other agencies are working on a NOx mitigation plan for New York State. It will serve as the framework for funding individual projects through investments of the approximately $127 million New York State is allocated from the VW settlement trust funds. Workshop participants identified the VW settlement projects as presenting accountability research opportunities that would assess the effectiveness of mitigation projects on air quality.
- Develop health studies to assess change in geographical exposure patterns for combustion by-products as a result of increased distribution generation, offshore wind production, further market changes such coal-fired powerplant closures, phase-out of petroleum products, expansion of the electric vehicle market, and improved energy management including the use of energy storage technologies.

## Topic B.3.d: Exposure Model Development for Urban, Rural and Regional Assessment

Problem Statement

New experimental designs are needed to conduct studies that will lead to improved exposure models that can be linked with air quality models, especially for population centers. Advancements in human health studies will depend on an improved ability to estimate population exposure, taking into account activity patterns and varied exposure conditions. For example, exposure model development needed include mobile emissions exposure in locations that are close to major roadways, distributed generation, long-range transport of ozone and PM, and increased exposure of rural populations to wood smoke. Some of this will require sophisticated micro-environmental air quality modeling that will be site-specific.

Research Focus

Some areas of New York State have elevated short-term levels of PM2.5 and are some areas are in non-attainment for the current ozone NAAQS. Large proportions of the state's population reside or work in the current non-attainment areas. The NAAQS are expected to continue to tighten over time. There are few air quality monitors in rural locations but health –relevant sub-daily ambient concentrations have been observed. An improved ability to model exposure linked with air quality models is needed. Model verification with pilot studies will also be needed.

## Topic B.3.e: Development and Demonstration of Real-Time Personal Speciation Monitors

Problem Statement

Personal exposure is a function of an individual's proximity to many sources and time spent in daily activities. The air quality of geographical regions near important local sources is not well represented by the network of monitors developed for characterizing air quality for a broader region. Recent advances in sensors and nanotechnology have revolutionized our ability to detect a wide range of materials in near real-time.

Research Focus

A need exists for the development, evaluation, and demonstration of personal monitors to measure PM components and co-pollutants over short-time intervals using miniature, light-weight monitors. Additionally, there is a need to expand the types of pollutants personal monitors measure and to investigate the quality, usability and accessibility of data collected.

## Topic B.3.f: Monetization of Air Quality and Public Health Benefits Due to Clean energy

Problem Statement

Increasing clean energy generation has important public health benefits due to a reduction in air pollution. Recent studies have examined the monetization of health impacts in relation to new national and regional energy policies. For example, Buonocore et al. 2016 modeled a national policy scenario resembling the U.S. Environmental Protection Agency's Clean Power Plan and estimated $29 billion in total national health benefits in 2020 with $1.6 billion in NYS alone.[3] In 2017, another study analyzed the public health impacts of the Regional Greenhouse Gas Initiative (RGGI) in 2009-2014 and estimated the value of its health and productivity benefits at $3.0-$8.3 billion, with NYS among the highest states receiving the benefits.[4] Additionally, Millstein et al 2017 evaluated wind and solar climate and air-quality benefits from 2007-2015 in ten different regions of the United States. The study found that the benefits vary dramatically by region and over time, with cumulative wind and solar air-quality benefits of 2015 US$29.7–112.8 billion mostly from 3,000 to 12,700 avoided premature mortalities, and cumulative climate benefits of 2015 US$5.3–106.8 billion.[5]

Specifically, in NYS and guided by the REV principles, the Value of Distributed Energy (VDER) Generation Phase One Decision was released by the Public Service Commission in March of 2017, and the Phase One Implementation Order was released Sept 14, 2017. This new methodology takes the first step in moving beyond Net Energy Metering (NEM) to a more accurate valuation and compensation of Distributed Energy Resources. VDER factors include the price of the energy, the avoided carbon emissions, the cost savings to customers and utilities, and other savings from avoiding expensive capital investments.[6] As a result, there is a need to monetize the avoided air emissions and public health impact from the changes in energy sources in NYS. This will require new methods to perform energy and air

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[3] Buonocore J. J., Lambert K. F., Burtraw D., Sekar S., Driscoll C. T. 2016. "An analysis of costs and health co-benefits for a U.S. power plant carbon standard." PLoS ONE 11(6):1-11.

[4] Abt Associates. 2017. "Analysis of the Public Health Impacts of the Regional Greenhouse Gas Initiative, 2009–2014." Available at: http://abtassociates.com/AbtAssociates/files/7e/7e38e795-aba2-4756-ab72-ba7ae7f53f16.pdf

[5] Millstein, D., Wiser, R., Bolinger, M. & Barbose, G. The climate and air-quality benefits of wind and solar power in the United States. *Nat. Energy* 2, 17134 (2017).

[6] For more information, visit https://www.nyserda.ny.gov/vder

quality modeling that allow health benefits analysis at finer-scale than previously (county-wide) with higher time resolution than before (annually).

Research Focus

Research is needed to quantify and monetize the air quality and health benefits of energy policies including but not limited to renewable energy, energy efficiency, and energy storage. This topic is related to Topics Band C above that improve air quality modeling and energy modeling, respectively. Projects are needed to develop more refined tools and incorporate NYS-specific data with increased spatial and temporal resolution to improve monetization estimates of the public health benefits for reduced air pollution due to clean energy. For example, there is a need to quantify and monetize the air quality and health benefits of deploying renewable energy and energy storage technologies rather than dispatching higher emitting peaking power plants during the summer in highly populated areas such as NYC. Projects could also be developed to inform the VDER process.